ENGINEERING AND CONSTRUCTION
IN EGYPT’S
EARLY DYNASTIC PERIOD

A Review of Mortuary Structures

Thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy

By

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VOLUME 1

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DECLARATION

I, Angela Sophia La Loggia, hereby declare and certify that my thesis, *Engineering and Construction in Egypt’s Early Dynastic Period*, has not been submitted for a higher degree to any university or institution other than Macquarie University.

This thesis is an original piece of research and the work of others is duly acknowledged where it has been used.

Dated:

Angela Sophia La Loggia
ABSTRACT

Throughout history people have marvelled at the pyramids, from the elemental beauty of the Step Pyramid of Djoser to the monumental scale and engineering achievement of the Great Pyramid in Giza. The knowledge needed to build such grand monuments was vast, but not acquired overnight.

This research reviews 1st and 2nd Dynasty mortuary structures from an engineering and construction perspective in order to gain an insight into not only the levels of knowledge possessed by builders in this early period of Egyptian history, but how they developed their skills. Using modern engineering principles, the tomb structures were analysed, the tools and construction materials were evaluated, the quantity of materials consumed in each tomb calculated, and finally the time and labour force that would have been required was estimated.

The precursors to the pyramids, the massive mud brick tombs of the 1st and 2nd Dynasties, reveal a high degree of proficiency, ingenuity and capability by the architects, engineers and builders of that time. These mud brick structures built, almost five centuries before the Giza pyramids, reveal a structured and well organised society with well developed construction and management skills. In fact, the construction time and labour force requirements in these earlier structures were efficient and small in comparison to ventures in the proceeding Dynasties. It is through these structures and the development of the skills required to build them that this study will show how these early builders were laying a solid foundation for future generations and the dawn of large scale stone construction.
This research is dedicated to my mum, dad and brother.

Without your encouragement and support,

this would still be an unrealised dream.

Thank you.
“Archaeologists have devoted much energy to the study of pots and pans, a study undoubtedly of much value; but why should things structural be so much neglected, when they are of equal importance with the others alike archaeologically, historically and ethnographically?”

Somers Clarke, “El Kab and the Great Wall” *Journal of Egyptian Archaeology* Vol. 7 (1921), 75.
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<td><strong>ASAE</strong></td>
<td>Annales du Service Antiquités de l’Egypte</td>
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<tr>
<td><strong>BACE</strong></td>
<td>Bulletin of the Australian Centre for Egyptology</td>
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<td><strong>BIFAO</strong></td>
<td>Bulletin de l’Institut Français D’Archéologie Orientale</td>
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<td><strong>BSFE</strong></td>
<td>Bulletin de la Société française d’Egyptologie</td>
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<td><strong>FIFAO</strong></td>
<td>Fouilles de l’Institute Français d’Archéologie Orientale au Caire</td>
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<td><strong>Kêmi</strong></td>
<td>Revue de Philologie et d’Archéologie Egyptiennes et Coptes, Paris</td>
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<td><strong>JARCE</strong></td>
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<td><strong>SASAE</strong></td>
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<td><strong>ZÄS</strong></td>
<td>Zeitschrift für Ägyptische Sprache und Altertumskunde</td>
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Chapter 1: Introduction Literature Review and Methodology

Much has been written on ancient Egyptian architecture and the Old Kingdom pyramids have been studied and re-engineered by countless experts and scholars in various fields. The foundation and catalyst for large-scale building activities, however, has only recently been more thoroughly investigated.

The objective of this research is to show the tombs of the 1st and 2nd Dynasty were well built, demonstrate that there was a much more in-depth understanding of engineering practice than previously thought and that material and labour resources were being effectively utilised. To determine what it means for a tomb to be well built, this study included:

- Undertaking an engineering analysis of the tombs
- Reviewing the types of materials and tools used to build the structures
- Estimating the quantity of material that went into constructing the tombs
- Determining the labour force required to build the tombs
- Extrapolating the time taken to build these tombs.

It is, however, important to first establish what it means for a structure to be ‘well built’. The dictionary defines ‘well built’ as being large or ample and having a good strong construction. In the proceeding research, a well built tomb is also defined as:

- Engineered, not over compensating for lack of understanding of materials;
- Good management of resources, both material and labour. A good engineered design leads to savings in material which translates into savings in labour and shorter construction times.

Other criteria (although more relevant in architectural and sociological analyses) include:

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1 The elite and royals tombs from the Early Dynastic period became more complex and larger in size, incorporating important innovations, reflective of developments and in the unified state. Increases in tomb size, for one thing, meant higher productivity rates were required to mass produce building materials, and new industries were emerging. Whilst tomb development has a long history, past the Predynastic period, it is at the commencement of the 1st Dynasty that we see a marked change, coinciding with the development of the state, kingship and monumental architecture.
Functionality – a structure can be functional regardless of the simplicity or complexity of the building. For example, a pit grave and a large mud brick mastaba tomb are equally functional as they are both achieving their intended purpose - to act as a burial place for the deceased. However, the engineering required for a pit grave is negligible compared with that of a mastaba, so whilst the pit grave meets the criteria for functionality, it tells us very little of the ability of ancient Egyptian builders. Functionality, therefore, is not a good criterion to use to define a well built structure in this study.

Form and Function – enables tomb development to be explored across the following four areas:
1. Pit graves with body placed without lining or covering
2. Pit grave with body wrapped in matting or some form of cover
3. Pit grave with walls lined with matting a plaster
4. Pit graves lined with mud brick.

Usage – the tombs were built for eternity and designed to accommodate this requirement. Whilst pit graves are more likely to survive the ravages of time and provide ample information on burial customs and the population, they provide little information on the engineering and construction abilities of the civilisation interred. Though skeletal remains however, researchers can gain insights into the working hardships that may have been experienced by those interred.

Beliefs – Egyptian tombs were houses of eternity. Although some did not last very long, in some cases later generations restored royal complexes as part of their mortuary beliefs, whilst in other instances, later generations re-used the construction materials for other buildings. Larger structures were architecturally designed to accommodate ritual offerings and the deceased in pit graves were equally honoured. Understanding these beliefs, however, does not reveal data on the ancient Egyptians capabilities in engineering and construction.

Others before this study have discussed and compared the size of the tombs, subsidiary chambers and funerary enclosures, but this has been done from the perspective of the
architecture and the footprint of the structures (i.e. plan area). This study contributes to the current body of knowledge by looking at:

1. The engineering of the structures. Whilst this does not assist as a dating tool, it does show the development of skills and ability of ancient cultures.

2. The material expenditure. Looking at the footprint of a structure only says so much. Depth and height complete the picture and add to the evidence in favour of the royal mortuary complexes being significantly larger.

3. The labour force of tombs. Labour force has only been reviewed to date for a handful of tombs (e.g. Qa’a), however, this study, being on a larger corpus of tombs of various Early Dynastic sites, offers a comparison on construction times and the man power utilised.

**Early Dynastic Tomb Architecture – A Brief Overview**

The architecture of tombs from the Early Dynastic period has been extensively researched and published. The following is a brief summary of the excavation and study of the sites discussed in this research.

*Saqqara*

A high escarpment borders the west bank of the Nile at North Saqqara, on the opposite side of the river from Helwan. During the 1st Dynasty this area of land was occupied by a series of mastaba tombs, their facades aligned along the escarpment edge, overlooking the northernmost sector of the Nile Valley.

The large mud brick tombs at Saqqara exhibit a steady development from the earliest, dated to the reign of Aha, through to the 2nd Dynasty. The 1st Dynasty tombs were comprised of two distinct structural elements: the substructure, which was an open-cut

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4 The first three sites are presented due to the importance of each, in geographical order, namely, Saqqara, Helwan and Abydos. Subsequent sites are presented separately, in geographical order.
pit roof with heavy beams, and the superstructure above ground. An enclosure wall usually surrounded the superstructure.\(^5\)

The form of the superstructure was generally rectangular, comprising a continuous series of large and small niches, forming the so-called palace-façade. Its hollow interior was divided into a series of compartments or magazines. The subterranean chambers were hewn into bedrock. In the beginning, there was no stairway entrance to the substructure. The stairway made its first appearance in tombs from the time of King Den, the entrance of which was blocked by a portcullis stone.\(^6\) An increase in the number of subterranean chambers and subsequent reduction of magazines in the superstructure led to the palace-façade brick panelling becoming less common by the end of the 1\(^{st}\) Dynasty and beginning of the 2\(^{nd}\) Dynasty.\(^7\) The good limestone in the Memphite region was ideal for underground tunnelling. By the 2\(^{nd}\) Dynasty, the tombs were a series of subterranean galleries and rooms cut into the natural rock.\(^8\)

The site of Saqqara was first excavated by J. E. Quibell during 1912 to 1914 and subsequently published in 1923.\(^9\) These excavations only located two large tombs of the 1\(^{st}\) Dynasty – S2105 and S2185, as the area being cleared was located far beyond the edge of the escarpment. Quibell’s attention centred on the tombs of the 3\(^{rd}\) Dynasty, particularly of Hesy,\(^10\) which meant the earlier structures he discovered were only briefly recorded with very little detail. Exploration of the site was continued by C. M. Firth in 1930; before this time, the outbreak of World War I had suspended all excavation activities. Firth commenced clearing the north end overlooking the village of Abusir. It is here he discovered and partly cleared tombs S3035, S3036, S3038 and S3041. The untimely death of Firth in 1931 saw work in North Saqqara come to a halt.\(^11\)

\(^7\) For example tombs S3338, S3121 and S3120 see Emery, *Great Tombs I*.
\(^10\) J. E. Quibell, *Excavations at Saqqara (1911–1912), The Tomb of Hesy* (Cairo, 1913).
Walter B. Emery was the most prolific excavator on the site and his publications are still extensively used by students and scholars.\(^\text{12}\) Emery began the task of re-excavating and clearing the top of mastaba tomb S3035 in late March 1936, a tomb Firth had left untouched, and Emery soon discovered the outlines of a group of magazines in the South-East corner.\(^\text{13}\) Digging down into these magazines, jar sealings bearing the names of Den and Hemaka were found. Emery went on to excavate at Saqqara until 1956, producing five tomb publications,\(^\text{14}\) and in later years wrote a book about the Early Dynastic period.\(^\text{15}\)

Despite possible shortcomings in the level of accuracy of tomb plans and elevations published by Emery, his early career as a marine engineer, where he became an excellent draftsman, provided him with suitable skills.\(^\text{16}\) Emery drew the tomb plans within a short period following excavation, and it is therefore difficult to conclude that they would be incorrect based on other excavator’s works being less than credible.\(^\text{17}\) Emery’s work should not be completely dismissed until the site can be re-excavated and new plans drawn up and comparisons made.\(^\text{18}\) Only then will scholars be able to comment with certainty on the level of accuracy of the original publication of these structures. The information contained in the plans and elevation drawings was viewed


\(^{13}\) See Emery, *Great Tombs III* (London, 1958), 1–2, for a concise summary of the history of excavations on the site during Emery’s time.


\(^{16}\) While the drawings by Emery, for example the intricate brickwork detail on the plans, certainly shows some poetic licence, the dimensions providing the size of the structures and notes describing the features of the tombs should not be disregarded.

\(^{17}\) Re-excavation by the French Institute has shown large errors with the original plans published by Montet at the site of Abu Rawash, however, such conclusions should not be drawn for every site until new work is undertaken. P. Montet, “Tombeaux de la 1\(\text{ère}\) et de la IV\(\text{e}\) dynasties à Abou-Roach” Kémi 7 (1938), 11–69; M. Baud, “La nécropole d’élite de la 1\(\text{ère}\) dynastie à Abou Rawach : essai cartographique”, Archéo-Nil 15 (2005), 11–16; Y. Tristant, “Deux grands tombeaux du cimetière M d’Abou Rawach (1\(\text{ère}\) dynastie)”, Archéo-Nil 18 (2008), 131–147. For example, re-exca vatation at the site of Helwan, discussed later, showed the original work undertaken in the late 1940’s by Zaki Saad to be quite accurate. E. C. Köhler, “Excavations in the Early Dynastic Cemetery at Helwan — A preliminary report of the 1998/99 and 1999/2000 seasons”, BACE 11 (2000), 83.

\(^{18}\) It is clear that Spencer reinvestigated or at least observed some of the Saqqara tombs as he makes reference to verifying some of the work originally undertaken by Emery. For example, with Tomb S3503, Spencer indicates that he could not obtain the brick size of this tomb as the mud brick superstructure was denuded down to rock, and for Tomb S3506, he corrects Emery’s work by saying: ‘... the main walls are built in an alternation of three courses of headers to one of stretchers, with reeds every fifth course. Whilst the face of the walls has this arrangement in parts, I found that the thickness of the wall was composed entirely of headers laid together with little mortar’. J. Spencer, *Brick Architecture in Ancient Egypt* (Warminster, 1979), 17–18.
by the author in combination with the photographs and text in Emery’s excavation reports for the purpose of extracting the dimensions used in this study and to further reduce the possible level of inaccuracy.

Emery’s dating of the 1st Dynasty tombs was not entirely correct and his theory that tombs at Saqqara were the tombs of the Kings of the 1st Dynasty was corrected by later scholars. As new evidence has surfaced and increasing work on the Early Dynastic period architecture is undertaken, the dating of these tombs has changed over the years. Dating of tombs is generally accepted as a fluid area considering the new evidence that comes to light allowing for reassessment of the data.

Since Emery’s extensive excavation of the site, there has been little work conducted on the Early Dynastic cemetery. Most recently the German Archaeological Institute, led by Günter Dreyer, has been excavating the 2nd Dynasty subterranean royal tomb of Ninetjer and only a small part of the corridor was cleaned of Hetepsekhemwy’s huge subterranean tomb. The Netherlands-Flemish Institute, during excavations of a New Kingdom necropolis at Saqqara, uncovered galleries dating back to the Early Dynastic period.


Discussion and papers on Saqqara, however, have continued despite the lack of excavation since Emery’s time. The most heated of these discussions has been the debate on whether the site of Saqqara or Abydos housed the royal burials of the 1st and 2nd Dynasty kings of Egypt. It is now well accepted that the site of Umm el-Qaab at Abydos was the resting place of the kings of the 1st Dynasty and two kings of the 2nd Dynasty. Kemp argued that the size of the entire mortuary complex should be considered, not just the tomb itself and this allowed for the subsidiary chambers and funerary enclosures to be added to the tombs in Abydos. Since, the tombs had no elaborate superstructure like those found at Saqqara, however, this further fuelled the debate.23 Kaiser and Dreyer, who also considered the size of the burial chambers, and showed the tombs at Abydos to be larger, reinforced Kemp's position.24

As well as the size of the mortuary complexes, other evidence showed human remains that suggest these structures could not be cenotaphs to the supposed royal burials in Saqqara, leading scholars to agree on Abydos as the royal burial site.25

Stan Hendrickx’s paper in Archéo-Nil 18 provides (in addition to a concise analysis on the ongoing debate between Abydos and Saqqara summarised above) a brief outline of the 1st Dynasty tombs, with information on dating. He concludes by saying that these (Saqqara) tombs of senior officials were probably all from the royal family or tombs of Queens. The royal iconography in the palace façade architecture should not be seen as a means of competing against the royal tombs in Abydos, but as an expression of the power of kings reflected in the graves of their leading high officials. Hendrickx goes on to say that for the people of the time, these monumental tombs, whose huge silhouettes dominated the capital Memphis, represented the king. If one accepts that the panelled

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25 Surprisingly, the debate has not totally abated. Firstly, Stadelmann, who, in the mid 80’s favoured Saqqara as the royal burial site later revised his opinion, favouring Abydos in 2005. It was thought that such a turn around would end the debate, but this was not to be. In recent years the debate has resurfaced. See: S. Hendrickx, “Les grands mastabas de la 1er Dynastie à Saqqara”, Archéo-Nil 18. (2008), 60–88; D. O’Connor, “The Ownership of Elite Tombs at Saqqara in the First Dynasty”, in K. Daoud, S. Bedier, and S. Abd el-Fatah (eds.), Studies in Honor of Ali Radwan. Suppl. ASAE 34.2 (Cairo, 2005), 223–23; J. Cervelló-Autuori, “Back to the Mastaba Tombs of the First Dynasty at Saqqara. Officials or Kings ?”, in Pirelli, R. (ed.), Egyptological Essays on State and Society (Napoli, 2002), 27–61.
façade is originally from Upper Egypt, it would have been used in Saqqara because of its symbolism of royal power, which the dead were buried to represent. Furthermore, the question of human sacrifice has attracted much attention, but the available archaeological data is extremely limited with no conclusive evidence to suggest it was practiced.\(^{26}\)

**Helwan**

The Helwan cemetery, on the east bank of the Nile, features medium-sized mastaba tombs and thousands of smaller graves, spanning the 1st Dynasty through to the end of the Old Kingdom. It is located between the modern villages of Ezbet Kamel Sedqi el Qebleyah in the north and Ezbet el-Walda in the south.\(^{27}\)

The site was first excavated in 1937 by Hjarlmar Larsen, who excavated six graves at what he called Maassara.\(^{28}\) In July 1942, the Egyptian archaeologist Zaki Youssef Saad began excavating the site, and called it Helwan. Saad conducted 12 excavation seasons from 1942 to 1954, and uncovered more than 10,000 graves which were published in two preliminary reports.\(^{29}\) The Egyptian Antiquities Organisation continued excavating at the site from 1966 to 1975.\(^{30}\)

Helwan would not be re-excavated for a further 22 years. In 1997 Macquarie University was given the concession to re-examine the artefacts and archaeological remains at the

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\(^{26}\) Despite the insistence by some scholars on human sacrifice as evidenced by the subsidiary graves all being covered over at the one time, or the “odd expressive position of some of the skeletons implied partial consciousness” (D. Wengrow, *The Archaeology of Early Egypt* (Cambridge, 2006), 247), this is hardly conclusive. Firstly, if the graves were covered at the same time, why couldn’t the people who died have been progressively buried in the subsidiary graves built by the state and King, and only at the time of the kings burial being covered over with the final ‘capping’ of mud-bricks and mud. This would show, thousands of years later to modern excavators, that the subsidiary graves were covered at one time and suggest one communal burial when, in fact, this may not have been the case. As to evidence pertaining to the position of the skeletons, the author is not a forensic scientist so is unable to add to the debate other than to say, if the evidence was conclusive it would be accepted by all scholars as fact.


site under the directorship of E. Christiana Köhler. The re-examination of the site by Macquarie University showed “that Saad’s work has been found to be quite accurate, which is something of a surprise considering the enormous speed with which he uncovered more than 10,000 tombs and more than 6,000 objects”.

The substructures of the Helwan tombs were typically pit burials, ranging from small oval pits to larger rectangular substructures. They were either single roomed or subdivided by mud brick walls to form multiple rooms. The introduction of the stairway was an adaptation to these pit tombs. By the middle of the 2nd Dynasty, subterranean gallery tombs had also begun to be built. The size and number of subterranean chambers varied from a single chamber to a complex structure made up of a series of galleries and rooms.

Remains of superstructures at Helwan, whilst rare, have survived in some instances, although generally only a few bricks high. Even where no traces of the superstructures remain, spatial distribution of the surrounding tombs may point to their existence at an earlier time. The exterior of the superstructure varied between simple rectangular niches on the east or west side to the more elaborate palace-façade panelling as seen at Saqqara, only on a smaller scale. In most cases these superstructures were inaccessible, built of solid mud bricks or filled with mud brick debris, sand and rubble. A unique feature of the Helwan cemetery is the level of monolithic stone found in a small number of tombs belonging to this early period. Large slabs of limestone were used to line, pave and in some instances roof the tombs.

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32 Köhler, *BACE* 11, 83.
33 Köhler, *Archéo Nil* 18, 113–130.
35 For example, Helwan Tomb 1473.H.2 see Saad, *Saqqara and Helwan*, Plate 53. Note the tomb is mislabelled as Tomb 1374 in the photograph on Plate 53, but correctly labelled on the site plan in the same publication.
37 It is possible that the stone at Helwan was used as a substitute to the timber lining of the elite tombs at Saqqara. The stone used in the Helwan tombs may have been less prestigious than imported cedar, but it would have been just as expensive to acquire. This will be discussed in greater detail in Chapter 4 – Material Expenditure.
**Abydos**

Abydos is located in southern Egypt in the low desert on the western side of the Nile, backed by limestone cliffs. The remains of tombs dating from as early as Naqada I through to the end of the 2nd Dynasty can be found here. The largest of the early Predynastic tombs is the multi-chambered U-j, dating to the late Fourth Millennium.

The 1st and 2nd Dynasty royal tombs at Abydos consisted of large substructures lined with mud bricks. The burial chambers were roofed with timber beams and the burial chamber contained a timber shrine. The tomb of Den was unique in that it was the earliest tomb at Abydos to have a stairway entrance, and the burial chamber was paved with granite stone slabs. The surrounding subsidiary chambers, were brick lined but not excavated as deeply as the burial chamber. The superstructures of these tombs, unlike those at Saqqara, were less imposing. Whilst only a few traces of superstructures survive at Abydos, it has been proposed that the earliest consisted of a simple mound covering the burial chamber. However, the superstructure from the reign of Djet onwards comprised two elements: a tumulus over the burial chamber located below the desert level and so formed part of the substructure, and a large mound covering this tumulus and the entire tomb.

The royal tombs made up for their lack of superstructures by constructing huge funerary enclosures. A total of eight funerary enclosures have been thus far located – six dating

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40 Petrie, when excavating the royal tombs at Abydos, interpreted the timber remains found within the burial chambers belonging to the original lining of the walls and floor. More recent excavations by the German Archaeological Institute in Cairo have shown them to be the remains of timber shrines placed within the substructure.


to the 1st Dynasty and two from the 2nd Dynasty. Each of these is rectangular in plan, the largest measuring 130m x 70m, with the majority averaging 90m x 50m.\textsuperscript{45}

The funerary enclosures at Abydos are severely eroded with only a footprint designating where they once stood. The remains of Khasekhemwy’s funerary enclosure (known as the Shunet ez-Zebib) still stands at a height of 11m, providing some insight into the original appearance of earlier funerary enclosures. Khasekhemwy also built another enclosure at Hierakonpolis,\textsuperscript{46} referred to by modern archaeologists as ‘the Fort’.\textsuperscript{47} It too is sizeable, with walls 5m thick and a peak height of 11m.\textsuperscript{48}

The royal tombs at Abydos were first excavated by E. Amélineau from 1895 to 1899.\textsuperscript{49} W. M. F. Petrie re-excavated the site with greater care than his predecessor during the period from 1899 to 1901.\textsuperscript{50} The next excavators, E. Naville and T. E. Peet, reinvestigated the site from 1911 to 1912.\textsuperscript{51} After this time, it was another 60 years before excavation of the site recommenced. More recent excavations by the German Archaeological Institute in Cairo, led by Günter Dreyer, have resulted in corrections being made to earlier work as well as new discoveries and interpretations of earlier work. Excavations by German Archaeological Institute commenced in 1973 with a re-examination of royal necropolis of Abydos, including the predynastic Cemetery U, Cemetery B of Dynasty 0 and the tombs of the 1st and 2nd Dynasty kings.\textsuperscript{52}


\textsuperscript{46} “...the Hierakonpolis Fort has many features that are unique, suggesting it may not simply be an initial version of a funerary enclosure.” R. F. Friedman, “Fixing the Fort at Hierakonpolis”, \textit{Archaeology’s Interactive Dig} (2002-2009). <http://www.archaeology.org/interactive/Hierakonpolis/fort.html>: sourced on 5 January, 2012.


\textsuperscript{48} A discussion of recent work being undertaken at Hierakonpolis is discussed later in this chapter.


\textsuperscript{50} W. M. F. Petrie, \textit{Royal Tombs of the Earliest Dynasties, Part I} (London, 1900); W. M. F. Petrie, \textit{Royal Tombs of the Earliest Dynasties, Part II} (London, 1901).


Excavations of the Funerary Enclosures were first conducted in the late 19th century by Mariette.\textsuperscript{53} Excavations continued throughout the 20th Century beginning with Ayrton in 1904,\textsuperscript{54} followed by Peet from 1911 to 1914\textsuperscript{55} and then Petrie, who excavated up to 1925.\textsuperscript{56} Re-examination of the site commenced in the 1980’s jointly with University of Pennsylvania Museum-Yale University expedition. In 1995 this became the Pennsylvania-Yale Institute of Fine Arts Expedition (PYIFA).\textsuperscript{57}

From the re-excavation and re-examination of the site some new interpretations of the data came forward. O’Connor first suggested that the Funerary Enclosures may have undergone ‘deliberately razing’ but added that wind erosion was certainly also significant and was perhaps the major source of destruction.\textsuperscript{58} It was proposed by O’Connor, based on evidence showing deliberate / ritualistic destruction of the funerary enclosure, that the life-span of these structures was perhaps not intended to be much longer than the life of the king.\textsuperscript{59} The funerary enclosures which survive with only a few brick courses high (3–4 courses), show no activity upon the site until the Middle Kingdom where structures dating to this period, or possibly a late First Intermediary period, were built over the remains of the funerary enclosure. This, however, raises a number of questions.

Evidence cited by O’Connor of the remains of brick debris which had been deposited very early along the exterior and interior of the walls of the enclosures (with the exception of Khasekhemwy’s, which was not destroyed) and intentional deposits of sand located beneath the debris certainly suggests that deliberate destruction of the

\textsuperscript{53} A. Mariette, Catalogue Général des Monuments d’Abydos Découverts Pendant les Fouilles de Cette Ville (Paris, 1880).
\textsuperscript{56} W. M. F. Petrie, Tombs of the Courtiers and Oxyrhynkos (London, 1925).
\textsuperscript{58} O’Connor, JARCE 26, 73; L. Bestock, The Development of Royal Funerary Cult at Abydos. Two Funerary Enclosures from the reign of Aha (Wiesbaden, 2009), 55.
\textsuperscript{59} It was further suggested the bricks were possibly reused for the successor’s enclosure (although most likely the material was broken down and fresh bricks were made). See D. O’Connor, “The social and economic organization of ancient Egyptian temples”; J. M. Sasson, J. Baines, G. Beckman, and K. S. Rubinson (eds.) Civilizations of the Ancient Near East (New York, 1995), 238-9; and O’Connor and Adams, Treasures of the Pyramids (2003), 78-85, for evidence of deliberate destructions of funerary enclosures.
enclosures is plausible.\textsuperscript{60} Based on this evidence, the majority of the mud brick debris was reused. This destruction, however, may have taken place at a later time.\textsuperscript{61} Nonetheless, if it did not, the question becomes: if, in fact, the enclosures were ritually destroyed and only had a limited life span, why would the courtiers associated with the king choose to be buried around such a ‘temporary’ structure? Why not be buried around the tomb? After all such burials around the actual tomb were substantial, the earlier burials containing greater numbers than later burials. Djer’s tomb was surrounded by 330 subsidiary chambers, his enclosure by 269. Djet had 223 subsidiary chambers around his tomb and 154 around his enclosure. By the time of Den, the number of subsidiary chambers had reduced to 153, only 148 of which were graves. A more in depth discussion on the reduction in the number of subsidiary chambers will be raised later, but the purpose of this comparison is to show that it would have been possible for a greater number of chambers to have been built around the tomb with space not being the underlying issue. So why build around a structure which would knowingly be torn down? Furthermore, if the Funerary Enclosures were “temporary structures” which underwent deliberate or ritualistic destruction, why then were the structures not built out of perishable materials and why were the massive superstructures of the Saqqara\textsuperscript{1st} Dynasty tombs allowed to remain when those belonging to kings were torn down? As a means of strong symbolism it is surprising that such grand monuments would be torn down, and the likelihood they were torn down during the Middle Kingdom seems more plausible.

Most recently Bestock discusses the early development of the royal Funerary Enclosures from Aha through to Merneith.\textsuperscript{62} The reason she stops her analysis at Queen Merneith is due to the fact that no funerary enclosures have so far been found for Den and his 1\textsuperscript{st} Dynasty successors.\textsuperscript{63} The work provides a concise summary of past and

\textsuperscript{60} O’Connor, \textit{JARCE} 26, 73; Bestock, \textit{Development of Royal Funerary Cult at Abydos}, 55.

\textsuperscript{61} ‘...the Early Dynastic royal funerary enclosures were preserved as an exclusive sacred space until the 11\textsuperscript{th} Dynasty. Early in Middle Kingdom, the central government appears to have granted private access to this previously restricted burial ground: the orthography of a 13\textsuperscript{th} Dynasty royal stela of Neferhotep I recording such an action, or an earlier Middle Kingdom royal decree’. S. P. Harvey, “Abydos, Middle Kingdom cemetery”, K. A Bard (ed.) \textit{Encyclopedia of the Archaeology of Ancient Egypt} (London / New York, 1999), 95–96.

\textsuperscript{62} Bestock, \textit{The Development of Royal Funerary Cult at Abydos}.

\textsuperscript{63} Others have suggested that the funerary enclosures termed “Unidentified” and so called “Western Mastaba” which have been dated to the late 1\textsuperscript{st} Dynasty (as they do not have accompanying subsidiary graves) may have belonged to Anedjib or Semerkhet but as yet no definitive evidence has come to light to show this to be a certainty. W. Kaiser, “Zu den königlichen Talbezirken der 1. und 2. Dynastie in Abydos und zur Baugeschichte des Djosergrabmals”, \textit{MDAIK} 25 (1969), 2, 18; O’Connor, \textit{JARCE} 26, 58.
present excavations and interpretation of the data. Bestock, in her conclusion, discusses the interpretation of the funerary enclosures of Aha in relation to other enclosures and possible reasons for Aha having three funerary enclosures built versus only single enclosures built by subsequent kings. The possibility that the Unidentified Enclosure “Donkey Enclosure” may have belonged to Djer, thus allowing for a second king to have had more than one enclosure, is eluded to but in the end shown to be unlikely.\textsuperscript{64}

The size of the funerary enclosures of Aha compared with those of Djer, Djet and Merneith, and the scale and number of subsidiary chambers surrounding the enclosures is compared with the accompanying tomb complexes. The size of both complexes, tombs and funerary enclosures, is discussed in relation to the footprint plan area and the fact that Djer’s had the largest structures built and greatest number of subsidiary chambers. But the discussion of size is in the context of interpreting the function of the funerary enclosures. Bestock concludes by stating:

Differences in size and subsidiary graves as detailed do not argue for a difference in function. The smaller interior space of the Aha I enclosure may not have accommodated ritual on as large a scale as the large enclosures. But that the type of use rather than the scale of use may have been different is not suggested by the evidence. The fact that the small Aha enclosures may not have accommodated one of the functions of enclosures, having very little open space, is made less relevant in the overall scheme of understanding of enclosures by the fact that a larger enclosure of the same reign did have accommodation for this function.\textsuperscript{65}

Bestock goes on to discuss the archaeological changes, the major one being simply that Aha had three enclosures, his successors only one, and that the architecture except for the feature just described, changed very little for the early 1\textsuperscript{st} Dynasty enclosures.

The analysis undertaken by the author of this research for the tombs and funerary enclosures at Abydos, and other sites for that matter, differ from that conducted by O’Connor, Adams and Bestock, in that their interpretations and analysis appears to focus on the function, use and purpose of these structures, by looking at the architecture

\textsuperscript{64} Bestock, \textit{The Development of Royal Funerary Cult at Abydos}, 97.
\textsuperscript{65} Bestock, \textit{The Development of Royal Funerary Cult at Abydos}, 96.
and footprints on the landscape in order to gain a greater understanding of the ritual purpose of these structures.

The information sourced from excavations published by Bestock, O’Connor and Adams, including details such as deliberate destruction of the enclosures (with the exception of Khasekhemwy) that points to a short life span of these structures, certainly proved invaluable to this research, from the perspective of gaining a better insight into the construction and the workers who built these structures. For this reason, the architectural assessment carried out by others is important for dating and, in some instances, assessing the added difficulty of the construction process (for example, how building a structure with a niched façade would be more time consuming than a plain façade). Questions on functionality and beliefs, therefore, are important for research such as that conducted by Bestock, but not necessarily crucial to this study with its focus on the engineering and construction of the structures to better understand developments in construction and the nature of the workforce engaged in the building of these structures.

_Naga-ed-Der_

The site of Naga-ed-Der lies on the east bank of the Nile near Abydos, opposite the modern town of Girga. The site was first excavated by the University of California’s Egyptian Expedition from 1901 to 1904 under the directorship of George A. Reisner. Additional work was undertaken by Reisner through the Harvard University-Boston Museum of Fine Arts Expedition from 1910 to 1912 and from 1923 to 1924.

The earliest phase of tomb construction can be found in Cemetery N7000. These tombs, from the 1st and 2nd Dynasties were found in Cemetery N1500 and N3000. These cemeteries would have served one or more towns in the region of Abydos. Remains of superstructures showed they were rectangular and built of mud brick walls,

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68 Cemetery N7000 was excavated by Albert Lythgoe and his field notes were subsequently published in A.M. Lythgoe and D. Dunham, _The Predynastic Cemetery N7000_ (Berkley, 1965).

69 G. A. Reisner, _The Early Dynastic Cemeteries of Naga-ed- Dêr_. Part I (Lepzig, 1908). Tombs dated to the 2nd and 3rd Dynasty were found in Cemetery N3000 and NS3500 and published by A.C. Mace, _The Early Dynastic cemeteries of Naga-ed- Dêr_. Part II (Lepzig, 1909).

the interiors filled with gravel, rubble, sand or mud bricks. In some cases enclosure walls were found with the superstructure. The majority of the tombs were small, mud brick pit tombs, the earliest and largest mastabas had niched panelled façades on at least their western (valley facing) and southern sides. The back panels of some niches were painted red.\textsuperscript{71}

The substructures were either roofed conventionally with timber or had vaults made of mud brick. Some of the burial chambers were accessed by a ramp or stairway, which was sealed with mud brick and occasionally large limestone slabs. Superstructure and substructure walls were often coated with mud plaster over which a layer of white gypsum plaster was sometimes applied.\textsuperscript{72}

\textit{Abu Rawash}

Abu Rawash, located 9km north of Giza, is the site of a number of small pit tombs, and large mud brick mastaba tombs with superstructure and subterranean chambers. Some of the larger tombs had accompanying subsidiary graves. The site of the larger tombs was first excavated by P. Montet who located 14 tombs dated to the 1\textsuperscript{st} Dynasty and four dated to the 4\textsuperscript{th} Dynasty.\textsuperscript{73} Montet’s work was continued by A. Klasens,\textsuperscript{74} who discovered an additional seven mastaba’s, bringing the total number of structures dated to the 1\textsuperscript{st} Dynasty to 21. Over half a century after Klasen, the site is being re-excavated by the French Institute of Oriental Archaeology in Cairo.\textsuperscript{75}

The re-excavation of the site by the French Institute of Oriental Archaeology in Cairo has revealed a great degree of inaccuracy in some of the earlier work. Re-measurement of the tombs has shown the tomb plans first drawn by Montet to be significantly

\textsuperscript{71} Podzorski, \textit{Archéo-Nil} 18, 89–102.
\textsuperscript{72} Podzorski, \textit{Archéo-Nil} 18, 89–102.
\textsuperscript{73} P. Montet, “Tombeaux de la I\textsuperscript{re} et de la IV\textsuperscript{e} dynasties à Abou-Roach”, \textit{Kêmi} 7 (1938), 11–69.
incorrect, possibly due to the large amount of time which passed between Montet excavating and subsequently documenting the excavations.76

Giza
Giza, the site of the most impressive mortuary structures in all of Egypt – the great pyramids of the 4th Dynasty, is also home to two mud brick mastaba tombs. One is dated to the reign of Djet of the 1st Dynasty and the other, Mastaba T, dated possibly to the 3rd Dynasty, excavated by Petrie.77 No new excavations of the elite cemetery have taken place.78

Tarkhan
Tarkhan, located approximately 60km south of Cairo, lies between El-Lisht and Meidum.79 The site was first excavated by Petrie, from 1911 to 1912, with over 2,000 tombs unearthed dating to all periods of Egyptian history, although the large majority belong to the Early Dynastic period.80 The cemetery at Tarkhan, just like that at Helwan, contains tombs from all levels of society, with three notably large tombs: 1060, 2038 and 2050.

Karâra
Karâra, site of a Coptic cemetery, was first excavated by Hermann Ranke in the winter of 1912 to 1913. Ranke found three Early Dynastic tombs beneath the Coptic graves which were published in 1926.81 The importance of this site is the fact that one of the three tombs, Tomb 3, was lined with monolithic limestone slabs. The location of this site has since been lost.82

81 H. Ranke, Koptische Friedhöfe bei Karâra, und der Amontempel Scheschonks I bei El Hibe (Berlin und Leipzig, 1926), 8–13.
82 Personal communication with E. C. Köhler.
Naqada

At Naqada, two large residential zones were uncovered by Petrie and Quibell (1896) and named the ‘South Town’. The South Town, dated to the late Naqada II period, includes a large rectangular mud-brick structure measuring 50m x 30m, which may be the remains of a temple or royal residence. To the south, a group of rectangular houses and a 2m thick enclosure wall can be discerned from Petrie’s plan. Unfortunately, excavations undertaken in the 1980s failed to relocate these walls. The North Town was devoid of architecture.

The so-called tomb of Menes, located near Naqada, most likely belongs to Queen Neithhotep, mother of King Aha. This tomb, along with Saqqara Tomb S3357, is the earliest preserved niched mastaba. The mud brick mastaba tomb measured 53.4m (N-S) x 26.5m (E-W) and had palace façade niches on all four sides. The superstructure was surrounded by an enclosure wall measuring 65.1m x 34.2m.

The site of Naqada also contains a main cemetery and cemeteries labelled T and B, first excavated by Petrie and Quibell from 1895 to 1896. Kaiser undertook a survey of the site in 1958, but no new excavations were conducted. This study only looks at the large elite burial ascribed to Queen Neithhotep.

Hierakonpolis

The site of Hierakonpolis was first excavated in 1898 by J. E. Quibell and F. W Green. Michael Hoffman, as field director, began excavating at Hierakonpolis in 1978 in a sector known as Locality 29. HK29 is part of an extensive zone of Naqada I habitation, where a type of oven or kiln and a rectangular house superimposed on the

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87 The larger cemetery of smaller graves is not considered as it does not contribute to results presented in this research from the perspective of an engineering and construction analysis of the tombs.
88 The earliest occupation at the site of Hierakonpolis goes back to the final phase of the Palaeolithic c. 15,000BP, based on artefacts discovered in association with sediments dating to the end of the Pleistocene. No material has yet been found dating to the period between the late Palaeolithic and Predynastic. B. Midant-Reynes, *The Prehistory of Egypt* (London, 2002), 200.
earlier traces of enclosures were uncovered.\textsuperscript{90} Since that time excavations at Hierakonpolis have continued with remarkable discoveries.\textsuperscript{91}

The ceremonial complex HK29A,\textsuperscript{92} consists of an oval paved courtyard, measuring 40m x 13m, surrounded by fences and walls. On one side, four postholes, which once contained wooded poles of more than 12m in height, were discovered.\textsuperscript{93} These formed part of a larger building. HK29B was located approximately 30m–40m north of HK29A, and based on the structures were dated to the Naqada II period.\textsuperscript{94}

Work at HK11C and HK24B showed that the prominence of Hierakonpolis was due to the production of beer and pottery making.\textsuperscript{95} The site of HK11 represents the earliest evidence of occupation uncovered thus far dating from Naqada IC to IIA period.\textsuperscript{96}

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\textsuperscript{93} The excavators concluded, given their height, they were most likely cedar wood imported from Lebanon. T. Hikade, G. Pyke and D. O’Neill, “Excavations at Hierakonpolis HK29B and HK25 – The campaigns of 2005/06”, \textit{MDAIK} 64 (2008), 153–154.

\textsuperscript{94} Wooden remains found in one of the post holes, when photographed and analysed under a microscope, were tentatively identified as \textit{ficus sycomorus}. For full details on postholes and pole dimensions see T. Hikade, G. Pyke and D. O’Neill, “Excavations at Hierakonpolis HK29B and HK25 – The campaigns of 2005/06”, \textit{MDAIK} 64 (2008), 153–159.


\textsuperscript{96} E. C. Watrall, “Tales of trash, excavations at locality HK11”, \textit{Nekhen News} 13 (2001), 8.
HK6 was an elite cemetery used from the Naqada I period. Tombs dated to the Naqada IC-IIA period were shallow sub-circular graves. During Naqada IIAB graves became more rectangular and were dug more deeply. The tombs at this period were still not brick lined until the Naqada IIC period, for example Tomb 100.

The Painted Tomb, Tomb 100 was one of a number of exceptionally large, rectangular funerary structures discovered in the midst of some 150 smaller burials lying west of Wadi Khamsini. All were subterranean, with no recorded traces of a superstructure. Consisting of a rectangle measuring 5.85m x 2.85m in area, with a depth of about 1.5m, the walls were lined with mud brick and there was also one free standing brick partition that emerged halfway along the east wall and also stretched about halfway across the width of the tomb. This wall divided the burial chamber and its interior surface was coated with plaster, to which paint was applied. Tomb 100, in terms of layout and construction, finds it closest parallels among the Naqada II graves of cemetery T at Nagada. The large tombs at these two locations are unparalleled in scale and architectural sophistication.

HK43 was a cemetery for the working class as evidence by the graves which contained very few, if any, grave goods, dated to Naqada IIA-C periods (3,800-3,400BC). A comparison of the commoner’s cemetery HK43 and the elite cemetery HK6 provides a unique opportunity to study the effects of social status differentiation at the same place and time in history, in an era when the foundations of the Egyptian civilisation were being laid.

The discovery of pillared halls at Hierakonpolis is helping clarify the history of this funerary precinct. A series of wooden buildings stretching back for generations are now detectable, while the discovery of 3rd Dynasty pottery deposits shows that some of these structures were still present and respected nearly 1,000 years after they were built. If these pillared halls were constructed for funerary rituals, these structures could be the

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earliest funerary temples in ancient Egypt. Even though they were constructed of wood rather than more durable materials, however, evidence points to the fact that these structures were not meant to be temporary. This is based on the remains of large quantities of beer jars and bread moulds dated to the 3rd Dynasty, and their careful placement, indicating that almost 1,000 years later, these buildings were still present and used for ritual purposes.

The locality HK25, covering an area of 300m² contained a large pillared structure, which contained 5 rows of 10 posts each, each post hole being approximately 40cm deep and just as wide. The posts were surrounded by a thick mud floor overlaying a layer of clean white sand – sand that we know from modern day sources is located approximately 1km east of HK25, at Wadi Khomeini. Building in this way “... resembles what we know from Dynastic Egypt, where a heap of clean sand, called the ‘High Sand’ and symbolising the Primeval Mound, was first deposited under cultic structures”. From bifacial tools found on the mud floor and dating to late Naqada I and early Naqada II (which are in themselves slightly older than the bulk of ceramics and lithics from HK25), this pillared hall highlights its importance in early architecture and construction. As Thomas Hikade wrote:

This vast complex in the heart of the Predynastic Town, together with the large ritual precinct in the Elite Cemetery up the wadi, show Hierakonpolis to be the

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103 See R. Friedman, “Remembering the ancestors: HK6 in 2008”, *Nekhen News* 20 (2008), 10–11, for plan of site. Michael Hoffman showed that the entrances to the post and wattle structures around the large mudbrick lined Naqada III tombs in HK6 were located on the north-eastern sides. This is the same side as the entrance to the 1st Dynasty royal funerary enclosures at Abydos. These structures may, then, have been the earliest funerary enclosures, foreshadowing the later structures built of mudbrick at Abydos. B. Adams, “Locality 6 in 2000: Amazing revelations”, *Nekhen News* 13 (2001), 5.

104 “This unanticipated activity in the 3rd Dynasty presents the intriguing possibility that the wooden architecture imitated in stone at the Step Pyramid complex in Saqqara was deliberately modelled on the sacred precinct at Hierakonpolis, and that the memory of its predynastic rulers was still venerated in Old Kingdom times. This discovery also possesses many questions regarding the ancient Egyptians’ view and knowledge of their own past, as well as their efforts to preserve monuments, concepts and customs that were already old even as Egyptian civilisation was being formed. Eight years of excavation have now proved that strong and rich rulers were present at Hierakonpolis from early time; although their names may be lost, the memory of their accomplishments was actively nurtured for at least a millennium, if not more.” R. Friedman, “Remembering the ancestors: HK6 in 2008”, *Nekhen News* 20 (2008), 11; T. Hikade, G. Pike and A. O’Neill, “Excavations at Hierakonpolis HK29B and HK25 – The campaigns of 2005/06”, *MDAIK* 64 (2008), 153–188; R. F. Friedman, et al., “Report on the 2006-2001 season of the Hierakonpolis expedition”, *ASAE* 83 (2009), 191–234.


impressive and inspiring birth place of monumental architecture in Ancient Egypt.\textsuperscript{107}

\textbf{Development of Mud Brick Construction – A Very Brief History}

Before investigating the use of mud brick in mortuary construction in Egypt, it is essential to delve further back into the prehistory of Egypt to see the first traces of construction. From this evidence, the driving forces can be mapped out and questions – Why were the first structures or tombs built the way they were? Were there outside influences? Was the use of certain materials simply due to the practicality of their proximity, their easy of handling, transporting or working? – answered.

Looking at the early Egyptians provides an insight into their intelligent use of resources and materials from the manufacture of tools, vessels/ pottery, decorative items to the construction of dwellings, graves and storage facilities (for grain), ovens/ hearths, as well as the use of practical materials, such as stone, for simple collection and use, compared to the manufacturing of mud bricks or the quarrying of actual stone, which was used later as the society became more developed and structured.

An examination of the early prehistoric sites in Egypt, and the materials used in construction, allows a tentative line of thought to take shape:

1. The use of dry stacked stone was followed by the use of mortared stone boulders. The use of stone boulders of irregular shape, un-worked pieces found in the surrounding landscape, would have limited the builders' construction capabilities for higher walls as the boulders would have been awkward to lay, possibly requiring substantial amounts of mortar to level them. In order to build the walls of a house, then, wattle and daub were used. The earlier builders, in seeing these two materials, may have thought to combine their merits to create a workable/ functional building material.

2. Mud brick had many advantages: it was durable in the hot dry Egyptian climate, easy to manufacture and transport and could be made locally to fit the required specifications. This development, however, would have shown the builders the

\textsuperscript{107} Hikade, \textit{Nekhen News} 20, 5.
merits of building with a product of constant size and shape. Once the idea and the first brick prototypes (that is, handmade bricks) were first developed, the rate of development progressed quickly. Handmade mud bricks were soon being made with moulds, leading to mass production. Such innovation provided not only a consistency in brick shape, making it easier to build with, but also enabled the use of unskilled labour and, as a direct consequence, increased productivity.

As bricks were mass produced, we observe a greater variety of use, the building of larger structures, and increased accessibility in the wider population.

3. Those who had used stone boulders would have soon recognised the merits of stone and the possibilities of working with and utilising larger pieces in various structures. For people who were skilled in working with hard and soft stones, creating intricate stone vessels, for example, the working of monolithic stone slabs, would not have presented itself as a major problem or difficult task, especially as the bulk of the stone used for construction purposes at its inception was limestone which was relatively soft. The main things which needed to be addressed were:

- Where would stone building material be used? What were the structural advantages of using stone over timber or mud bricks? Mud bricks, for example, would of course not be able to be used independently as a lintel, nor could it offer the same level of protection as a solid stone door.

- Would the stone be used en mass (within the same structure)? The complete use of stone at an early age would have been seen as a waste of time and resources. Why cut stone blocks when mud bricks are structurally adequate, quicker to produce and locally sourced?
Development of Material Usage

Looking at the early Egyptians use of construction materials provides an insight into the intelligent and practical use of materials such as stone, mud and timber. In line with this idea comes the first grave site found in Egypt, dating back to 33,000 years ago, where numerous graves were located at Boulder Hill, 400m north of NK4\textsuperscript{108}. These graves were found to be covered with large blocks of unworked slabs of stone. Stone would

\textsuperscript{108} Nazlet Khater 4 is a site in Upper Egypt between Assyut and Sohag, which dates from between 35,100 to 30,360 years BP. P. M. Vermeersch, E. Paulissen, S. Stokes, C. Charlier, P. Van Peer, C. Stringer and W. Lindsay, “A middle Palaeolithic burial of a modern human at Taramsa Hill, Egypt”, \textit{Antiquity} 72 (1998), 475–484; I. Crevecouer, “Étude anthropologique du squelette du Paléolithique supérieur de Nazlet Khater 2 (Égypte). Apport à la compréhension de la variabilité des hommes modernes”, \textit{Egyptian Prehistory Monographs (EPM)} 8 (Leuven, 2008).
have been seen as the most practical and permanent material to use. Mud was used in Egypt well before the development of mud bricks. The simplest use was in lining fire pits. Mud was also used to coat basketry and matting and employed to line grain silos or to cover the floor of circular huts.

The first traces of Upper Egyptian Predynastic settlements were found by Gertrude Caton-Thompson, at Hemmamiya North Spur, during the transition period from Badarian to Naqada I. Nine ‘hut’ circles, varying from about 1m to 2.5m in diameter and a straight wall 8.2m long were built. The walls of the hut circles were about 35cm thick and built using a mixture of mud and limestone fragments. The circular structures may be regarded as human dwellings, as indicated by the presence of a hearth. Other, much smaller circles, contained desiccated sheep or goat dung and may have been storage areas. The ceramics and lithic material essentially conform to the Naqada I culture.

The Badarian / Naqada I settlement at Hemmamiya gives the impression of a small community, an average of 50 to 200 people appears to have occupied these sites over the course of 200 years, from 3,830BC to 3,625BC, according to calibrated radio carbon dates. Living in post, wattle and daub houses of round or semicircular plan possibly dome-roofed with a number of smaller outbuildings, this type of settlement plan is paralleled in Lower Egypt at sites like Merimde and El Omari, which date to the 5th millennium BC and may not be truly representative of all types of Upper Egyptian Predynastic settlements.
It may be at approximately the Naqada I-II transition that cereal farming began to play a decisive role in Egypt’s development, providing opportunities for long term occupation at key points of contact between the Nile Valley and its resource rich hinterlands. Cultivated cereal grains are found in abundance at early 4th Millennium sites in the Naqada and Armant regions, and further south at Hierakonpolis.¹¹³

By the Predynastic period, Egyptians were capable of producing sufficient surplus quantities of food enabling other industries to develop as much of the labour force was not required to work in the fields.¹¹⁴ The economy was being transformed from one based on pastoralism to one that was entirely agriculturally based. Such a shift allowed for, amongst other things, the distribution of labour from agricultural duties to large scale building projects. It is generally considered that each ‘non-producing’ person (e.g. craftsmen, builders, officials) require at least 50 agricultural producers to support them. In large urban centres, the total number of non-producers would have been no more than a few hundred.¹¹⁵ For Egypt, the advent of food surpluses encouraged the development of localised storage redistribution systems which enabled the periodic concentration of large numbers of people to undertake public works, such as tomb construction and the building of town walls and irrigation basins.¹¹⁶ How much labour was required and its impact to society is discussed in a later chapters.

**First Mud Brick Structures¹¹⁷**

True mud brick buildings of the Predynastic period still remain but are few in number. In the ‘South Town’ at Naqada dated to the late Naqada II period, Petrie excavated a corner of a walled mud brick settlement.¹¹⁸ Bricks were also used to line the burial chambers of the elite tombs at Naqada (Cemetery T) and Hierakonpolis (Tomb 100),

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¹¹⁸ Most likely mud bricks were first used in settlements before being used in tombs, simply due to the advantages of this building material in the construction of living shelters, even if they were only used for constructing the foundations. There was no immediate need for mud bricks in the earliest tombs, which were pit graves. For information on predynastic settlements and first uses of mud bricks, see Y. Tristant, “L’habitat prédynastique de la Vallée du Nil. Vivre sur les rives du Nil aux Vᵉ et IVᵉ millénaires”, *BAR* 1287 (London, 2004), 119.
during the Naqada IIC-IID period, and Cemetery U at Abydos in the period preceding the 1st Dynasty.\textsuperscript{119} At El Amrah, the site that gave its name to the Amratian epoch, Petrie found a miniature clay model of a house in a grave dated to the Naqada II period.\textsuperscript{120}

During the Naqada II period, the manufacture of rectangular wooden frames and roofing for graves, the wrapping of bodies and artefacts in multiple layers of matting, an overall increase in grave size and the use of mud brick linings for some tombs became common.\textsuperscript{121}

It is, however, in the Naqada III period that the first traces of monumental architecture appear, particularly the platform of the Early Dynastic temple and the large tombs in the cemetery known as ‘Locality 6’ at Hierakonpolis. It was in Naqada III that the rich tombs incorporating mud bricks appeared and the distinctions between different tombs were accentuated by variations in the quantity and quality of grave goods.\textsuperscript{122}

\textit{Engineering Versus Architecture – A Review of Work}

Whilst much has been written on the architecture of tombs from the Early Dynastic period, the same cannot be said on the engineering and construction of tombs, with few exceptions.

Architecture defines the structure and/or behaviour of a building that has been constructed. It encompasses the practice of planning and designing buildings that meet functional, technical, social, and aesthetic needs. Engineering covers the practical aspects such as designing to meet structural requirements, cost or material estimating and construction administration. It is these pragmatic requirements which have been mostly absent in the field of Egyptology, and the requirements this research aims to address.

\textsuperscript{119} Kemp, \textit{Ancient Egyptian Materials and Technology}, 79.
\textsuperscript{120} Hoffman, \textit{Egypt Before the Pharaohs}, 148. The use of mud bricks in construction were, most likely, employed in settlements before tombs. The lack of surviving settlements from the earliest periods distorts the results.
\textsuperscript{121} Wengrow, \textit{Archaeology of Early Egypt}, 122.
\textsuperscript{122} Midant-Reynes, \textit{Prehistory of Egypt}, 234.
In ancient times, the role of engineer would have been undertaken by the architect or head builder, which was most likely the same person. However, modern day studies have made a distinction between architecture and engineering based on the definition of each.

Engineering has long been a neglected area in the field of Egyptology, despite the foresight of the early engineers being responsible for the conceptual ideas and designs that became a reality through construction.

It is for this reason that this research is unique and important in understanding the development of Early Dynastic skills in engineering, construction and project management, the skills which eventually culminated in the building of the grandest of all structures – the massive pyramids of the 4th Dynasty. These structures were built from the knowledge attained over the preceding four centuries; the acquisition of which is the focal point of this research.

**Studies on Engineering and Construction**

Whilst some sources give the impression that the construction and engineering process of structures, most notably the pyramids, will be discussed, these works generally offer only a review on the architecture, religious significance and activities conducted by the population. There are other works which look at the mathematical, geometrical and symbolic aspects of pyramids.

Further studies have discussed, to varying degrees, the comparative footprint of different mortuary structures. The results obtained here, of the estimated material expenditure, compliments earlier analysis undertaken on the comparison of the structures footprints. By simply looking at the footprint of a structure, neither the depth

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123 The position and term of *engineer* is understood to reflect the concept of *engineering* in ancient times. The term engineering has a more recent etymology which derives from the word *engineer* that dates to the early 1300’s, when and *engine’er* originally referred to the constructor of engines. Source: Oxford Dictionary.


125 C. Rossi, *Architecture and Mathematics in Ancient Egypt* (Cambridge, 2004). This study also looks at the architecture of the pyramids.

nor the height of building is considered, giving a false impression of the scale of the structure. It is only by looking at all aspects of the structure – from the architectural footprint, the material consumed and time taken for construction – that a better understanding of the development of ancient Egyptian skills and engineering capacity can be gained.

The following studies are exceptions, where scholars working in related fields have discussed the engineering and construction of the structures. The most notable is the work by C. B. Smith, who is also an engineer.

1. C. B. Smith, *How the Great Pyramid was Built* \(^{127}\)

Smith’s credentials as an engineer speak for themselves, providing a hands-on approach to the subject presented in his book. \(^{128}\) The subject matter centres on the construction of the Great Pyramid of Khufu from a project management perspective by looking at the workforce required to acquire necessary construction materials, the labour force required to build the structure, the number of support workers (including men engaged in sharpening tools, feeding, and clothing), and, of course, project managers, overseers, and scribes. \(^{129}\) In addition to the workforce, the time taken to complete the necessary tasks, such as stone quarrying, transportation and placement are provided in detail and the results summarised in a “critical path schedule”. \(^{130}\) Smith approaches the field of Egyptology through the eyes of an engineer with experience in the construction industry, which was pertinent to this research.

2. E.-M. Engel, *Tombs of the 1st Dynasty at Abydos and Saqqara* \(^{131}\)

Eva-Marie Engel’s paper on the 1st Dynasty tombs at Abydos and Saqqara centres on the discussion of the royal burial site and debates conducted by scholars over time about the true site of the royal tombs. The article discusses the size of the substructure of tombs, comparing the two sites in order to further reinforce that the kings were buried at Abydos and not Saqqara. In this respect, the work undertaken in this research reinforces

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\(^{127}\) C. B. Smith, *How the Great Pyramid was Built* (New York, 2004).

\(^{128}\) C. B. Smith holds a PhD in engineering. He was an Assistant Professor of Engineering and Director of the Nuclear Energy Laboratory at UCLA as well as having worked on many major public works projects as the president of a global engineering, architecture and construction firm.

\(^{129}\) Smith, *How the Great Pyramid was Built*, 117, 202–221.

\(^{130}\) Smith, *How the Great Pyramid was Built*, 228–229.

the study in Engel’s paper, as the material expenditure of the tombs at Abydos and Saqqara is extended to look beyond the substructure at all materials used in the construction of the tombs from the two respective sites, and many others.132

3. E.-M. Engel, *The Royal Tombs at Umm el-Qa ’ab*133
Similarly, in one of Engel’s more recent papers, she looks at the royal tombs at Abydos; the most important aspects being the reconstruction work undertaken with respect to the tomb of Qa’a, and the brief discussion on the time taken to excavate the substructure of this tomb and the number of workers employed.134 This has enabled the work to be expanded to other tombs from the royal cemetery at Abydos as part of the research presented here in Chapters 3 and 4.

4. M. T. Lally, *Engineering a Pyramid*135
This article reviews briefly the stages of pyramid construction, including the tools used and possible methods of moving the massive stone blocks used to construct pyramids. It discusses the placement of the stone blocks at angles for the pyramid of Meidum, before turning to the pyramid of Khufu. Whilst the article makes reference to the benefits of force distribution when stone blocks are placed at a sloping angle and hence the engineering functionality merit, overall the paper drowns in wall angles and provides very little insight into pyramid construction.

5. G. A. Reisner, *The Development of the Egyptian Tomb down to the Accession of Cheops*136
Reisner’s exhaustive study reviews the development of the tombs and provides tomb dimensions and details that were very useful when calculating quantities consumed in the construction of certain tombs, including volume of material excavated for substructures and subterranean tombs and timbers used for roofing some of the structures.137 The comparisons and the grouping of tomb types made is not relevant to this study, but could form the basis of future studies in combination with information presented in this work.

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132 Refer to Chapter 3 for results.
134 Engel, *Archéo-Nil* 18, 32–33, 35.
137 The data provided by Reisner was useful as supplementary information where original tomb reports were lacking. The use of this data is referenced in the subsequent chapters.
Studies on Architecture and Materials

1. W. M. F. Petrie, *Tools and Weapons* and *Egyptian Architecture*

Petrie’s study on tools and weapons discusses the various tools used by early builders, based on actual finds. The study by Petrie on architecture, however, is dated, especially since Petrie’s work pre-dates the discovery of the Saqqara tombs by Emery and discussion from the site of Abydos has been largely superseded by re-excavation of the site in recent years.

2. P. T. Nicholson, and I. Shaw, *Ancient Egyptian Materials and Technology*

This volume of work provides a concise study on various materials and technologies used in ancient Egypt. The introduction by the editors Nicholson and Shaw summarise the importance of this work very succinctly:

… the nature of Egyptology has gradually changed, and new technological and socioeconomic questions are now being asked of archaeological data. It is no longer possible for the traditional Egyptologists alone to tackle such questions as the composition of materials, providence and the means by which different materials were produced.

These new approaches are reflected in this book. Each chapter has been written by one or more specialists, drawing not only on conventional Egyptological skills but also on expertise in the natural sciences applied to archaeological data.

The research undertaken on materials from ancient Egypt was essential in this study for examining the construction processes employed, and enabling the formulation and presentation of realistic labour and construction scenarios. The data presented on mud brick manufacturing, the types of timber sourced and the techniques used in woodworking assisted in developing timelines for certain activities. Furthermore, the collection of pertinent images from tombs of workers in ancient Egypt was particularly valuable in reaffirming working practices.

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139 See reference to excavations history of the site of Umm el-Qaab / Abydos earlier in this chapter.
140 P. T. Nicholson and I. Shaw, *Ancient Egyptian Materials and Technology* (Cambridge, 2000); see also A. Lucas and J. R. Harris, *Ancient Egyptian Materials and Industries*.
3. S. Clarke, and R. Engelbach, *Ancient Egyptian Masonry*\(^ {142} \)

This study looks at stone use in construction, the tools employed, quarrying methods, types of stone and construction methods. The later work by Dieter Arnold titled *Building in Egypt: Pharaonic Stone Masonry*,\(^ {143} \) published over 70 years later, whilst discussing additional material from the intervening years, did not add greatly to the original work by Clarke and Engelbach. It is surprising that Arnold does not make reference to this earlier work in his bibliography given that it is almost reproduced verbatim in parts.

4. A. J. Spencer, *Brick Architecture in Ancient Egypt*\(^ {144} \)

Spencer’s study on *Brick Architecture in Ancient Egypt* is a study on the brick architecture and ‘constructional techniques employed to overcome individual architectural problems’.\(^ {145} \) The book is divided into three sections. Part 1 discusses brick manufacturing and the early use of brick in ancient Egypt. This data is now dated, as is to be expected, due to new excavations in the 30 years since the book was first published, and bonding corpus which Spencer expands on from the original work conducted by O. H. Meyers.\(^ {146} \) Spencer also makes mention of an older publication tackling brick architecture from 1904, *L'Art de Bâtir chez les Egyptiens*, by A. Choisy, but states that while containing a ‘fair amount of information, … is inaccurate or over simplified’.\(^ {147} \)

The study highlights the lack of urban architectural remains for study from the Early Dynastic period, which is one of the reasons this research looks at mortuary structures of the Early Dynastic Period.\(^ {148} \)

Spencer briefly touches on the design of retaining walls with a brief description of the impact of lateral forces on the wall thickness to resist the imposed load. His comment, however, of the Egyptians understanding of designing trapezoidal walls as being more

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\(^ {145} \) Spencer, *Brick Architecture*, v.


\(^ {147} \) The author was unable to obtain a copy of this book and offers no comments other than those presented by Spencer in his book *Brick Architecture in Ancient Egypt*.

\(^ {148} \) Remains of domestic and urban architecture have survived, however, they are few in number. For a brief overview see E. P. Uphill, *Egyptian Towns and Cities* (2001).
economical providing ‘a considerable saving in material, without loss of stability’ at an 
early date is not entirely correct.149 Details from excavation reports from 1st and 2nd 
Dynasty tombs show the cross-section of walls to either be rectangular (i.e. the same 
thickness at the base as at the top of the wall) or thicker at the top than the bottom to 
follow the angle of the cut pit.150

The study by Spencer gives a neat summary of brick sizes from the earliest to the later 
period in ancient Egyptian history, proving useful where gaps existed in excavation 
reports and other primary sources.

5. R. Klemm and D. D. Klemm, _Stone Quarries in Ancient Egypt_151
Klemm and Klemm's book is heavily focused on the chemical make-up of rocks and 
reads more like a book on the geology of Egypt. Modern day testing methods are used 
to analyse the type and grade of rocks in order to identify the potential source of stone 
used in structures or statues, primarily from the Old Kingdom onwards.

The Old Kingdom saw large scale use of stone in structures, however, the potential 
analysis and discussion of stone used in Early Dynastic structures would have been a 
valuable resource. The limestone chamber of Khasekhemwy or the granite pavement 
from Den’s burial chamber is well attested, as is the use of stone in it most fundamental 
form of the portcullis stone and as lining of some tomb chambers. Discussion on the 
quarries pertaining to the 4th Dynasty pyramids and later periods is very detailed, 
however, the use and function of the quarries during this period is diluted with the 
heavy handedness of geological descriptions.152

The discussions throughout the book on quarrying activities are an important resource 
on quarrying techniques and the development of tools (through chisel marks, for 
example) throughout ancient Egyptian history and add to other studies.153 There is also 
a brief discussion on the potential size of the work force engaged in quarrying the large

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149 Spencer, _Brick Architecture in Ancient Egypt_, 112.
150 For example, the tomb of Den at Abydos has thicker brick walls at the top than the base. The pit cut to 
form his burial chamber had battered excavation to ensure the loose material did not collapse on itself 
during excavation.
152 References to the Early Dynastic period are generally confined to the use of stone in vessels. Klemm 
and Klemm, _Stone Quarries in Ancient Egypt_, 245.
153 Clarke and Engelbach, _Ancient Egyptian Masonry_; Arnold, _Building in Egypt._
unfinished obelisk belonging to Hatshepsut, the time taken to complete, and potential reinterpretation of why it remained unfinished.\textsuperscript{154} The discussion on the workforce and construction time of any structure is crucial in shedding further light on historical evidence in the study of Egyptology, and other ancient cultures.

The reinterpretation of the use of stone for Djoser’s step pyramid structure is refreshing. It is here, for example, where the geology of the site around the Saqqara Plateau is particularly important as the limestone in the area is of a ‘shabby structure’ consisting of 20cm-60cm thick limestone and sandstone in alternating layers. This made the extraction of the limestone a relatively simple task of pulling free, but the size of the stone was limited to this thickness. The stone blocks used on Djosers’ pyramid were smaller in size to those used on the later pyramids of the 4\textsuperscript{th} Dynasty due to the stone available within close proximity of the structure, and not because the builders were trying to emulate mud brick construction which had been common until this time.\textsuperscript{155}

6. A. Badawy, \textit{A History of Egyptian Architecture, Vol. 1 - From the Earliest Times to the End of the Old Kingdom}\textsuperscript{156}

Alexander Badawy had a degree in Engineering Architecture and a PhD, and this is reflected in his work. The study briefly discusses the ‘Archaic Period’, however, the book is heavily weighed towards the Old Kingdom. This is no surprise as it was published in 1954, when the Early Dynastic period was still getting little attention. Even more recent studies on Egyptian architecture tend to discuss quite briefly this early period in Egyptian history, with most discussions taking no more than a few pages.

\textit{Other Studies}

In addition to the books discussed above, a number of studies centre on the overall history of the Early Dynastic period but also examine the architecture of tombs. Two

\textsuperscript{154} Klemm and Klemm, \textit{Stone Quarries in Ancient Egypt}, 248.
\textsuperscript{155} Klemm and Klemm, \textit{Stone Quarries in Ancient Egypt}, 56. Similarly, the geology of the site was important in the development of subterranean gallery tombs in Saqqara and Helwan, for example, but not followed in Abydos due to the loose sandy material in the region. This is discussed in greater detail in the subsequent chapters.
such books are David Wengrow’s *The Archaeology of Early Egypt* and Toby Wilkinson’s *Early Dynastic Egypt*.\textsuperscript{157}

The study of tomb architecture has been pursued by many researchers and continues today. Almost all archaeological sites today have the services of an architect on hand when excavating tombs and other structures. Architecture is used as a tool for dating as changes and developments in mortuary and non-mortuary structures are assessed. Engineering and construction of tombs (and other structures) offers an equally important contribution to Egyptology (and of course studies of other cultures) as the construction of structures enables the information of labour and work crews to be established which, in turn, gives rise to questions of social conditions and the state of the economy.\textsuperscript{158}

As these early mortuary structures did not starve the population of workers – the tombs were able to be constructed in short time frames with small work crews (see subsequent chapters on labour expenditure and construction time frames), unlike later projects (e.g. 4\textsuperscript{th} Dynasty pyramid construction). However, the construction of large mortuary structures reinforced the concept of divine kingship to the general population and the importance of the king’s position. It would most likely have also served to give the population a sense of purpose and pride in being able to achieve these projects. It would undoubtedly create new industries, thus keeping the population of a growing unified nation occupied and employed. This meant food on the table and shelter for families to grow. If this had not been the case, the workers and their families could revolt or, more easily, return to activities which allowed their basic needs to be met. Any revolt would lead to instability. As construction activities only grew in complexity and size in to the 3\textsuperscript{rd} and 4\textsuperscript{th} Dynasties, this was not the case. Even with Khasekhemwy’s large building activities – two funerary enclosures – it was a smooth transition into the 3\textsuperscript{rd} Dynasty. The step pyramid of Djoser, Khasekhemwy’s successor, began as a mastaba which grew and grew until the Step Pyramid emerged. Undoubtedly the King was challenging his builders to construct something more


\textsuperscript{158} As discussed earlier, an economy which has sufficient food surpluses to enable labour to be diverted solely into non-producing activities such as building must be in a good position. An abuse of this position, however, can lead the state into decline if balance is not maintained.
impressive and enduring, a pyramid made of stone, but the workers would need to have been agreeable to this new project.

Methodology

As the title suggests, *Engineering and Construction in Egypt’s Early Dynastic Period*, only mortuary structures form the basis of this study. This is mainly due the limited remains of urban and domestic architecture.159

Each of the following chapters reviews a specific stage in the building process: engineering, tools and resources, material expenditure, labour force and construction. Each chapter incorporates a methodology of its own, which explains the processes undertaken to complete the work and how the data has been collected and analysed.

Chapter 2 reviews the engineering principles necessary to determine the structural adequacy of various components of the tombs from the Early Dynastic period. The analysis of a select group of tombs was undertaken to look at the three major structural elements: retaining walls, free-standing walls and roofs.160 Three sites were chosen to perform an engineering analysis of tombs from the Early Dynastic period: Saqqara, Helwan and Abydos.161 These sites were selected primarily because they offered an

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159 The large scale mud brick construction of the Fortress at Elephantine is not reviewed in this study. For details on this structure refer to M. Ziermann, *Elephantine XVI* (Mainz am Rhein, 1993). In summary, the fort has a long history. It was during the middle of the 1st Dynasty when a military fortress was established on Elephantine. During the late 1st Dynasty or possibly early 2nd Dynasty, the fortress was expanded. By the late 2nd Dynasty, the town within the secure walls of the structure begin to change. Residential areas and work places were growing. Ziermann stated that before the construction of the fort, remains of an urban centre are not to be found. So, if the fortress didn’t cause the birth of the city, it certainly contributed to the ongoing development of the urban fabric within its walls. At the instigation of the State, buildings appeared in the eastern part of the city towards the end of the 2nd Dynasty, built originally as supply centres, and by the 3rd Dynasty these buildings may have been the administrative centre of an official body. During the second half of the 3rd Dynasty and early 4th Dynasty, several large manufacturing workshops were established. The fortress continued to function beyond the Old Kingdom. Furthermore, despite the growing number of Predynastic and Early Dynastic settlements being unearthed over recent years, especially in Buto and the Nile Delta, domestic remains are also not reviewed primarily due to the engineering and construction ability of a society being more accurately measure through large scale structures, which in this case, a large corpus of evidence exists in the remains of mortuary structures. For full references on Predynastic settlements see, Y. Tristant, “L’habitat prédynastique de la Vallée du Nil. Vivre sur les rives du Nil aux Vᵉ et IVᵉ millénaires”, *BAR* 1287 (London, 2004).

160 Tombs selected for analysis were based on size and, more importantly, for at least one of the following three structural components: retaining walls, free-standing walls or a significant roof structure (as opposed to, for example, a simple brushwood roof).

161 The order of the sites is geographical, moving north to south, with Saqqara selected first due to the large size of the tombs. Helwan, located opposite Saqqara on the east bank of the Nile, contains some large and medium sized tombs, with the majority being small pit graves. Abydos, located south of
insight into the whole spectrum of the population, from the common worker buried in a pit grave through to the elite and royalty. A broad focus on the whole population enabled the formulation of theories on the engineering capabilities of the ancient Egyptians at this stage in their history.\textsuperscript{162}

In order to design the tombs using modern engineering principles, data on tomb measurements including walls heights, lengths, thickness, restraint conditions, roof spans and the material they were constructed from was collected from the original excavation reports. Additional information on the geology of the sites was essential for determining pressures exerted on the structures. Finally, the data was used to calculate the capacity of the various structural elements of the tomb in order to compare with the actual structure.\textsuperscript{163}

Modern engineering principles formed the basis by which one could access the validity of the question presented at the commencement of this chapter: “how well were these tombs built?”, based on a definition of ‘well built’ that indicates a structure engineered, thereby not compensating for lack of understanding of materials and good management of material and labour resources. Without this point of reference, that is, modern engineering, one could simply argue that the structures are still standing (putting aside the effect of weathering and reuse of materials over the centuries) so they must be ‘well built’. However, the definition of ‘well built’ would not be satisfied, and a comparative analysis of the sites would not have been possible.

Chapter 3 discusses the resources and tools used directly or indirectly in the construction of these structures. The main building material for mortuary construction in the Early Dynastic period was mud brick. Timber in this early period was a common means of roofing these tombs as well as being used to line and pave the burial chambers

\textsuperscript{162} For the purpose of arriving at conclusions on the engineering understanding of early Egyptian builders, these three sites provide sufficient data. For other areas of this research, a greater number of sites were considered as will become evident in the subsequent chapters.

\textsuperscript{163} The calculations are presented on the CD in the Appendix (refer to Contents page for full listing of file names). Furthermore, a brief overview of the engineering design methodology and approach adopted is presented in the appendix and explains in greater detail for the reader interested in delving into the process undertaken in re-designing the structures using modern techniques.
of select wealthy and royal tombs.\textsuperscript{164} Stone, although utilised sparingly, was found from the earliest Dynasties, most extensively at Helwan.

The development of skills by the early builders was not limited to the design and construction of the structures, but is also evidenced in the tools used to acquire the materials and build the tombs. Without the proper tools and support teams to supply and repair them, work would have slowed down, even halted.

Tools used by the Egyptians have been found as part of burial deposits as well as in non mortuary contexts. Evidence of the tools employed by the builders can be interpreted through wall paintings and written records from later periods in Egyptian history.

Chapter 4 provides a cursory description of the tombs, from original excavation reports followed by a breakdown of the material resources utilised in constructing the structure.

The methodology undertaken firstly involved calculating the volume of the substructures in order to determine the total amount of material excavated. Secondly, the total volume of mud bricks measured in cubic metres (m\textsuperscript{3}) was calculated for both the substructure and superstructure. The number of mud bricks used within each tomb structure was estimated by calculating the volume of a single mud brick and then converting the total volume of the mud brick structure into individual mud brick units.\textsuperscript{165} As the material used for the mortar was the same as that used to make the mud brick, the volume of mud bricks was not differentiated between the volumes of mortar consumed. The volume of mortar based on the size of an average mud brick from the Early Dynastic period equated to approximately 12\% of the total mud brick volume calculated.

Other items estimated in the construction of the tomb included:

- Face area of plaster and paint on walls (m\textsuperscript{2})
- Volume of sand placed to build up the false floor (m\textsuperscript{3})

\textsuperscript{164} The royal tombs had timber shrines placed within the burial chamber, originally stated by Petrie to be lining the brick walls and subsequently shown to be timber shrines following re-excavation of the site by the German Archaeological Institute in Cairo.

\textsuperscript{165} The size of the bricks used for most tombs was provided in excavation reports. For all other tombs the average size was used for the calculations.
• Area of reed matting used to strengthen the brick walls, over the false floors and
the timber roofs (m²)
• Quantity of limestone used to line, pave and roof the tombs (measured both in
m³ and converted into tonnes)
• Quantity of timber beams and planks used to roof and line the tombs or
construct timber shrines. 166

At the commencement of this research the sites chosen were those that had tombs which
were constructed with mud bricks. As these sites were investigated, tombs which did
not contain mud bricks but contained stone were also incorporated into the corpus. The
tomb selection criteria were based on analysing the major sites which contained several
sizable mortuary structures dating to the 1st and 2nd Dynasty. 167

Chapter 5 reviews the project management of tomb construction. This entailed the
builder or project manager being responsible for overseeing the acquisition of materials,
ensuring an adequate labour force to manufacture and transport the materials to the site
on time, and, finally, to make sure there was a sufficient workforce employed to
construct the tomb.

In estimating the labour force, modern day manual rates were used as a starting point
and factored accordingly to allow for variations in material workability and the tools
used in ancient times. 168 For jobs which have changed little over time, for example,
bricklaying, a practical number of workers was assumed, with minimum and maximum
productivity rates to provide a range of days these tasks may have taken to complete.
Similarly, the number of porters employed to move spoil during excavation work, carry
mud bricks from manufacturing brickyards to site and transport water and raw materials
for mixing mortar, plaster and paint, was also estimated based on a range of workers.

166 The roofing quantities are based on the size and number of beams and planks estimated to have been
necessary as part of the engineering analysis undertaken in Chapter 2.
167 Whilst new cemeteries are been unearthed every year, the most important criteria for tomb and site
selection was that the published material had to be accessible now, in order to be utilised in this
research.
168 J. S. Page, Estimator’s General Construction Man-hour Manual (Texas, 1959); R. L. Peurifoy, and G.
Although it may be argued that using modern day manual rates may be diminished by their reliance on models from non-Egyptian sources, and that work patterns in Egypt (modern and ancient) have significant differences from those of other countries, such a statement is debateable. The labour output rates based on workmen on excavation sites and modern construction sites in Egypt have been considered and modern day work rates sourced from construction handbooks used by estimators around the world when estimating labour requirements have been factored. In reality, construction workers around the world all work to equally with the main exception being the level of modern machinery available to the labourer, and, most recently, the impact of Occupation Heath and Safety requirements. These two items will impact on the productivity of workers.\textsuperscript{169}

The availability of unskilled labour throughout the year fluctuated depending on agricultural demands on the population. Harvest time, for example, would have occupied a larger portion of the population compared with the inundation season. It is also possible that multiple construction projects being built simultaneously would put further strain on the number of both skilled and unskilled labour. In addition to the workers, a ‘support crew’ would be required to sharpen tools, mix materials (such as mortar and plaster), and perhaps even feed the workers.

Chapter 6 reviews the final process – the estimated time taken to construct the tombs. From a review of the time taken to undertake the various tasks in the construction program discussed in Chapter 5 it was possible to assess the total time it would have taken to build each tomb and present a comparison of the various sites. Variations on the number of workers and the impact on the total construction time was assessed in order to determine an economical balance, that is, the benefits of smaller work crews against the time taken to build these structures.

Chapter 7 examines how construction played an important role in Egyptian society. The possible interpretation and implications of such large scale building projects and their impact on day to day activities are assessed here. Such projects generated employment for locals and spawned new industries throughout the country. This led to the

\textsuperscript{169} The effect of the number of workers on total construction time is considered solely for determining variations in the total time taken to build the various structures. This is presented in the labour and construction chapter. The effect of unions and labour unrest is evident in ancient as well as modern working environments, but is not considered in this study as it looks as the most efficient and economical ‘total’ construction times needed to build the structures in question.
emergence of towns and urban growth. The construction of these tombs, after all, did not only employ workers directly engaged with the building activity. Workers had to be clothed and fed, tools and materials supplied, funerary goods provided. Furthermore, a good proportion of the workers employed would have been locals with skilled tradesmen moving from one site to the next as dictated by the wealth of the tomb owners.

Finally, the development of skills in the area of project management during this early period served as a foundation for architects, engineers and builders alike to strive for greater challenges. Construction in Egypt continued to escalate in complexity and size. The emergence of the 3rd Dynasty saw the dawn of the Pyramid builders and large scale stone structures.

*Final Introductory Remarks – From Blueprint to Construction*

The construction of any project begins with the client (in this case, the tomb owner), requesting a structure to be built to his or her specifications. Once the client has conveyed their requests, the process is ready to begin. An architect is engaged to turn ideas and mental images into working drawings, which are, in turn, passed on to a design team to engineer the building in order to make it structurally adequate.

Utilising information garnered from existing plans of the mortuary structures built during the 1st and 2nd Dynasties, an analysis of the process from engineering, to material procurement, labour mobilisation and construction can now begin to be determined.
Chapter 2: Engineering of the Early Dynastic Tombs

The Egyptian monuments and tombs were constructed using empirical design. This research reviews the tombs from the Early Dynastic period using modern Engineering design principles to determine how well these early structures were designed, how conservative these builders were when adopting new construction techniques, and why they were building this way.

Unlike modern buildings today, which are built based on engineered designs that are centred on mathematical analysis of loads and strengths of the materials used in the structure, the ancient Egyptians constructed structures based on empirical design, which is based on practical and experimental limits.170

The engineering analysis undertaken demonstrates that these structures were not built ad-hoc, but were constructed with a significant level of expertise, ingenuity and resourcefulness at this early period in Egyptian history.171 Such resourcefulness allowed for fewer materials and faster construction times. The amount of materials that went into these tombs, however, was significant, meaning that an inadequate design would still have resulted in a waste of resources and time.

This chapter reviews the engineering principles necessary to determine the structural adequacy of various components of the tombs from the Early Dynastic period. The analysis of the select group of tombs was undertaken to look at the three major structural elements: the retaining walls, the free-standing walls and the roofs.172

2.1 Methodology

Three sites were chosen to perform an engineering analysis of tombs from the Early Dynastic period: Saqqara, Helwan and Abydos.173 These sites were selected primarily

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170 For a brief description on modern engineering principals discussed in this chapter, refer to Appendix.
172 Tombs selected for analysis were based on size and, more importantly, at least one of the following three structural components: retaining walls, free-standing walls or a significant roof structure (as opposed to, for example, a simple brushwood roof).
173 The order of the sites is geographical, moving north to south, with Saqqara selected first due to the large size of the tombs. Helwan, located opposite Saqqara on the east bank of the Nile, contains some large and medium sized tombs, with the majority being small pit graves. Abydos, located south of
because they offered an insight into the whole spectrum of the population; from the common worker buried in a pit grave through to the elite and royal, thus enabling the formulation of theories on the engineering capabilities of the ancient Egyptians at this stage in their history.\textsuperscript{174}

In order to design the tombs using modern engineering principles, data on tomb measurements including wall height, length, thickness, restraint conditions, roof span and the material they were constructed from was collected from the original excavation reports. Additional information on the geology of the sites was essential for determining pressures exerted on the structures, as will be defined in the subsequent pages. Finally, the data was used to calculate the capacity of the various structural elements of the tomb in order to compare with the actual structure.\textsuperscript{175}

2.2 Sites

2.2.1 SAQQARA

Saqqara is situated in the Western Desert approximately 24km south of Cairo and immediately southwest of the modern village of Abusir. The earliest cemeteries of the Memphite necropolis were located at Saqqara atop a cliff of Eocene limestone.\textsuperscript{176} In the 2\textsuperscript{nd} Dynasty, the royal necropolis moved from Abydos to Saqqara, possibly to be closer to the new capital.\textsuperscript{177} A more practical reason, however, may be the geology of the site as a governing factor for the move. The limestone provides a solid material in which to excavate extensive subterranean galley tombs, for example the tombs of Hetepsekhemwy and Ninetjer of the 2\textsuperscript{nd} Dynasty.\textsuperscript{178}

2.2.2 HELWAN

Helwan is situated on the east bank of the Nile, opposite the site of Saqqara, and 21km south of Cairo. Helwan is located to the south of Mokattam in the eastern cliffs where the stone quarries were in close proximity – possibly one of the reasons Helwan was one of the sites where stone was more frequently used in the Early Dynastic period. The these two sites was discussed last, despite being the site of the royal tombs of the 1\textsuperscript{st} Dynasty kings and two 2\textsuperscript{nd} Dynasty kings.

\textsuperscript{174} For the purpose of arriving at conclusions on the engineering understanding of early Egyptian builders, these three sites provide sufficient data. For other areas of this research, a greater number of sites were considered as will become evident in the subsequent chapters.

\textsuperscript{175} The calculations are presented in the Appendix.

\textsuperscript{176} B. M. Sampsell, \textit{A Travellers Guide to the Geology of Egypt} (Cairo, 2003), 97.

\textsuperscript{177} Sampsell, \textit{Geology of Egypt}, 100.

\textsuperscript{178} Sampsell, \textit{Geology of Egypt}, 100–101.
Mokattam Formation is the source of limestone at the famous quarries of Gebel Tura and Gebel Hof in the Cairo area. The name Mokattam comes from the massive cliffs of Gebel el- Mokattam, where the formation is 130m thick.179

2.2.3 ABYDOS
The kings of the 1st Dynasty and the last two kings of the 2nd Dynasty were buried at Abydos. The tombs are located some distance from the inhabited floodplain, and approximately 2km due north are the large mud brick funerary enclosures. Corresponding to the burials, eight enclosures have so far been located.180

Cutting into the geological stratum at Abydos one encounters loose sands and gravels, and unlike the rocky conditions a few metres below the sand at Saqqara which is ideal for constructing subterranean tombs and cutting substructures generally without the need for retaining walls, subterranean construction was not possible at Abydos because substantial retaining walls would have been required.

2.3 Chronology
The tombs discussed in the proceeding pages of this research are presented in chronological order, as are the graphs illustrating the engineering results.181

2.4 Engineering Analysis
2.4.1 RETAINING WALL DESIGN
The design of gravity retaining earth structures is based on the theory of mass. That is, a thicker wall (i.e. a heavier wall) will resist greater lateral earth pressures enabling a higher wall to be built. Furthermore, a wall built with a lean-back, results in the reduction of lateral earth pressures distributed against the wall, allowing the wall to be built higher with a reduced thickness.

181 The chronological sequence for the Saqqara tombs is based on information provided by E. C. Köhler in combination with the order that the tombs are presented by S. Hendrickx, in “Les grands mastabas de la 1er dynastie à Saqqara”, Archéo-Nil 18 (2008), 60–88. Likewise, the chronology of the Helwan tombs was also provided by E. C. Köhler. The position of the kings buried at Abydos is well attested and also presented in order of their reign.
However, wall construction can fail and the main reasons for failure are sliding, overturning and bearing capacity. The analysis of the tombs showed that sliding and bearing capacity were not governing factors in the potential failure of the walls.\textsuperscript{182} For this reason, the results presented here concentrate on an analysis of the retaining wall’s capacity to resist overturning.\textsuperscript{183} For a retaining wall to resist overturning, the resisting forces must be equal to or greater than the overturning forces. The design methodology adopted is based on the Coulomb Earth Pressure Theory.\textsuperscript{184}

**Modes of Failure**

In the design of gravity earth retaining structures, the modes of potential failure that need to be considered are:

**Overturning.** Overturning is the rotational movement of the wall in an outwards direction away from the retained soil mass. As with most conventional retaining wall design methods, a major consideration is the ability of the structure to resist overturning under loaded conditions. This is addressed by grouping the forces acting upon the structure into overturning forces and stability forces and determining their point of action upon the system. From these forces and location of action, their moments (moment = force x distance) are determined about the toe of the wall for the wall to be stable, the sum of the stabilising moments need to be greater than the sum of the overturning moments. It is common design practice to apply factors of safety to both the stabilising forces and overturning forces.

**Base Sliding.** Base sliding is the lateral movement of the entire wall.

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\textsuperscript{182} The analysis was undertaken at the commencement of this research by the author. Sliding is the lateral movement of the entire wall. Bearing capacity and excessive settlement is the failure of the underlying foundation strata resulting in a downwards rotation of the wall structure. This also results in a local deformation of foundation material in the vicinity of the base of the wall.

\textsuperscript{183} As with most conventional retaining wall design methods, a major consideration is the ability of the structure to resist overturning under loaded conditions. This is addressed by grouping the forces that act upon the structure into overturning forces and stability forces and determining their point of action upon the system. From these forces and location of action, their moments (moment = force x distance) are determined about the toe of the wall for the wall to be stable, the sum of the stabilising moments need to be greater than the sum of the overturning moments. It is common design practice to apply factors of safety to both the stabilising forces and overturning moments.

\textsuperscript{184} In the design of any earth retaining structure, there are two primary areas of concern: firstly, the lateral earth pressures and secondly, the foundation bearing capacity and overall stability. Both are based on the strength parameters of the soils, that is, the angle of internal friction, soil density and cohesion. Active earth pressure is typically calculated for a wedge of soil trying to slide down a potential failure surface and being retained by the wall system. The basic assumptions for this active wedge theory were developed by Coulomb in 1776. This theory models the weight of the soil mass sliding along a theoretical plane of failure. The lateral earth pressure is the net force required to hold the wedge of soil in place. If unrestrained, a soil embankment will slump to its angle of repose. Some soils, such as clays, have cohesion that enables vertical and near vertical faces to remain partially intact, but even these may slump under softening influence of ground water. When an earth-retaining structure is constructed, it restricts this slumping. The retained soil exerts an active pressure on the wall. Overturning is resisted by the vertical load of the structure.
**Bearing Capacity and Excessive Settlement.** The failure of the underlying foundation strata resulting in a downwards rotation of the wall structure is known as bearing capacity or excessive settlement. This also results in a local deformation of foundation material near the base of the wall.

**Soil Properties**
The purpose of a retaining wall system is to safely hold back the soil. When designing a retaining wall, then, it is essential to assess the material properties that the wall is holding back. The angle of internal friction, cohesion, and the density of the material are used to determine the forces that will be exerted on the wall structure. All walls lining the substructures of Early Dynastic tombs can be classified within this system.

**Retaining Walls Built Against Rock Cut Faces**
Some retaining walls are built in front of stable rock faces. The backfill in the relatively narrow gap between the wall and the natural rock outcrop is partly supported by friction from the wall and from the outcrop. Since the friction is distributed vertically, it reduces vertical stress within the soil mass which in turn reduces the horizontal stress and the overturning forces. The loading on the retaining wall, therefore, is less, compared to one exposed to the full pressures of loose soil, where a thicker wall would be required.

**Buttress Walls**
A buttress is a structural element built against or projecting from a wall, which serves to support or reinforce the wall. Buttresses are fairly common in the 1st Dynasty royal tombs at Abydos.

**Analysis of Retaining Walls with Stone Lining**
*Helwan.* The tombs analysed in Table 2.1 were those that contained the most stone in the form of wall lining.

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185 This data is based on research undertaken by the author for the Postgraduate Certificate of Research Preparation at Macquarie University in 2003. A. La Loggia, “The use of stone in Early Dynastic Egyptian construction”, *BACE* 19 (2008), 73–95.
Tomb Date Description

1390.H.2 Dyn 1 The burial chamber is lined with limestone slabs placed horizontally and not vertically.

385.H.4 Late Dyn 1 or early Dyn 2 The burial chamber was lined with limestone slabs and it is possible that the roof was also built of stone slabs.

Op. 1/1 Late Dyn 1 or early Dyn 2 The stairway entrance was built of stone, and the walls and the floor were paved with stone. The burial chamber was lined with stone slabs behind which smaller slabs, horizontally laid, assisted in retaining the cut.

1.H.3 End of Dyn 1 or slightly later A large tomb, with a stairway built of stone and walls built of mud brick lined with white limestone slabs. The portcullis stone was in place before the burial chamber, which was also built of mud brick, but encased with large white limestone blocks.

Table 2.1. Early Dynastic Period Helwan tombs with stone lining

Tomb Height Actual wall thickness (m) Theoretical wall thickness

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Height (m)</th>
<th>Retaining Wall</th>
<th>Stone Lining</th>
<th>Total</th>
<th>No Loading</th>
<th>Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1390.H.2</td>
<td>1.6</td>
<td>Unclear</td>
<td>0.20</td>
<td>0.20</td>
<td>0.37</td>
<td>-</td>
</tr>
<tr>
<td>385.H.4</td>
<td>2.0</td>
<td>n/a187</td>
<td>0.42</td>
<td>0.42</td>
<td>0.49</td>
<td>-</td>
</tr>
<tr>
<td>Op. 1/1188</td>
<td>2.6</td>
<td>0.630</td>
<td>0.26</td>
<td>0.89</td>
<td>0.61</td>
<td>0.91</td>
</tr>
<tr>
<td>1.H.3(Wall A)</td>
<td>3.2</td>
<td>0.650</td>
<td>0.21</td>
<td>0.86</td>
<td>0.77</td>
<td>1.03</td>
</tr>
<tr>
<td>1.H.3(Wall B)</td>
<td>3.2</td>
<td>1.060</td>
<td>0.21</td>
<td>1.27</td>
<td>0.77</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Table 2.2. Thickness of retaining walls - summary189

Interpretation of Results – Stone Lined Helwan Tombs

Tomb 1390.H.2. The burial chamber of Helwan Tomb 1390.H.2 was cut into gravel and retained by stone walls. No plan was published of this tomb.190 Based on a 1.6m high retaining wall, the wall thickness would have needed to be 0.37m to withstand the lateral earth pressures. The thickness of the actual mud-brick retaining walls of this tomb was unclear from the excavation report.

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186 The loading is assumed to be from the rubble placed above the roof to fill the interior of the superstructure above the roof of the substructure.

187 The rectangular burial chamber was cut into gravel and then walled with limestone slabs. Z. Y. Saad, The Excavations at Helwan: Art and Civilization of the 1st and 2nd Egyptian Dynasties (Oklahoma, 1969), 29.

188 Tomb Op 1/1, following re-excavation by Macquarie University (Köhler, BACE 9, 65–72), showed the limestone walls to slope 3–4 degrees from the cross-section provided. As no data on the slope for the other tombs could be ascertained, a 3 degree set back was assumed in the calculations.

189 The soil parameters used in the design process: soil friction angle $\phi = 40^\circ$; soil density $\gamma = 20\text{kN/m}^2$; cohesion $c = 0\text{kPa}$.

190 The dimensions of the burial chamber were estimated; see W. Wood, “The stone tombs of Helwan”, Journal of Egyptian Archaeology 73 (1987), 59–70. The burial chamber is lined with limestone slabs measuring 2.5m x 0.8m x 0.2m and laid horizontally in two courses.
Tomb 385.H.4. The 2m high retaining walls of Helwan Tomb 385.H.4 would have needed to be 0.49m thick. The stone slabs lining the tomb are approximately 0.42m in thickness, which means they could simply have been placed into the excavated pit to form the burial chamber, without the mud brick walls behind them. The effect of the cross-walls acting as buttresses meant the stone slabs were sufficiently thick to resist earth pressure.

Tomb Op. 1/1. The burial chamber of Helwan Tomb Op. 1/1 was cut into gravel and retained by stone walls. An interesting feature of this tomb is that it had smaller stone slabs, possibly off-cuts from the quarry, which had been stacked and mortared together acting as the retaining walls behind the large slabs lining the tomb. The calculated thickness of the retaining walls of Tomb Op. 1/1 equated to 0.61m. The effect from the additional weight of an assumed 2m high mud-brick mastaba resulted in the need for the retaining walls of the burial chamber to be approximately 0.91m thick. The actual walls are 0.89m thick, which, due to the effect of cross-walls behaving as buttresses, resulted in the walls being structurally adequate.

Tomb 1.H.3. The calculated results for Helwan Tomb 1.H.3 showed a total thickness of 0.77m as a requirement for both walls to be adequate. The effect of the additional dead load from the superstructure when incorporated into the design revealed that the overall thickness of the walls needed to be increased to 1.03m. Wall A, which had a total depth of 0.86m, should therefore have collapsed; Wall B, at 1.27m, was adequate.

The two walls on each side of Wall A, however, were possibly acting as buttresses. As a general rule, the length at which cross-walls act as buttresses is the height of the wall. As the walls of this tombs are approximately 3.2m in height, and the back wall (Wall A) is only 4m long, the buttress walls (Walls B) are influencing the full length of Wall A. As this is not the case with Walls B, the Egyptian designer would possibly have allowed for this and accurately built these walls thicker in order to compensate. This demonstrates that by the Early Dynastic period, Egyptian designers were well aware of the structural requirements of retaining walls and the effect of buttress walls.

Analysis of Mud Brick Retaining Walls

Saqqara

Of the seventeen 1st Dynasty tombs that were analysed at Saqqara, eight had retaining walls. The other tombs had substructures cut into the rock strata thus negating the need for retaining walls.

As constructed by the ancient Egyptians, Graph 2.1 shows the height of the retaining wall, the actual thickness of the mud brick wall and the calculated theoretical thickness required to achieve the given height. Of the eight tombs analysed, seven had adequate retaining walls built. Tomb S3038, the exception, had a retaining wall thickness less than the theoretical thickness required. The tomb underwent three construction phases, leaving the retaining walls with rubble three-quarters of the way up. The rubble then counter balanced the lateral earth pressures acting on the wall.

192 Tombs S3121 and S3120 may date to the 2nd Dynasty as per E.C. Köhler.
193 Emery, Great Tombs 1, 87.
194 Whether the Egyptian builders took this into consideration when building a less than adequate wall we will never know, however, one could argue that the rubble was put in place to compensate for the possible wall failing as it was not originally sufficiently thick in construction. The chamber was immensely small and did not appear to have served any significant purpose.
Helwan

Of the twenty-five Helwan tombs selected from the Early Dynastic period, thirteen, which had retaining walls around the burial chamber and magazines, were analysed. The initial results showed that the majority of the retaining walls should conceivably have collapsed as the theoretical wall thickness required was greater than the actual retaining wall thickness (Graph 2.2 and 2.3). As the walls are still in-situ, this is clearly not the case.

Further analysis revealed that a number of these retaining walls were actually built in front of a rock cut, rather than the loose gravel stratum, so the pressure exerted by the earth behind the retaining wall would have been minimal, as discussed earlier. The retaining walls built in front of a stable rock-face were re-analysed to take into account the reduced earth pressure, and the subsequent results showed that the walls were more than adequate (Graph 2.4 and 2.5). This demonstrates the ancient Egyptian builders' knowledge and understanding of their surrounding environment and geology in order to build effectively and efficiently.

195 Many of the graphs presented in this chapter may appear to be incomplete or to have information missing (as results are not present for every tomb, for example, in the case of Graph 1 there is no data for tombs S3504, S3507, S3035 and others). However, the tombs selected for analysis in Chapter 2 were those that contained structural elements such as retaining walls, free-standing walls and a roof. While some of the larger more elaborate tombs contained all three structural components, other tombs did not and therefore no results would be available for analysis and hence presented on the graphs. (Abbreviations used on graphs: RW = Retaining Wall; Calc = Calculated).
Graph 2.2. Helwan results\(^{196}\) – retaining wall along magazines

Graph 2.3. Helwan results – retaining wall along burial chamber

\(^{196}\) The tombs have been graphed in chronological order gratefully provided by E.C. Köhler.
When analysed against modern engineering standards, the retaining walls in some of the earliest mud brick tombs in Abydos, the tombs in Cemetery U, were found to be failing with the exception of Tomb U-j (as illustrated on Graph 2.6). The graph shows the actual thickness of the retaining wall to be less than the calculated
thickness required to withstand the earth pressure exerted on the wall. These results are also apparent when observing the remains of the single and double skinned mud brick retaining walls, which are bulging or collapsing due to the soil pressure behind the walls. Tomb U-j, the largest of all the tombs in Cemetery U, consists of twelve chambers and shows a higher level of care in the construction, which could be attributed to the designer’s increased knowledge, or, just as likely, to their ability to acquire greater amounts of materials and build not only a bigger tomb, but a better one.

Graph 2.6. Abydos U- Tombs – retaining wall results

Cemetery B Tombs. Late Dynasty 0

Tomb B1/2. The brick lining of the first chamber (B1) was too thin and collapsed. Another chamber (B2) was built deeper to reach a more solid layer of gebel and the thickness of the walls was increased.

Tomb B7/9, possibly belonging to King Sekhen/ Ka, is a pit tomb with sloping sides measuring 6.00m-6.05m x 3.10m-3.25m and 1.8m deep. The tomb was lined with

197 These walls were constructed with a slight slope on the face, generally ranging between 3-4 degrees, which was taken into consideration in the design. Refer to CD calculations for the slope angle on the brick walls.

198 The tombs were sorted in chronological order based on the excavation reports in G. Dreyer, “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 3./4. Vorbericht”, MDAIK 46 (1990), 53–308; Dreyer, MDAIK 47, 93–104; G. Dreyer, et al., “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 5./6. Vorbericht”, MDAIK 49 (1993), 23–62.


200 King Sekhen/ Ka as per Engel, Archéo-Nil 18, 37.
mud brick walls of single brick thickness approximately 26cm thick and the walls were laid with a 5 degree slope. The single skin of brickwork was not sufficient to retain the sandy strata of the excavated pit, resulting in the long walls of the tomb overturning due to the pressure of sand behind the wall. The short walls remained upright due to the (possibly unintentional) effect of the long walls acting as buttress supports. The same is the case with the double chamber tomb of Narmer B17/18 as discussed below.

Tomb B17/18 was ascribed to Narmer. The burial chamber B18, measured 3.35m x 5.6m and 2.8m deep, and the mud brick walls were sloped at 9 degrees. B17 was the accompanying subsidiary magazine. The southern chamber collapsed and was rebuilt with thicker walls and wooden planks reinforcements in the side walls.

The construction of thicker walls and increased wall slopes demonstrates how the early builders and designers in ancient Egypt were learning by trialling and correcting their errors. These learnings are clearly visible with the construction of the 1st Dynasty tombs.

_Abydos – Royal Tombs._ By the 1st Dynasty, the designers had ensured the retaining walls of the royal tombs were sufficiently constructed. Initially the retaining walls were thicker than necessary, as demonstrated by Aha’s graves – B10, B15 and B19 (Graph 2.7). From the reign of Djer onwards, however, the retaining walls were of equal thickness to, or just slightly greater than, the calculated theoretical result. This means, firstly, that the designers knew what they were doing and secondly, despite the fact that these were royal tombs and the owners undoubtedly had unlimited resources at their disposal, they were not prepared to waste materials needlessly.

However, this trend is not replicated on the retaining walls built around the burial chambers. With the exception of the two tombs of the 2nd Dynasty kings, Peribsen and

201 Kaiser and Dreyer, MDAIK 38, 221–222.
202 The brick size for B7/9 was 25–26cm x 13cm x 7cm. Kaiser and Dreyer, MDAIK 38, 222.
203 Petrie, _Royal Tombs_ II, 7; Kaiser and Dreyer, MDAIK 38, 241–260. This was shown to be true from the engineering calculations which are presented in the CD accompanying this research and results of which are discussed above.
204 G. Dreyer _et al._, “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 13./14./15. Vorbericht”, MDAIK 59 (2003), 85.
205 Dreyer _et al._, MDAIK 59, 85.
206 Engel, _Archéo-Nil_ 18, 37.
207 Dreyer _et al._, MDAIK 59, 85.
Khasekhemwy, the walls here were much thicker than necessary (Graph 2.8). The reasons behind such construction are most likely the same – to provide the tomb owner with increased security since most tombs were broken into by tunnelling through the walls of the tombs, rather than the roof. Unfortunately, the lure of expensive grave goods was too tempting to resourceful thieves who still managed to gain access.

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**Graph 2.7. Abydos results – retaining wall built along magazines**

**Graph 2.8. Abydos results – retaining wall built along burial chamber**

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208 Emery, *Great Tombs II*, 5.
2.4.2 FREE-STANDING WALL DESIGN

Unlike retaining walls, free-standing walls are exposed on both sides and do not retain soil. As such the design process to determine the structural capacity of free-standing walls is different. Such walls were present inside the mud brick superstructures separating the magazines, and occasionally, the substructure if a large area had to be subdivided into multiple rooms through a series of cross-walls.\textsuperscript{209}

\textit{Design for Robustness}\textsuperscript{210}

Robustness is the ability of a wall of a certain thickness to be able to stand up over a given height and length. The capacity of a wall will vary depending on the height of the wall and whether the wall is spanning vertically, that is, whether it is restrained at the top by the roof, the overall length of the wall, and whether or not it is supported by cross-walls.

\textit{Saqqara}

Fifteen 1\textsuperscript{st} Dynasty Saqqara tombs were analysed with free-standing walls. The free-standing walls creating the magazine cross-walls in the superstructure and those built within the substructure and around the burial chamber were analysed independently and the results graphed.

\textit{Superstructure Free-standing Walls}

The walls built to subdivide the interior of the superstructure into individual magazines in the Saqqara tombs, when analysed, showed that in most cases they were not overly conservative. The walls were not much thicker than was structurally necessary resulting in fewer mud bricks being required and a shorter construction time (Graph 2.9).

\textsuperscript{209} For the purpose of distinguishing between the Saqqara tomb walls in the superstructure and substructure, the cross-walls within the superstructure will be classified as magazine walls and those in the substructure as burial chamber walls.

\textsuperscript{210} The design undertaken was based on Australian Standards code AS3600: 2001 Section 4.6 Design for Robustness.
Tombs S2185, S3471, S3035 and S3505, however, had substantially thicker walls. This may have been because the tomb owners were concerned the walls may collapse, or perhaps they felt the need for greater security by building thicker walls than structurally necessary. The answer may lie in the analysis of the burial chamber walls.

Substructure Free-standing Walls
The walls constructed in the substructure to compartmentalise the burial chambers with other rooms (with the exception of S3036 and S3038) were exceptionally thick (Graph 2.10). This supports the theory that thicker magazine and burial chamber walls were due to security rather than the structural integrity of the wall. Since the majority of the tombs were entered by tunnelling under the superstructure and breaking through the walls rather than the roof of the tomb, thickening of these walls, while not making them impregnable, would have made the task of tunnelling a more arduous and risky one for the tomb robber.

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211 Emery, *Great Tombs II*, 5.
Graph 2.10. Saqqara results - robustness for internal substructure burial chamber walls

**Helwan**

Fourteen of the twenty-five Early Dynastic period Helwan tombs analysed had free-standing walls and the results were graphed (Graph 2.11 and 2.12). Unlike the Saqqara tombs, not all Helwan tombs had surviving superstructures and the walls analysed in most cases were built within the substructure. The cross-walls built around the presumed burial chamber that did not retain soil were distinguished against those walls built to form chambers for storing grave goods.\(^{212}\)

The Helwan tomb results show the actual and the calculated height of the walls to be almost the same in the majority of cases, with the exception of tombs 1473.H.2, 599.H.2 and 1502.H.2.

\(^{212}\) The distinction was made based on the data available from excavation reports and then estimated by the author if no information was forthcoming.
Graph 2.11. Helwan results - robustness for internal magazine walls

Graph 2.12. Helwan results - robustness for internal burial chamber walls

When compared with the Saqqara results, the results for the majority of the Helwan tombs demonstrate that they were built more economically, resulting in fewer material resources being required in their construction. Despite these results, the larger Helwan tombs belonged to officials of influence and other persons of wealth and status.
Abydos

The results for robustness of the Abydos royal tombs vary depending on the position of the walls within the substructure. The internal walls show the earlier tombs to follow no discernible trend. The walls of Djer, Merneith and Anedjib were built very conservatively while those of Djet and Den were built almost equal to the capacity of the calculated results (Graph 2.13). By the end of the 1st Dynasty and through to the last two tombs of the 2nd Dynasty, a trend emerges that shows the walls to be in no way conservative, but nonetheless following a clear pattern. As the wall height increased so too did the wall thickness, at a ratio of approximately 6:1. That is, for a 3m high wall, the wall thickness was 0.5m.

The results for the walls along the burial chamber reflect a more robust construction, most likely as a means to improve security, as seen in the tombs at Saqqara (Graph 2.14).
2.4.3 ROOF DESIGN

Analysis of Stone Roofs

When checking the capacity of the ancient stone roofs using modern engineering principles, information on the tensile strength of the material, in this case limestone, was used to compare the maximum allowable span to the actual span. The conditions are remarkably different in a building with a roof carrying only its own weight compared with one which has the additional load of a superstructure.

In constructing stone roofs, the Egyptian builder had to first determine the type of roof structure and then select suitable materials for its construction. Based on the known dimensions of the stone beams found, the possible maximum span of tombs constructed

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213 Beams are structural members which transfer the loads they carry to the supports by bending, as well as their shear actions. These bending deflections of a beam are often a primary design consideration. On the other hand, most beams have small shear deflections and are usually negligible. The strength (bending) of a limestone beam under loading depends on the properties of the material. When bending predominates in a beam, the effective ultimate strength is reached when the most highly stressed cross-section becomes fully yielded. The data required for an elastic analysis include both the distribution and the magnitudes of the applied loads and the geometry of the beam. In particular, the cross section of the beam is needed.

214 W. Gomma, A. Soliman, M. R. El Tahlawi, "Geotechnical properties of limestones exposed along the Nile Valley, Egypt", Rock Mechanics 6 (New York, 1974), 247–253; C. B. Smith, How the Great Pyramid was Built (New York, 2004), 249. The quality and strength of limestone can vary considerably, with the Ultimate Stress ranging from as little as 20MPa up to 200MPa. As a comparison, granite ranges from 70MPa up to 280MPa and the compressive strength of structural grade concrete ranges typically from 20 to 40MPa. R. F. Warner, B. V. Rangan, and A. S. Hall, Reinforced Concrete 3rd Ed. (Longman Cheshire, 1989).

with stone roofs was calculated. In a reversal of the process, Tomb 385.H.4 was assessed to determine if it may have once been roofed with stone.

Stone performs well in compression but not in tension, which is why the Egyptians could build a mountain of stone such as the Great Pyramid in Giza, but not span a very large distance. When the Egyptians used stone to cover an opening, the maximum roof span achievable was not large. This is one reason why timber, a highly ductile material, was used extensively as a means of roofing tombs in the Early Dynastic period.

Similarly, modern structures built of concrete (which performs well in compression but not in tension) have the addition of steel reinforcement enabling concrete to be used under high tensile loads. The steel reinforcement provides an effective means of resisting the internal tensile forces, thus preventing the concrete from cracking beyond what is structurally safe. The concept of composite structural action has only recently (within the last 120 years) been understood.

Fig. 2.2. Non-reinforced beam in tension
Fig. 2.3. Reinforced beam in tension

**Stone Roof Results**

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Site</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2185</td>
<td>Saqqara</td>
<td>Dyn 1 Reign of Djer</td>
<td>Side walls of the substructure lined with stone; the cross-walls built of rough masonry; roof built of large stone slabs.</td>
</tr>
<tr>
<td>S3507</td>
<td>Saqqara</td>
<td>Dyn 1 Reign of Den</td>
<td>At the foot of the stairway, two rock-cut pilasters surmounted by a limestone lintel (carved with a frieze of seated lions). The lintel supports a stone slab roof covering in the southern area of the burial chamber.</td>
</tr>
<tr>
<td>S3121</td>
<td>Saqqara</td>
<td>Possibly Dyn 2</td>
<td>The passage leading to the burial chamber roofed with large blocks of limestone.</td>
</tr>
<tr>
<td>60.H.1</td>
<td>Helwan</td>
<td>Dyn 1</td>
<td>The burial chamber was roofed with limestone slabs. A vertically placed slab was also found in the tomb separating the chamber. It did not reach up to the top of the roof (and as such was not supporting the roof).</td>
</tr>
<tr>
<td>385.H.4</td>
<td>Helwan</td>
<td>Late Dyn 1 or early Dyn 2</td>
<td>The burial chamber was lined with large white limestone slabs, the largest of any tomb.</td>
</tr>
</tbody>
</table>

Table 2.3. Early Dynastic tombs with worked stone as roofing material

Table 2.4 summarises the results of tombs, which had or may have had a stone roof as detailed in Table 2.3. The data comprises the true span of the chamber roof including the dimensions of the stone beams (as found by the excavators or estimated by the author), and the theoretical maximum allowable span. The results thus presented show the maximum theoretical span achievable following engineering structural capacity calculations based on two conditions: the roof with no loading from rubble placed above it, and the roof allowing for the additional weight of rubble.
Table 2.4. Maximum allowable roof span (italics mark assumed beam dimensions)

<table>
<thead>
<tr>
<th>Tomb</th>
<th>True Span (m)</th>
<th>Beam Dimension (breadth x depth) (m)</th>
<th>Theoretical Maximum Span Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No loading from superstructure</td>
<td>Loading from superstructure</td>
</tr>
<tr>
<td>S2185</td>
<td>1.61</td>
<td>0.25 x 0.25</td>
<td>2.05</td>
</tr>
<tr>
<td>S3507</td>
<td>3.15</td>
<td>0.40 x 0.40</td>
<td>4.04</td>
</tr>
<tr>
<td>S3121</td>
<td>1.02</td>
<td>1.12 x 0.603</td>
<td>5.26</td>
</tr>
<tr>
<td>60.H.1</td>
<td>2.00</td>
<td>2.3 x 0.25</td>
<td>3.70</td>
</tr>
<tr>
<td>385.H.4</td>
<td>3.00</td>
<td>1.20 x 0.70</td>
<td>5.77</td>
</tr>
</tbody>
</table>

**Saqqara**

_Tomb S2185_. The stone roof remains of Tomb S2185 at Saqqara were limestone slabs approximately 0.25m thick spanning a distance of 1.6m. In order to determine how well the roof was designed, the maximum achievable span was calculated. It was assumed that sand and rubble had been placed over the roof to form the false floor, to a depth of 0.5m. Based on the thickness of the slabs, they were capable of spanning a distance of 2.0m, indicating a very efficient design.

_Tomb S3507_. The burial chamber of Tomb S3507 measured 3.15m (E-W) x 4.75m (N-S) and 4.75m deep. The burial chamber had a roof that was comprised of timber beams and heavy timber planks. Below this timber roof, at a depth of 2.25m, a secondary timber roof was placed on a cut-in shelf. Along this same level, a lintel rested on two rock cut pilasters on the east and west walls of the burial chamber. In turn, this lintel supported a stone flag roof covering the south area of the burial chamber. The limestone beams measured approximately 0.4m x 0.4m and spanned a distance of 1.47m.

The analysis concluded that the stone beams were capable of spanning a distance of 4.04m. Due to the primary timber roof being built above both the secondary timber roof and stone roof, no additional weight had been applied from above. Therefore, these stone beams were capable of spanning the full length of the burial chamber. This could show that these early builders were cautious, which is fitting, as this is one of the earliest roofs built of worked stone. It is more likely, however, that the owner chose to

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216 The actual length of the stone lintels is 1.47m, but the burial chamber is 3.15m in width.

217 The break in the stone slabs is, in fact, due to robbers breaking through this part of the tomb, and not due to the roof collapsing. J. E. Quibell _Excavations at Saqqara (1912-1914) Archaic Mastabas_ (Cairo, 1923).

218 Emery, _Great Tombs III_, 77.

219 Emery, _Great Tombs III_, 77.
be buried with the traditional timber lining and that the stone roof and decorated lion frieze lintel were added as an architectural feature, and not for structural reasons.

*Tomb S3121.* The corridor leading to the burial chamber of Tomb S3121 at Saqqara was roofed with seven limestone beams, each measuring approximately 1.0m x 0.6m and 2.0m in length.\(^{220}\) The maximum span achievable was calculated at 5.3m if the beams were solely supporting their own weight. The stone roof, however, had rubble and sand placed over the beams and the additional load from the dead weight reduced the maximum allowable span to 3.3m.\(^{221}\) The actual width of the corridor was 1.15m.\(^{222}\)

*Helwan*

*Tomb 60.H.1.* The stone roof of Tomb 60.H.1 at Helwan was still intact at the time of excavation. The limestone slabs were 0.25m thick and spanned a 2m opening.\(^{223}\) Calculating the theoretically allowable span of the slabs, with an assumed 0.40m depth of sand and rubble placed over the roof, resulted in a maximum span of 2.3m. As noted with the design of the retaining and free-standing walls, the roof design followed a similar trend of efficient and economical design in the Helwan tombs.

*Interpretation of Stone Roof Results*

Analysis of the stone roof beams in Saqqara tombs S3507 and S3121, found in-situ, confirmed they were capable of spanning a distance greater than the actual span. The stone roof slabs of Tomb S2185 at Saqqara and Tomb 60.H.1 at Helwan were found to be slightly more than adequate for the given span. This shows that some of these early designers were either being cautious for structural reasons or security reasons, or both, and that they were also, in all probability, aware of the capacity of the limestone they utilised.

With circumstantial evidence pointing to Tomb 385.H.4 once having been roofed with stone, this tomb was reversed-engineered. That is to say, the size of the limestone slabs that would have been required to span the length of the roof 385.H.4 was calculated. It

\(^{220}\) Emery, *Great Tombs I*, 118.
\(^{221}\) Whilst this is almost double the actual span, it is possible that the limestone was not of the best quality, or, that the depth of rubble placed over the roof was greater than that shown in the tomb report and thus a greater load was imposed on the roof than allowed for in the designed. Of course, it could simply be that this was the size of the beams made available.
\(^{222}\) Emery, *Great Tombs I*, 118.
\(^{223}\) Köhler, *Archéo-Nil* 18, 120.
was determined that Helwan Tomb 385.H.4 may once have been roofed with stone, providing that the slabs measured 1.20m x 0.70m and at least 3.4m long, to span the 3m distance.

**Analysis of Timber Roofs**

In the same way the material properties of limestone were used in determining the maximum allowable span for tombs roofed with stone, so too the flexural strength and density of timber was necessary in order to analyse the timber roofs.\(^{224}\) Imported cedar from Lebanon was used for the roofs' timber beams and planks at Saqqara.\(^{225}\) Cedar was also used in lining and paving the burial chambers of some of the Saqqara tombs in the same manner limestone slabs were used to line a small group of Helwan tombs. The timber used in the Helwan tombs would have been sourced locally, and was most likely acacia and tamarisk.\(^{226}\)

**Saqqara**

The initial results showed that the roof of only seven of the fifteen 1\(^{st}\) Dynasty Saqqara tombs analysed were adequate (Graph 2.15).\(^{227}\)

The huge load of sand and rubble placed above the timber roof structures to form the false floor of the magazines within the superstructure is the primary reason for their theoretical failure. When the imposed load on the roof was removed (Graph 2.16), the results show the roofs to be more than capable of spanning the required distance with the only exceptions being tombs S3506 and S3505, which had roof spans of 11.6m and 8.2m respectively.\(^{228}\) We know that sand was placed on top of these roof structures to form the false floor from evidence left on the mud brick walls of the magazines.\(^{229}\) We can tell that the mud plastering of the walls in the magazines was undertaken after the placement of the sand because the mud plaster stopped at the height of the sand floor. It

\(^{224}\) C. B. Smith, *How the Great Pyramid was Built* (New York, 2004), 249.


\(^{226}\) At Abu Rawash, analysis by Ahmed Fahmy from Helwan University of timber found in the 1\(^{st}\) Dynasty tombs currently undergoing re-exca-vation by the French Institute of Oriental Archaeology in Cairo, has found the timber to be acacia and tamarisk. Furthermore, despite the elite nature of the larger 1\(^{st}\) Dynasty tombs at Abu Rawash, and similar architecture, there has been no evidence of cedar found thus far. Personal communication, Y. Tristant.

\(^{227}\) For the roofs to be theoretically adequate, the maximum allowable span line on the graph needs to be above the actual span line.

\(^{228}\) Emery, *Great Tombs* III, 9; 40.

\(^{229}\) Emery, *Great Tombs* I, 73.
is from this evidence that the height and thus the loading imposed from the false floor was calculated.

Did the roofs collapse as soon as they were loaded with sand? This seems unlikely, as the Egyptians would have built sturdier roofs in later tombs. It is more likely that either the dimensions taken from the plans may not have provided accurate data or the actual span was reduced through the provision of roof supports in the form of columns or partition walls.
In considering the first point, the widths and heights of the walls were drawn to scale from the original excavation reports. This detailing on the elevation drawings, showing roof beams and planks, may have been drawn to provide a stylistic reconstruction rather than precise observations of the diameter and spacing of the beams. Therefore, the roofs where data was sourced solely from elevation drawings were re-designed to determine the impact of increasing beam diameters and reducing the spacing between beams. The analysis resulted in a further three tombs becoming adequate: S3503, X and S3111. The diameter of the timber beams was increased by a practical amount of only 10cm. Modifying the dimensions and reducing the sand depth had minimal impact on the roof design of tombs S3506 and S3505, so, with some roofs still showing signs of failure, could supports have been used?

**Tombs with Roof Supports**

**Saqqara**

**Tomb S3506.** Tomb S3506 underwent three construction phases. During the final phase, the white plastered surface of the original structure was covered with sand, on which a wooden floor was laid. Emery wrote:

> After clearing the substructure and revealing the timber floor, the foundations of a large wooden structure could be traced in the southern half of the room. Its character can not be ascertained, but it rested directly on the wooden floor and was far too large for a coffin, measuring approximately 5.0 x 6.0m.

It is possible that the wooden structure also served to support the roof, with impressions on the floor possibly due to the heavy load applied to the timber shrine leaving distinct circular indentations.

**Tomb S3038.** Tomb S3038, like S3506, also underwent three construction phases. During the final design phase, the burial pit was divided into a series of rooms. These

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230 Emery, *Great Tombs I; Great Tombs II; Great Tombs III.*
231 Tombs S3357 (Hor-Aha), S3471 and S3505 were not redesigned as beam dimensions were provided in Emery’s excavation reports.
232 Beams spaced closer together would have had the total load distributed over a greater number of beams, and thus, each beam would have been subjected to smaller loads.
233 For Tomb S3111, the roofs over the magazines became adequate but the much larger span of the burial chamber resulted in the beams still being inadequate.
234 Emery, *Great Tombs I, 74.*
235 Emery, *Great Tombs III, 44.*
brick partitions served to reduce the overall span of the roof.\textsuperscript{236} This type of brick wall partitioning may have once also existed in other tombs and acted to support the roof, with all evidence now destroyed through fire and the passage of time.

\textit{Helwan}

Little or no evidence remains of the roofing structures of the Helwan tombs, the calculations were based on averaging the beam dimension of those tombs where data was available.\textsuperscript{237} The depth of sand placed on top of the roofs to form the false floor was assumed to be the height from the bottom of the ledge, where the roof beams were placed, to ground level. The results show that of the seventeen Helwan tombs analysed, eight were capable of spanning the required distance with the full weight of sand and rubble placed on top of them (Graph 2.17). If no sand was placed over the roofs, they would all have been capable of spanning the required distance (Graph 2.18).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{helwan_results.png}
\caption{Helwan results - roof span with loading from sand}
\end{figure}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Beam Spacing and Dimension (m)} & \textbf{Span (m)} & \textbf{Actual span} \\
\hline
0.00 & 0.00 & 0.00 \\
0.20 & 1.00 & 1.00 \\
0.40 & 2.00 & 2.00 \\
0.60 & 3.00 & 3.00 \\
0.80 & 4.00 & 4.00 \\
1.00 & 5.00 & 5.00 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{236} Emery, \textit{Great Tombs} I, 91.

\textsuperscript{237} Average beam dimensions of the Saqqara tombs were also used as a guide for the beam diameter and beam spacing used to analyse Helwan tombs where no information was available.
As with the Saqqara tombs, increasing the beam diameter and reducing the span between the beams resulted in the roofs of Helwan tombs 559.H.2, 1.H.3 and 553.H.2 becoming adequate. As such, the roofs of these three tombs were capable of spanning the required distance with the right combination of beam size and spacing.

For tombs 1473.H.2 and 407.H.4, the roofs appear to have been capable of spanning the required distance with the assumed depth of sand above, but only if supports were present. At Helwan, postholes have been found in some tombs. Tombs 150.H.5 and 653.H.4 had postholes along the perimeter of the substructure. However, such positioning along the perimeter meant that as roof supports, such posts would have been redundant. The postholes in these tombs may have instead formed wooden compartments.\textsuperscript{238} If these posts served to hold wooden compartments in place, would such compartments, spanning out towards the centre of the tomb, have been capable of supporting the roof?

Calculations undertaken on the effects of these timber compartments as roof supports showed that the timber planking would need to be 20cm up to 30cm thick in order to provide sufficient support before buckling under the weight of the roof. The thickness

\textsuperscript{238} Köhler, \textit{Archéo-Nil} 18, 113–130.
varied depending on the load imposed on the timber planks forming the compartment walls.

With no overwhelming evidence to suggest that the majority of the Saqqara and Helwan roofs were supported, did the ancient Egyptian designers simply misjudge and underestimate the capacity of some of the roofs? This is highly doubtful especially when the rest of the tomb structure shows such precision in design. To thoroughly answer this question, then, we first need to review the roof structures of the royal tombs at Abydos.

**Abydos.**

Evidence of timber roof beams have been found in a few of the royal tombs at Abydos, including the tomb of Aha, Djer, Den, Qa’a and Khasekhemwy.\(^{239}\) For the remaining tombs, the calculated sizes of the beams were based on averaged figures. The material used to roof smaller spans, such as the subsidiary chambers, may not have been of cedar but of acacia, sycamore or tamarisk timber found locally.\(^{240}\) Engel writes:

> The ceilings of all the chambers consisted of wooden beams of irregular shape…and huge beams for royal burial chambers which were up to 40cm thick. The later ones were probably imported cedar wood from Lebanon although this could not be verified by analysis until now.\(^{241}\)

The roof of the king’s chamber did not only cover the centre part but also the store chambers around the wooden shrine. Most likely the wooden shrine built into the chamber served as a support.\(^{242}\)

Of the ten tombs analysed, only the roofs of Aha, Djet and Qa’a were structurally adequate. All other roofs theoretically failed, due to the imposed load from the sand tumulus placed over the burial chamber (Graph 2.19). As with the Saqqara and Helwan

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\(^{239}\) Chambers B19 and B15. Kaiser and Dreyer, *MDAIK* 38, 216, Abb 2; There were a few surviving beam holes on the south wall of the tomb. Dreyer, *Rundbrief DAI*, 2006, 13, Dreyer, *MDAIK* 59, 112–113; Fig. 18 (b).

\(^{240}\) For the tomb of Khasekhemwy, according to Dreyer, based on the small spans (2.1m) of the magazine chambers and the very irregular shape of the beams, it is expected that no imported, expensive cedar was used and the timber from the nearer surrounding areas, for example, acacia or sycamore, was more likely used. Dreyer *et al.*, *MDAIK* 59, 112.

\(^{241}\) Engel, *Archéo-Nil* 18, 32.

results, the removal of the sand led to all the roofs being adequately supported (Graph 2.20). However, we know that a tumulus did exist as evidenced from the remains Djet’s substructure.  

Graph 2.19. Abydos results - roof span with loading from sand

Graph 2.20. Abydos results - roof span with no loading from sand

Dreyer, *Rundbrief DAI Kairo* (2008), 177, Abb. 27.

The span of the roof for calculating its capacity is taken to the internal dimensions for the burial chamber. Although the roof also covered the store rooms of the tombs positioned along the perimeter of the burial chamber, the walls would assist in supporting the roof. This means the actual span would be from opposite sides of the burial chamber walls where the timber shrine would have been located.
Did the roofs collapse shortly after construction and did the ancient Egyptian designers simply misjudge and underestimate the capacity of the roofs? It is important to determine what, if any failure mechanisms were in place, to provide answers to the ancient Egyptians roof design methodology.

Re-examination of Roof Designs

Re-examination of the roof designs led to a different approach being adopted in order to determine the failure mechanisms. When designing roof structures, the two most common failure mechanisms are (1) excessive deflection of the roof, and (2) bending, also referred to as the roof strength. Modern design principles use numerous safety factors to limit the possibility of failure.\textsuperscript{245} For modern ceilings, the level of deflection can be no more that 0.4\% of the total span. This means that for a roof with a span of 4m, a deflection of no more than 1.6cm is permissible before it is deemed to have failed by modern standards.\textsuperscript{246} The ancient Egyptians may not have been too concerned if the roof was deflecting excessively, provided the roof was structurally adequate.\textsuperscript{247} Proof of this may lie in the differences between the stone roofs and the timber roofs, and the Egyptians’ understanding of how these two materials behave.

As discussed earlier, the stone roofs were more than adequate in spanning the required distance when designed using modern engineering principles. Stone is strong under compression but weak in tension. This means that stone will not deflect when a load, such as sand on a false floor, is applied, and will crack along the base (Figure 2.4).

\textsuperscript{245} The use of reduction factors on the strength of the material decreases the margin of error by allowing for these material variables. Reducing the factors of safety would not result in the structure failing (unless the strength of the materials used were less than what was assumed), but would simply reduce the possible variables and uncertainties in the material properties such as the strength of the material. It is important to note, when theoretical calculations were undertaken on the pyramid of Radjedef, at Abu Rawash, by M. Valloggia, the results showed a factor of safety three times superior to the calculated minimum. M. Valloggia, Abou Rawash I: le complexe funéraire royal de Rêdjedef, FIFAO, 63 (Cairo, 2011), 42.

\textsuperscript{246} Based on modern Australian standards.

\textsuperscript{247} The fact that a majority of the tombs were broken into through tunnelling under the roofs through the superstructure mud brick walls, rather than through the roof, suggests the roofs were very robust. Furthermore, as the tomb robbers had subsequently set fire to the chambers, this would suggest the roofs were intact, perhaps with a high degree of deflection, but intact all the same.
Timber, unlike stone, is ductile and will deflect when a load is applied (Figure 2.5). The timber roofs were re-analysed, and the level of deflection and strength (labelled as ‘bending’ in the following graphs) of the roof were examined independently and the results graphed.

**Saqqara**

Graph 2.21 shows the roofs were strong enough to span the required distance but in almost all cases, were deflecting beyond acceptable modern standards.\(^{248}\) Increasing the level of allowable deflection resulted in all the roofs of the 1\textsuperscript{st} Dynasty tombs at Saqqara becoming adequate (Graph 2.22) with the exception of tombs S3506 and S3505, due to

\(^{248}\) The *Actual span* line on the graph needs to fall below the *Limited span (Bending)* and *Deflection* lines, for the roofs to not fail.
the large spans.\textsuperscript{249} These tombs most likely had partition walls similar to those found in Tomb S3038, or, timber supports.

\textsuperscript{249} Tomb S3506 had a roof span of 11.6m and Tomb S3505 had an 8.2m span.
Helwan

Similar results were generated upon re-examination of the Helwan tombs. Using modern deflection criteria resulted in a large proportion of the roofs failing under deflection (Graph 2.23). However, when the level of allowable deflection was increased (Graph 2.24), the Helwan roofs were shown to be adequate.

Graph 2.23. Helwan tombs – maximum allowable roof span with modern deflection criteria

Graph 2.24. Helwan tombs - maximum allowable roof span reduced deflection criteria
**Abydos**

As demonstrated with the roofs of the Saqqara and Helwan tombs, the roofs of the royal tombs at Abydos were re-designed, this time looking at the strength of the roof and the deflection independently of each other (Graph 2.25).

Graph 2.25. Abydos tombs – maximum allowable roof span with modern deflection criteria

Of the ten tombs analysed, seven failed under deflection based on modern acceptable standards. When the level of allowable deflection was increased for the Abydos royal tombs to the same degree as those used on the Saqqara and Helwan tombs, the results were unexpected.
Initially, seven of the ten royal tombs failed under modern deflection criteria. Increasing the level of deflection resulted in all the tombs being adequate (Graph 2.26).

In re-analysing the results, the allowable deflection ratio was increased from 0.4% to 5%; the roofs were able to deflect 5% of their span. A roof spanning 4m by modern standards, for example, would only be able to deflect 1.6cm. At 5%, though, the roof would deflect 20cm. Realistically this would not cause the roof to fail. If one looks at many timber roofed structures from at least 100 years ago, the beams can be seen to be ‘sagging’ or deflecting.

2.5 Conclusions
From an analysis of the retaining walls, free-standing walls and roofs, it is evident that the ancient Egyptians built these structures based on their experience. The results have shown that the Egyptian builders were designing based on a good understanding of local geology, as evidenced by the care taken in the construction of retaining walls. These designs also showed that builders compensated for walls built against rock compared to those built against the gravel stratum, and also made full use of buttress walls.

250 The reason for the conservative allowable deflection ratio in modern standards is due to potential of cracks forming in the plaster sheeting ceilings, for example. Whilst such cracking would not be a structural issue, the general population, unaware of engineering standards, may think differently.
The free-standing walls separating the magazines and burial chambers showed differences in thickness between those built at Saqqara and those at Helwan. The Helwan tombs were less conservative, but still structurally adequate, leading to a saving of resources. However, the Saqqara walls were thicker, particularly around the burial chambers of these tombs, suggesting the thickness of the walls may have had more to do with security.

Finally, the design of the roofs showed that the Egyptians were constructing them with a thorough understanding of the way certain materials perform, such as the differences in the behaviour of stone compared with timber under imposed loads. Whilst not designed to the same level of conservatism, when assessed against modern standards, they were certainly adequate and fit for the purpose.

So why were the ancient Egyptians building this way? Based on the research undertaken from an engineering perspective, the early Egyptians’ construction methods were practical and demonstrated an effective use of resources through a good understanding of the surrounding environment and the capacity of the materials utilised.

There was a building evolution from the Predynastic period to the Early Dynastic period and it continued to grow into the Old Kingdom. While monumental mud brick construction did not emerge until the 1st Dynasty, there is a clear linear growth from the Predynastic period to reach that point. One need only look to Abydos, at Cemetery U, where tombs begin as pit cut graves, before enlargements lead to improvements in design. Pit graves soon began to be lined with mud bricks to support the cut, and later partition walls were used to support an increase in grave size. The increase in size of tombs led to a greater mobilisation of labour, and the need to adequately engineer a structure.

Five thousand years ago, ancient Egyptians builders demonstrated a sophisticated degree of engineering knowledge. Such skills, developed throughout the Pre- and Early Dynastic periods, were further enhanced with the undertaking of Djoser’s Step Pyramid. What began as a mastaba above the subterranean gallery tomb, consistent with those of King’s Hetepsekhemwy and Ninetjer, also buried at Saqqara, and no doubt to Khasekhemwy’s Funerary Enclosure at Abydos, would transform into the first pyramid
in Egypt. Such an achievement would not have been possible without the forward thinking builders who came before them.
Chapter 3: Resources and Tools

The main building material for mortuary construction in the Early Dynastic period was mud brick. The massive mud brick tombs and funerary enclosures of the 1st and 2nd Dynasty kings at Abydos and the elite at Saqqara demonstrate the prolific use of this material. Timber, in this early period, was a common means of roofing tombs as well as being used to line and pave the burial chambers of select wealthy and royal tombs. Stone, although utilised sparingly, was found from the earliest Dynasties, most extensively at Helwan.

The skills and knowledge these early builders were developing was not limited to the engineering and construction of the structures, but also in the tools they needed to source basic building materials and to construct the tombs. Without the proper tools (and the support teams who supplied and repaired them), work would have slowed down and eventually even halted.

The following section describes the resources used in tomb construction and the tools utilised throughout the different building stages. Tools used by the Egyptians have been found as part of burial deposits as well as in non mortuary contexts. Evidence of the tools employed by the builders can be interpreted through wall paintings and written records from later periods in Egyptian history. Labour resources will be discussed separately in Chapter 5.

3.1 Mud Bricks

The most commonly employed construction material for mortuary structures in the Early Dynastic period was mud bricks. The Egyptian mud brick was not fired, however, so tombs containing fired bricks were due to the tombs being set alight by robbers in antiquity.251 Whilst fired bricks would have provided the Egyptians with a more durable and higher strength product, the dry climate and design requirements of the tombs meant such properties were not necessary.

Mud Brick Making

Mud bricks in ancient Egypt were made from Nile mud with chopped straw and sand, mixed in varying quantities, to produce bricks of different characteristics. Depictions of

the brick manufacturing process from ancient Egypt survive in the form of Middle
Kingdom models and a brick making scene from the 18th Dynasty tomb of Rekhmire –
TT100 depicting this process in great detail.252

The process of making mud bricks in ancient times (and even to this day in Egypt)
involved the brickmakers’ pushing the brick mixture into a wooden mould, then
smoothing along the top by hand. The brick was then loosened from the mould, and left
on the ground to dry. The mud bricks were placed in rows, each separated by only the
thickness of the mould frame. The brick moulds were made of timber and mortised
together. The bricks would be left to dry for about three days before being turned over
for a similar amount of time. After one week they would be firm enough to move for
stacking and storage until needed.253 The production of mud bricks and labour force
requirements are discussed in Chapter 5.

Mud Brick Sizes254

Mud bricks used on individual tombs were generally all of the same size, with some
notable exceptions; Saqqara tombs S3506 and S3035, and Tarkhan Tomb 2050 used
smaller bricks to form the intricate panel façade in the superstructure compared to those
used to build the rest of the structure.255 In other tombs, the same brick size was used
throughout the structure.

The size of the mud brick in the Early Dynastic period was smaller than those in later
periods. A summary of brick sizes documented from various tombs and sites is
summarised in Table 3.1.

252 Model of mudbrick making in M. De Meyer, “The Tomb of Henu at Deir el-Barsha”, Egyptian
Archaeology Magazine – No 31, Bulletin of Egyptian Exploration Society (2007); N. de G. Davies,
Paintings from the Tomb of Rekh-mi-re at Thebes (New York: MMA, 1943).
253 H. Fathy, Gourna: A tale of two Villages (Cairo, 1969), 252. In experiments on brick mix designs, Fathy
concluded that “… pure Nile mud shrinks by over 30% in drying, but the sand and straw in the bricks prevents
the formation of cracks. Experiments with brickmaking in modern times have shown that the best mixture of
the constituents is 1m3 of mud, 1/3 of that amount of sand, plus 20kg of straw”.
254 An extensive study on brick sizing was published in J. Spencer, Brick Architecture in Ancient Egypt
(Warminster, 1979).
255 W. B. Emery, Excavations at Saqqara, The Tomb of Hemaka (Cairo, 1938); W. B. Emery, Great
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<tr>
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<td>B17/19</td>
<td>24 x 12 x 7</td>
</tr>
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<td></td>
<td>Aha B19</td>
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<tr>
<td></td>
<td>Djer</td>
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Table 3.1: Mud brick sizing

The size of the average modern day brick is approximately 23cm x 11cm x 7.6cm, not too dissimilar to those employed in the Early Dynastic period. This particular sizing is not coincidental. In fact, this is essentially the perfect size for handling a brick with one hand, without causing great fatigue to the labourer, enabling the laying of up to 1,000 bricks per man per day – a good productivity rate without the risk of sustaining injuries.

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<sup>256</sup> The brick sizes listed in this table were sourced from the original excavation reports for the respective tombs and supplemented with Spencer, *Brick Architecture.*
caused by long-term handling of heavy materials. The smaller brick size would have also made the drying process quicker during manufacturing.

3.2 Mortar

The binding material used was essentially the same as the mix design used to make mud bricks. The mortar employed in ancient Egypt before the Greco Roman times was clay, for use with sun-dried bricks, and gypsum, for use with stone.257

Clay Mortar

Clay mortar was Nile alluvium, consisting of clay and sand, which was mixed with sufficient water to bring it to the required viscosity, sometimes with the addition of a small quantity of chopped straw.258 The mortar was poured out along the mud brick wall, a more practical and efficient means of applying mortar to such a large surface area, than applying mortar to each individual brick. This method was possible due to the thickness of the walls.

Small stone blocks forming the retaining walls behind the monolithic stone slabs lining tomb Op1/1 at Helwan were mortared together with a pinkish orange mud mortar.259

Djer’s tomb at Abydos consisted of an almost square subterranean pit, lined with thick mud brick walls. The division brick cell walls had rough unplastered ends with the imprint of wood grain lining the chamber, still visible on the mud mortar adhering to the bricks.260 The mud brick pilasters around the chamber of Merneith’s tomb had the remains of a cast of plaited palm-leaf matting, left on the mud mortar.261 Semerkhet’s tomb appeared to have been built hastily, the brick walls being of poor quality. Furthermore, the amount of mortar between the brickwork was used sparingly, and not consistent with other constructions.262

258 Lucas and Harris, *Materials and Industries*, 75.
262 Dreyer, *MDAIK* 56, 119, 129.
On the roof of Tomb 3 at Karâra, the roofing beams were partly covered with Nile mud, before which reed mats and then mortar had been laid.263

Gypsum Mortar

In much of the stonework, the facing stone blocks were dressed such that mortar as a binding or pointing material was not necessary and, although employed, it acted largely as a cushion between the stone to prevent the edges from being damaged while they were being placed in position.264 In stone construction, gypsum was used at least since the 2nd Dynasty. It consisted of burnt gypsum and sand and very often chipped limestone.265

3.3 Stone types and Quarry Methods266

As early as the beginning of the Dynastic period, ancient Egyptians had thorough experience in stone working as evidenced from stone vessels produced from various types of hard rock, with very carefully worked surfaces. The hard stone vessels from the Predynastic and Early Dynastic periods attest to the extensive experience in drilling out rock and in external processing, for instance the production of relief designs and the smoothing and polishing of hard surfaces.267

The most common stone utilised in construction during the Early Dynastic period was limestone, although granite and sandstone were also used in limited quantity.

Limestone

Limestone, considered a soft stone, is a sedimentary rock, which has many origins. It consists essentially of calcium carbonate, some magnesium carbonate and siliceous matter such as quartz grains.268 Limestone was created by sedimentation in a marine environment. In mineralogical terms, calcium carbonate is called calcite (CaCO₃), that is, limestone is composed of grains of calcite.269

263  Ranke, Karâra, 9–10.
264  Lucas and Harris, Materials and Industries, 75.
267  Klemm and Klemm, Stone Quarries, 245.
269  Klemm and Klemm, Stone Quarries, 23.
Limestone was quarried using various methods including: large open excavations; the removal of the vertical faces or horizontal tops of cliffs; and the excavation of deep edits and galleries, in order to reach the better quality stone. Numerous ancient limestone quarries were located between Cairo and Esna, the more important ones being on the east bank of the Nile.\(^{270}\) The extensive number of limestone quarries meant that transportation of the material to sites was over short distances of 60km or less.\(^{271}\)

The stone used in the 1st Dynasty tombs at Abu Rawash was sourced from quarries that were very close to the site. The stone found in these tombs was mainly used for portcullis slabs, for example Tomb M11. The re-excavation of the tombs by the French Institute of Oriental Archaeology in Cairo found upright and horizontally placed limestone slabs forming what may be the enclosure wall and pavement of Tomb M012.\(^{272}\)

In Lower Egypt the Mokattam Formation, approximately 130m thick, is the source of limestone at the famous quarries of Gebel Tura and Gebel Hof.\(^{273}\) The lowest layers of this formation are of very fine quality, and were used extensively in the Old Kingdom, where this stone was ideal for carving the fine reliefs found in the tombs of this period. In the eastern cliffs south of Mokattam is Helwan, where the stone quarries were in close proximity, and would not have needed to be transported far.

At Saqqara limestone began to be used in architectural elements, for example, Tomb S3507\(^{274}\) and Tomb S3506\(^{275}\), where stone door frames and lintels were employed. The passage leading into the substructure of Saqqara Tomb S3121 was roofed with large limestone beams.\(^{276}\) Limestone was used in some of the larger Helwan tombs to line the walls, and for paving and roofing the structure, for example, Helwan tombs 9.H.1 and

\(^{270}\) For a full listing of quarries refer to Arnold, *Building in Egypt*, 29–30. Interestingly, the site where extensive use of stone occurs in non-royal applications and non-elite applications are on the east bank, the site of the quarries studied here, for example, Helwan.

\(^{271}\) Arnold, *Building in Egypt*, 27.

\(^{272}\) Personal communication, Yann Tristant.


\(^{274}\) A limestone lintel spans a pair of rock cut pilasters at the base of the stairway leading into the substructure of Tomb S3507. This lintel supported a secondary roof made up of stone beams. Emery, *Great Tombs III*, 77, pl. 86.

\(^{275}\) A main stairway leads to the burial pit of Tomb S3506. The 16 brick built stairs terminate at a narrow landing and a finely built gate of limestone opens directly into the pit, 1.2m above floor level. The gateway consists of three cut slabs of limestone, 0.37cm thick, which form the jambs and lintels. The stone lintel was inscribed with text. Emery, *Great Tombs III*, 40, pl. 55.

\(^{276}\) W. B. Emery, *Great Tombs of the First Dynasty Part I* (Cairo, 1949), 116, pls. 46, 49.
Op1/1. The main usage of limestone during the Early Dynastic period in construction, was for the purpose of protecting the tomb, following the introduction of a stairway entrance, through the portcullis stone.

The process of selecting material meant that Pharaonic quarries only occur at certain levels. Sometimes more than one layer of a hillside was suitable for construction use and was quarried. These layers, which are stable despite weathering, provided early builders time to establish quarries with nature pre-selecting the most resistant layers. It was rare for the entire slope to be excavated, as this produced a large amount of waste from limestone layers, which were unsuitable for use in construction. Open quarries seem to only become common in the New Kingdom.

Archaeological evidence of Early Dynastic usage of ancient quarries, for example, pottery sherds and stone tools, is not available, and one could deduce that any such evidence is now long gone due to the use of the quarries in later periods. For this reason, microscopic analysis of stone is a useful tool to provide a greater insight into where the stone was sourced.

Chisel marks from different excavation periods have been preserved with unusual clarity due to the exceptional quality of the rock and protection from weathering and daylight that the site offered. The chisel marks in limestone quarries of the Old Kingdom and Middle Kingdom are very similar to each other and are characterised by rather irregular short running notches at the worked surfaces and walls, created by copper chisels too soft to be carefully controlled. The limestone slabs used to line Helwan Tomb Op1/1 had the remains of diagonal chisel marks on the surface. Some of the monolithic stone slabs used in Op1/1 show natural, often parallel fissures, which

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277 Tomb Op1/1 was originally labelled 40.H.3 when first excavated. Z. Y. Saad, Royal Excavations at Saqqara and Helwan (1941-1945), Suppléments aux Annales du Service des Antiquités de l’Égypte 3 (Cairo, 1947), 164, pls. LXII, LXIX, LXX. Re-excavated and published by Macquarie University. Köhler, Helwan I.


279 Klemm and Klemm, Stone Quarries, 23.

280 Klemm and Klemm, Stone Quarries, 52–53, 90.

cause the stone to split easily. It is possible the stone was sourced from the ancient quarries in the area of Helwan or Tura/Mas’asara.282

In the early New Kingdom, a new type of chisel mark resulted from improved bronze metallurgy. In Early Dynastic times however, bronze was not available to the Egyptian builders, who had to contend with working with copper. In Pharaonic times, simple copper or bronze chisels were used to excavate square blocks of 1.5m to 3.0m into approximately 20cm wide grooves of flutes. These blocks were then wedged off from underground at the required height. A block-shaped grid pattern remains at the north-west corner of the pyramid of Khafre.283

Quarried stone blocks were transported to the construction sites and workshops using rollers or wooden sledges. A relief from the beginning of the New Kingdom shows a sledge loaded with a block of stone, being pulled by six oxen.284

Where as definite quarry areas can be made out on the Giza Plateau, the same can not be said for Saqqara North, Saqqara South and Abusir. The primary reasons for this are the geological composition and limestone, which consist of 20cm to 60cm thick sandy limestone to calcareous sandstone beds, alternated with layers of lower compact calcareous mud.285 This layout meant the original thickness of the limestone layers was reflected in the thickness of the construction stones. Large amounts of construction stones were able to be obtained in Saqqara in a short time, although they were smaller than the stones normally used to build the 4th Dynasty pyramids in Egypt. The use of smaller stone pieces for the pyramid of Djoser has generally been interpreted as a deliberate following of the mud-brick format that had been common until that time. However, it is more likely as result of the natural properties of the rock.286

Whilst we have digressed to the 3rd Dynasty this use of stone by the early Egyptian builders once again reflects a competent and practical use of the resources available to

286 The rock material used for the body of the Djoser pyramid has a low resistance to weathering, which was taken into account when the pyramid was covered with a high quality limestone casing. Klemm and Klemm, *Stone Quarries*, 56.
them and a sound knowledge of the materials used – an underlining theme throughout this research.

Sandstone
Sandstone is a sedimentary rock, and, like limestone, is considered a softstone. It is made up of sand-sized particles of detritus rock and mineral fragments held together by quartz, calcite, iron oxide, clay and other materials.287 The quartz or silicate grains measure between 0.063mm and 2mm. Unlike limestone, which can sometimes be confused with sandstone when viewed superficially, sandstone will scratch iron (limestone is too soft to do so).288

Sandstone quarries begin south of Esna, and can be found on both sides of the Nile River. These quarries, however, would have serviced the Egyptians in later periods. Sandstone began to be used in large quantities from the 11th Dynasty onwards, as seen in the mortuary complex of Menthuhotep I.289 The absence of quarries around Hierakonpolis is a result of the poor quality of the local sandstone in the Western mountains, which are flat in this area. Requirements for sandstone blocks could have been sourced from the far more significant quarries located opposite at Elkab (Nekheb), where sandstone quality was far better.290 A number of tombs at Elkab, dating back to Naqada IIIA1 (Dynasty 0) through to the 1st Dynasty, contain un-worked sandstone slabs in the construction.291 This sandstone is found along the edges of the Wadi Hellal, breaking into slabs when eroded and alleviating the need for quarrying.292

Granite
Granite, a hardstone, is an igneous rock, formed from melted or molten materials. Quartz, alkali feldspar, and, to a lesser degree, plagioclase and mica are its essential components. In some rocks, microcline is also present.293 The geological source of granite or granodiorite in the area south of Aswan was not initially the bedrock in the mountains themselves, but mostly rounded blocks, some more than 100m³ in size, that

287 Nicholson and Shaw, Materials and Technology, 54.
289 Nicholson and Shaw, Materials and Technology, 54.
291 S. Hendrickx, El Kab V: The Naqada III Cemetery (Brussels, 1994). The stone slabs were used as roofing, and in some instances to separate a chamber.
292 Hendrickx, El Kab, 150–151.
293 Nicholson and Shaw, Materials and Technology, 35.
had been created by the weathering processes. Granite quarries are located between Aswan and the el-Shellah district in the south.

The granite used in Den’s burial chamber pavement and Khasekhemwy’s Hierakonpolis temple as doorjambs was coarse-grained granite with quartz, microcline, oligoclase and biotite plus minor hornblende and accessory minerals. This is the so-called ‘monumental red or pink granite’ of Egypt.

During the early periods, huge boulders of granite, which did not require the additional effort of quarrying, were used as a ready source. These boulders would soon have been exhausted and actual quarrying would have become necessary. Granite, being a hardstone, was always quarried using the open-cut method. This method involved pounding the granite with even harder stones known as diorite balls, weighing up to 5kg. This led to small flakes of granite breaking off, eventually forming a trench around the blocks, before the final extraction took place.

Generally, the quality of the rock rather than its accessibility dictated where a quarry was located. This is evidenced in the location of many ancient quarries on the upper slopes of hills and escarpments, rather than at their base where similar but lower quality rock exists.

The construction of the first tombs incorporating stone masonry in the Early Dynastic cemeteries of Helwan, Saqqara and Abydos was the incentive for the rapid growth in the quarrying limestone and granite for building.

3.4 Tomb Excavation Tools

Records from the New Kingdom provide an insight into the use and maintenance of tools for the cutting of the Theban mountain tombs. These tombs were cut into

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294 Klemm and Klemm, Stone Quarries, 233.
295 Arnold, Building in Egypt, 36–37.
296 Petrie, Royal Tombs II, 9–10.
298 Nicholson and Shaw, Materials and Technology, 35.
299 Arnold, Building in Egypt, 37.
300 Nicholson and Shaw, Materials and Technology, 6.
301 Nicholson and Shaw Materials and Technology, 5–6; La Loggia, BACE 19, 73–95.
302 Pharaonic examples are provided due to the lack of available evidence from the Early Dynastic period. Based on seal impressions and labels found with grave goods from this early period, Egyptians were
limestone, but when flint was encountered, the harder material quickly resulted in the soft copper chisels becoming blunt. Coppersmiths were employed to reforge these valuable commodities, as indicated in surviving records of the issuing of chisels to workers:

[Year 1], Fourth Month of winter, Day 21.
Day of [issuing] the chisels to the gang.
Chisels, 68. Itemization:
  34 on the right side
  34 on the left side
Total, 64 (sic)

Year 6, Third month of summer, day 23. Handling over the blunted portion of the chisels of Pharaoh by the (three) captains, the two deputies, and the two police inspectors. They (lit. you) went to the Enclosure of the necropolis to (?) the doorkeeper Kha-em-waset, the policeman Amen-mose, the policeman Nakhte-Sobek, and Had-nakhte, the scribe of the treasury of Medinet Habu. They found 307 deben of copper. 303

**Metal Tools – Chisel**

Petrie classified metal chisels into the following categories: 304

- A – square bar
- B – deep bar and narrow edge
- C – thin and wide edges
- D – circular bar.

The metal tools of the Pharaonic period were mainly of copper or bronze. 305 Although metal chisels were used for stone working, their use was limited to work that is more detailed. Rough work, such as excavation of tombs and quarrying stone was undertaken using stone tools, as metal was too valuable and the tools, due to the softness of copper

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305 Further discussion on chisel marks can be found under *Limestone* heading in this chapter.
and even bronze (compared with steel), would need to be constantly sharpened or replaced.

Copper chisels from tombs are known since the 1st Dynasty and, due to the softness of the product as discussed above, were most likely used for woodworking. These include, but are not limited to, Tomb 1 at Abu Rawash, Saqqara Tombs S3471 and S3504, the royal tombs at Abydos of Djer and Khasekhemwy. Some of the chisels from the 3rd Dynasty, however, were certainly used for dressing stone, especially those from the Djoser precinct. As such, the excavation of substructures and subterranean tombs would have been accomplished with stone tools; the use of metal tools would have been primarily for ‘touch-up’ work and working with softer materials such as timber.

**Stone Tools**

Despite the existence of metal chisels from the Early Dynastic period, stone tools certainly formed the majority. Stone is abundantly available and harder stones could only be cut with stone tools, as copper chisels would have been impractical because of the severe wearing. Four main groups of stone tools can be recognised from the numerous objects found in nearly all Pharaonic construction, quarry, and mining sites: picks, pounders, two-handled rammers and grinding stones.

**Picks**

Surviving tools show the stone pick to have been an elongated implement of granite, chert, basalt, quartzite, or even hard, silicified limestone, 30cm to 50cm in length. Representations on tomb walls would indicate that the stone was not held in the hands but between two sticks attached with a leather strap, as depicted in the tomb of Ti. The stone pick was effective in excavating tunnels and shafts for tombs or breaking the separation trenches for building blocks in quarries. The curved line produced by wielding the pick is visible in many unfinished surfaces and walls, indicating that skilled workers using this bulky tool could achieve a certain degree of flatness on the stone.

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306 P. Montet, “Tombeaux de la 1ère et de la IVe dynasties à Abou-Roach”, Kémi 7 (1938), pl. X; Emery, Great Tombs I, 30–37, 42–48; Emery, Great Tombs II, 59, pls. VI, IXA, XXXI.
307 Arnold, Building in Egypt, 257–258.
308 Arnold, Building in Egypt, 260.
309 H. Wild, Le Tombeau de Ti (Cairo, 1966), pl. CLXXIII.
310 Arnold, Building in Egypt, 262.
Pounders

Pounders were roughly or completely spherical balls, mainly of dolerite, with a diameter of 15cm to 30cm and weighing between 4kgs to 7kgs. Dolerite is present in a number of vein systems at Aswan. This slightly metamorphosed mafic igneous rock acquires sharp edges when broken. It is a very fine-grained material, which is mechanically highly resistant on account of its intensive grain intergrowth.\(^\text{311}\) They were found at most of the construction sites in the Old and Middle Kingdoms. Pounding was the main method of working granite.\(^\text{312}\)

When the dolerite balls themselves broke apart during striking, they were used to smooth rock surfaces that had been firstly coarsely worked with hammering. However, for polishing hard surfaces, an abrasive agent was used and sourced from 1m to 3m thick hydrothermal quartz veins located to the south-east of the village of Nag el-Gezira, about 3km north of Aswan.\(^\text{313}\)

Grinding Stones

The final surface treatment of the Pharaonic stone building was carried out with grinding stones. Grinding could be done with all types of stone. For the grinding of limestone and sandstone, grinders made of sandstone could be used. The treatment of harder stones required the use of abrasive sand. Even the grinder itself would probably be of a harder substance. The sand could be dry, but dampened sand would produce less dust and cleaner work. The fine polishing was probably carried out without water.\(^\text{314}\)

The polishing and abrasive agent, hydrothermal quartz, was divided into different sieved fractions offering different levels of quality. Suspended in water, it was then used to work the surface of the stone in a circular movement, together with the smoothing stones. The sharp edges of the newly broken quartz grains, with a Mohs hardness of 7, were capable of finely polishing all Aswan granites.\(^\text{315}\)

\(^{312}\) Arnold, *Building in Egypt*, 262.
\(^{313}\) Klemm and Klemm, *Stone Quarries*, 249.
\(^{315}\) Klemm and Klemm, *Stone Quarries*, 249.
3.5 Timber

The main roofing material for Early Dynastic tombs was timber. Cedar would have been used to span the larger tombs in Abydos and Saqqara, although the local timbers Acacia, Sycamore and Tamarisk were used on smaller tombs and subsidiary chambers. Emery wrote:

Egypt was always sparsely wooded, and although local wood may have been used in room linings, etc., the great joists and planking for roofing were imported from Lebanon. Although a certain amount of palm timber must have been available, cedar was the only wood suitable for the span necessary in the large subterranean rooms of the royal tombs.  

Cedar

Cedar of Lebanon (Cedrus Libani) is a large tree that can grow to a height of 30m to 40m. The diameter of the tree trunk ranges between 1m to 2.5m. The young trees are conical in shape, but gradually become more flattened with widely spread branches. Cedar was used for roof beams and lining of burial chambers. The timber was rafted and towed along the Mediterranean coast to be stored in timber yards in the Delta. The Palermo Stone records that forty ships sailed to the Lebanese coast where cedar trees were felled:

Bringing of 40 ships filled (with) cedar wood
2 cubits, 2 fingers

To appreciate the magnitude of trade, one must consider that the sawn and aged timber of several Lebanese cedars must have been required for each royal tomb. Such demand must have required substantial technical and organisational skills including large ships to transport the timber from Palestine, or at least dispatch it from the Delta, as well as a military like organisation of trade expeditions; unfortunately no such archaeological evidence exists.

**Acacia**

Typically a flat topped tree, the acacia heartwood is red, hard and durable. This timber was used for roof beams and coffins. Acacia could also be used as reinforcement between layers of mud brick walls to add strength.\(^{320}\)

**Sycamore**

The sycamore tree produces wood which is pale, light, fibrous, coarse and of poor quality. The tree stands erect and develops massive lateral branches. It was used for roof timbers, coffins, wagons and statues.\(^{321}\)

**Tamarisk**

Tamarisk trees can grow up to 15m tall, but are usually much smaller. Found along water courses and saline desert regions, the use of tamarisk wood can be traced to the Neolithic period and Predynastic period.\(^{322}\) At Abu Rawash, analysis by Ahmed Fahmy of the Helwan University, of timber found in the 1\(^{st}\) Dynasty tombs currently undergoing re-excavation by the French Institute of Oriental Archaeology in Cairo – found the timber to be acacia and tamarisk. Furthermore, despite the elite nature of the larger 1\(^{st}\) Dynasty tombs at Abu Rawash, with their similar architecture to those situated in Saqqara, there has been no evidence of cedar found thus far.\(^{323}\)

**Acquisition of Timber**

The saw was used from the beginning of the 1\(^{st}\) Dynasty and possibly earlier. The equipment at this time may not have been the best, as attested to by a piece of cut timber from a grave in Tarkhan, which had saw marks highlighting how troublesome the work proved to be.\(^{324}\)

**Tree Felling**\(^{325}\)

The axe was one of the most important tools for Egyptian craftsmen engaged in woodworking. From the late Predynastic period to Graeco-Roman times, different types

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\(^{322}\) Nicholson and Shaw, *Materials and Technology*, 345.

\(^{323}\) Personal communication, Y. Tristant.

\(^{324}\) The saw marks ran in varying directions indicating a tool which may have been difficult to work. W. M. F. Petrie, *Tarkhan I and Memphis V* (London, 1913), pl. XXXIV. Alternatively, the saw marks could also be interpreted as having been cut by someone with less experience.

of blades were fitted to the Egyptian axe. The first flat blades were made of native copper. The equal-faced blades were shaped and hardened by hammering, primarily along the edges. The earliest forms of metal blades were similar to stone axes. Metal axes from the beginning of the Dynastic period did not have special attachments for handles and their cutting edge had a semicircular outline, while others resembled a trapezium.326

The ancient process of tree felling could be interpreted from tomb wall reliefs showing woodcutters at work. For example:

- The tomb of Sekhemkara at Giza (dated to 4th Dynasty reign of Khafra), contains a depiction of a man felling a tree; he has chopped a deep notch at the base of the truck, and a tree is falling away from him. The scenes on the relief fragments show the large size of the felled timber. An overseer, shown holding a staff, supervises men who are removing the branches from the trunk.327
- In the tomb of Nefer and Kaha at Saqqara, there is a scene showing two men felling a tree using the ‘double-notch’ technique.328
- The 12th Dynasty tomb of the nomarch Khnumhotep III at Beni Hasan (BH3)329 shows three wood cutters felling a small tree and feeding the foliage to gazelles.
- A scene in the tomb of Ipu at Thebes depicts a woodcutter removing branches from the tree (TT217).330

Conversion of Timber

At times, branches were simply used in their natural state, as seen in the subsidiary chambers of Khasekhemwy’s tomb at Abydos.331 The typical process, however, once a tree had been cut down, was to quickly convert the timber into wood in order to prevent the development of defects such as splits in the timber which can open into holes either radially from the centre of the trunk or around growth rings.332 In the Dynastic period, long planks were most likely split from the trunk, making it necessary for woodcutters to select straight grained timber with few defects. The technique of cleaving was

326 Petrie, Royal Tombs II, 28, pls. 9a, 45; B. Scheel, Egyptian metalworking and tools, (Shire, 1989), 47; E. Teeter, ed. Before the Pyramids (Chicago, 2011), 447, fig. 112.
327 Nicholson and Shaw, Materials and Technology, 353.
328 Nicholson and Shaw, Materials and Technology, 353.
329 P. E. Newberry, Beni Hasan I (London, 1893), Plate XXIX.
330 N. de G. Davies, Two Ramesside Tombs at Thebes (New York: MMA, 1927), Plate XXX.
332 Nicholson and Shaw, Materials and Technology, 354.
practiced from as early as the Predynastic period. The process of cleaving timber is depicted in the 6th Dynasty tomb of Iteti at Deshasha.\footnote{W. M. F. Petrie, Deshasheh 1897 (London, 1898), pl. XXI; “Two men are shown splitting a log, which is strapped to a trestle, with the point of a long pole being driven into the split; a third man is preparing a log with an axe, probably defining the edges of the planks to be cleaved. This scene also shows the timber conversion was achieved by a saw, with the log being bound with rope to a vertical sawing post, suggesting that accurately sawn planks would usually not have been greater in length that the height of the sawyer” in Nicholson and Shaw, Materials and Technology, 354.}

**Seasoning**

In freshly felled ‘green’ timber, the moisture had to be reduced by a process of seasoning. This was necessary to prevent the timber from warping or shrinking. This process involved the circulation of air around the boards, traditionally undertaken by stacking boards horizontally and placing spacers between them, as illustrated in the tomb of Iteti.\footnote{Petrie, Deshasheh, pl. XXI.} To control the rate of drying, reed mats may have been placed over the timber.\footnote{Nicholson and Shaw, Materials and Technology, 355.}

**Wood Working Techniques - Tools**

During the Predynastic period, native timbers were commonly employed, with little demand for imported wood. By the beginning of the Early Dynastic period this had changed and specialised copper woodworking tools, allowing for timber to be worked with a higher degree of accuracy, were introduced. The metal saw was already known at the beginning of the 1st Dynasty. Saws of different types and sizes were used throughout Egyptian history for the production of boards, planks and veneers. A good quality collection of woodworking tools was discovered by Emery in the Early Dynastic Saqqara tomb, S3471.\footnote{Emery, Great Tombs I, 30–37, 42–48.} The introduction of copper saw the conversion of timber into good quality boards, as well as the more complex cutting of timber to various lengths across the grain and the creation of sophisticated joints. Logs or thick planks were often lashed to a post stuck into the ground, which served as a vice.\footnote{B. Scheel, Egyptian Metalworking and Tools, (Princes Risborough, 1989), 50–51.}

The adze was used to shape the timber. During the Early Dynastic period, adze shafts were straight.\footnote{Emery, Great Tombs I, Figure 19.} From the 2nd Dynasty a type of blade with a rounded upper end developed. From the 3rd Dynasty blades with a marked notch in the upper end were...
used. A scene in the 5th Dynasty tomb of Nefer and Kaha at Saqqara shows two men dressing a log with large adzes.

Handheld abrasive blocks of siliceous sandstone were used by the carpenters to smooth the timber by rubbing along the grain. Rubbing against the grain would have scuffed the timber and damaged its appearance. This process, used throughout the Dynastic period, is depicted in the 5th Dynasty tomb of Ti at Saqqara and the Ramesside tomb of Ipuy at Thebes.

3.6 Alignment Tools

Having manufactured and acquired the necessary materials for tomb building, the final stage, the actual construction of the tomb, required skilled supervisors as well as labourers to see it built accurately. Mud brick walls had to be aligned to ensure they were upright and level, monolithic stone slabs and the walls of excavated subterranean tombs needed to be checked to ensure they were flat, and the overall structure had to be built to the original planned dimensions. To achieve this, proper alignment and measuring tools were required.

No direct evidence from the Early Dynastic period has been found showing the use of alignment and measuring tools; this, however, does not automatically mean such tools were not used. In order to construct such large mud brick structures, in some cases intricately niched, alignment tools must have been used, given the degree of accuracy in the construction. For now, however, Pharaonic examples are cited. Emery found on Saqqara Tomb S3504, the imprint of a plucked cord on the mud plastered surface of the bench surrounding the palace façade superstructure, providing the builders of the time the level for the top of the bench. The painted exterior walls of Saqqara Tomb S3505, still retained the guiding lines of the craftsmen, for the painted decoration.

341 Wild, *Le Tombeau de Ti*, pl. CLXXIV.
Cubit Rod
Cubit rods were made of wood, the length varying from 52.3cm to 52.9cm, with a thick rectangular cross-section and a fifth side produced by a chamfered top edge. The nby-rod (mentioned on a Theban ostraka from the tomb of Senenmut), was also used as a measuring tool by stonemasons, which may have measured approximately 67cm to 68cm and was subdivided into seven segments, each approximately 10cm.\textsuperscript{345} When excavating the royal tombs at Abydos, Petrie, in some instances, provided measurements in cubits.\textsuperscript{346}

Measuring Cords
For measuring great distances, ropes were used. Since the number 100 is represented in hieroglyphs by the rope, it is possible that measuring ropes of 100 cubits (52.5m) were used.\textsuperscript{347} To ensure its practical use, such a long rope would need to have been made of fine material as a heavy or bulky rope would have proved impractical.

Plumbs
Plumb-bobs were used by ancient Egyptian bricklayers, masons, and carpenters to ensure that their constructions were "plumb", that is, perfectly upright. Plumbs consisted of a plumb-bob, suspended from a peg or a stick, which could also be used to reel up the cord. The board was held vertically against the wall to be tested, and the plumb bob was attached to a wooden cross board so that the cord, if in a vertical position, would touch a second cross board the same size as the first below it.\textsuperscript{348}

Up until the modern age, on most tall structures, plumb-bobs were used to provide vertical datum lines for the building measurements. A section of the scaffolding would hold a plumb line that was centred over a datum mark on the floor.

Builders Squares
In order to check right angles, Egyptian Builders and masons made use of the square in buildings as well as for dressing blocks. The square consisted of two arms connected at right angles with pegs or tongue and groove. One of the two legs could be strengthened

\textsuperscript{345} Arnold, \textit{Building in Egypt}, 250–251.
\textsuperscript{346} W. M. F. Petrie, \textit{Royal Tombs of the Earliest Dynasties} I (London, 1900), 16–17.
\textsuperscript{347} Arnold, \textit{Building in Egypt}, 252.
\textsuperscript{348} Arnold, \textit{Building in Egypt}, 253.
by a footboard, which allowed the square to stand independently upright. In the tomb of Rekhmire, a square is shown lying in a carpenter’s workshop, suggesting it was used by other craftsmen as well.349

Square Levels
The Egyptian square level always had two legs of equal length, connected at right angles with a cross board so that the tool was in the shape of the capital letter 'A'. The legs were made in such a way as to make it stand. A plumb-bob was suspended near the connecting corner of the two legs that could coincide – when the level was standing horizontally – with a mark in the centre of the cross lath.350

Boning Rod
Egyptian masons used boning rods to dress blocks and obtain completely flat planes. The boning rod consisted of three pegs of equal length, two of which were tied together with a string. The edges of the stone block were given their final flat draft, the connected pegs stood on end on opposite edges with the string taut between them. The amount of stone to be trimmed could then be measured with the third peg. Dressing down large blocks to a true face involved running a saw cut about 1cm along all sides before hammer dressing the surface.

The tomb of Rekhmire shows this process of fine dressing being undertaken by holding two rods of wood with a string stretched between the tops of the rods.351 A mason holding a rod of equal length on any point of the stone face would then chisel away the amount that stood above the string. From the pyramid times onwards, the Egyptians used an adze for dressing the faces of stones.352 The rods were 10cm to 13cm long.353

3.7 Scaffolding
Scaffolding is represented in the tomb of Rekhmire where sculptors are depicted working on a freestanding colossal royal statue. The scaffolding consists of light poles,
tied together by knots or rope.\textsuperscript{354} Scaffolding was reinforced with ropes of twine and anchored deep into paving or rocky ground. Surviving evidence of such holes remains at the pyramid temple of Khufu, Mentuhotep’s temple, the hypostyle hall of Ramesses III’s and the temple at Medinet Habu.\textsuperscript{355} Large postholes located in front of major brick walls at Amarna point to anchor points for the assembly of scaffolding as the brickwork went up.\textsuperscript{356} Some mud brick walls, of considerable thickness, were found to have holes running perpendicular to the face (initially suggesting they were used to attach the scaffolding) but connected to longitudinal channels in the interior. These channels in the brickwork are thought to have formed a ventilation system to assist in the drying of the brickwork.\textsuperscript{357}

When Emery excavated the Saqqara tombs: S3357, S2185, and S3503, four postholes were found in the pavement in front each of the large niches of the individual superstructures. Emery believed the postholes were used to hold standards and not the remains of scaffolding footings.\textsuperscript{358} Emery subsequently suggested they were used for scaffolding.\textsuperscript{359} This seems doubtful based on the care taken in all aspects of the construction. Surely, if the holes were the remains of scaffolding support posts, the builders would not have been so careless as to not fill the holes with mud following the removal of the scaffolding and the completion of the tomb. It stands to reason that Emery’s original suggestion of the holes acting to support standards seems more probable, and any evidence of scaffolding was covered up, in the same manner as modern day construction.\textsuperscript{360}

The corridor between the enclosure wall and superstructure walls of Saqqara Tomb S3505, along the east side only, was paved with thick stamped mud overlaid with white

\textsuperscript{354} N. De G. Davies, \textit{The Tomb of Rekh-mi-Re at Thebes} (New York, 1943), pl. 60; Arnold, \textit{Building in Egypt}, 231.
\textsuperscript{355} Arnold, \textit{Building in Egypt}, 211.
\textsuperscript{357} Spencer, \textit{Brick Architecture}, 116.
\textsuperscript{358} W. B. Emery, \textit{Excavations at Saqqara, Hor-Aha} (Cairo, 1939), 10. This would seem logical based on the care taken in the construction of these tombs. Leaving evidence of the building phase would surely have been an unthinkable oversight of the earlier builders and supervisors.
\textsuperscript{359} Emery, \textit{Great Tombs} II, 131.
\textsuperscript{360} In today’s building, the area where the scaffolding is secured into the brickwork, a single brick is removed. When the scaffolding is dismantled, the brick is mortared back into place. Following the immediate completion of the building, the areas where the bricks have been replaced are generally evident due to the difference in mortar colour. With weathering and drying of the mortar, all evidence eventually disappears.
gypsum plaster. Upon lifting up sections of the pavement, Emery found a series of circular holes, averaging 16cm in diameter, evenly spaced at 1.75m centres.\textsuperscript{361} This suggests they may have been the remains of scaffolding imprints.

### 3.8 Plastering

Aside from the aesthetic appeal of plastering the walls of mud brick structures, the plaster also served a practical purpose. The brick wall required a firm surface for protection from the elements. An occasional downpour would have resulted in streams of water rapidly cutting through walls of unplastered brick. The plaster would have provided protection from this as well as adding to the mechanical strength of the wall.\textsuperscript{362} Records from the New Kingdom provide details on the preparation of raw gypsum for making plaster:\textsuperscript{363}

Year 17 First month of inundation: work of the gypsum-maker, right side, (received) by scribe Wen-nefer:

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing gypsum, amounting to</td>
<td>1/8 sack of gypsum daily</td>
</tr>
<tr>
<td>Makes, left-side, (per) 10 (days)</td>
<td>1 ¼ sacks</td>
</tr>
<tr>
<td>Makes (per) month</td>
<td>3 ¾ sacks</td>
</tr>
<tr>
<td>Makes (per) 4 months, makes</td>
<td>15 sacks gypsum</td>
</tr>
<tr>
<td>Left Side</td>
<td>15 sacks gypsum</td>
</tr>
<tr>
<td>Total, right and left,</td>
<td>30 sacks</td>
</tr>
</tbody>
</table>

**Clay Plaster**

The use of clay plaster dates from the Predynastic and Early Dynastic times. The quality of plaster varied considerably from a course textured plaster\textsuperscript{364} that was generally, but not always, mixed with straw, to a finer textured and better quality plaster made with and without straw\textsuperscript{365} and often as a finishing coat to the coarser kind. The clay plaster was usually covered with gypsum plaster in order to provide a more suitable surface for

\textsuperscript{361} Emery, Great Tombs III, 7.  
\textsuperscript{362} Nicholson and Shaw, *Materials and Technology*, 92. The plastering of the mud brick walls enabled the walls to become a composite structure, acting as a homogenous mass.  
\textsuperscript{363} McDowell, *Village Life*, 211.  
\textsuperscript{364} The coarser plaster consisted of ordinary Nile alluvium. Essentially, this plaster was a mixture of clay and sand in varying proportions with a small natural admixture of calcium carbonate (calcium of lime) and occasionally a small proportion of gypsum, which was purely accidental as it had not been burnt and had no binding property. Lucas, and Harris, *Materials and Industries*, 76.  
\textsuperscript{365} The finer plaster was a natural mixture of clay and limestone, both in a very fine state of division, found in hollows and pockets at the foot of the hills and plateau from which it had been washed out by the occasional rainstorms that occurred. Lucas, and Harris, *Materials and Industries*, 76.
painting, for example, Saqqara Tomb S3357. The exterior of the superstructure was originally faced with a thick mud plaster and white gypsum plaster. As well as clay plaster, taffl was also used.

_Gypsum Plaster_

Gypsum plaster is the characteristic wall plaster of ancient Egypt and is known from Early Dynastic times. No evidence can be found for the use of lime before the Ptolemaic period. Plaster referred to as ‘lime plaster’ in tomb reports pertaining to Early Dynastic tombs is, in fact, gypsum.

Although limestone was a more plentiful and accessible ingredient than gypsum, the latter was preferred in making plaster because of the low burning temperatures required. The temperature required to burn gypsum varies from 100°C to 200°C, but is generally kept at approximately 130°C – a temperature easy to reach and maintain. In sharp contrast, the temperature required to produce lime by burning limestone (calcium carbonate) is 900°C. Reaching this higher temperature, however, would have required significant amounts of fuel for burning, and, since fuel would have been in short supply, the production of lime was impractical.

Gypsum plaster was usually applied as a final coat to a wall already plastered with mud plaster. The mud brick walls of Saqqara Tomb S3503 were faced with mud plaster about 2cm thick and then 1cm thick gypsum plaster was applied, before finally being white-washed. The superstructure façade of Saqqara Tomb S3507 was mud plastered, 2cm thick, finished off with white gypsum plaster. It was painted yellow with the inner recess of the large niches painted red.

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366 Referred to in the tomb report as ‘lime stucco’, Emery, Hor-Aha, 15. For additional examples refer to Chapter 4 of this research.
368 Lime was not used in ancient Egypt until the Ptolemaic Period, and plaster frequently termed ‘lime plaster’ or ‘lime stucco’ is always gypsum until this later period. Lucas, and Harris, Materials and Industries, 76.
369 Lucas, and Harris, Materials and Industries, 75, 79.
370 Emery, Great Tombs II, 130.
371 Emery, Great Tombs III, 76. For further examples, refer to Chapter 4 of this research.
Gypsum plaster was also employed for the purpose of covering up faults and irregularities on the stone walls and for smoothing surfaces before painting.372

**Plastering Tools**

Egyptians used their hand for spreading plaster in early times. But the need for finely stuccoed walls for tomb painting led to the use of the plasterer’s float, not dissimilar to those used by plasterers today.373

The plaster was smoothed with a wooden float that was cut from one piece of timber. A large float with cylindrical grip was used for the rough coat. It had a bevelled end in order not to disturb the coat in the corner of an adjoining wall.374 The smaller float was lighter and smoother, and was used to apply the final, finer textured coat.375

**3.9 Painting**

A corridor between the enclosure wall and superstructure of Tomb S3504 was stamped-mud, over which a thin layer of gypsum plaster was applied and then painted green.376 Surrounding the superstructure of Tomb S3503 was a stamped mud pavement, covered with white gypsum plaster and then painted red and blue.377 Saqqara Tomb S3505 consisted of a rectangular superstructure with the typical niched palace façade. The north, east and south walls were built with elaborate recessed panelling, while the west façade had a simplified panelling, similar to that employed on the enclosure walls of Djoser’s mortuary complex. The mud brick walls were faced with gypsum plaster and then painted with elaborate frescos of geometric patterns.378 The remains of painted walls were also found in Saqqara Tomb S3121.379

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372 Lucas, and Harris, *Materials and Industries*, 77.
375 Gypsum plaster and probably mortar were often prepared or carried in bottoms of broken beakers and bottles. Such containers, partially filled with gypsum and showing fingerprints of the workmen, are frequently found at construction sites. D. Arnold, *The Encyclopedia of Ancient Egyptian Architecture* (London, 2003), 292–293. The author was unable to find any examples where tools had been found around the perimeter of the Early Dynastic tombs.
378 Emery, *Great Tombs III*, 6, pl. 6–8.
379 Emery, *Great Tombs I*, 116, pl. 50. Evidence of painted decoration on the exterior walls of other Saqqara tombs exists, in some cases through the remains of splashes of paint, for example tombs S3504 and S3503. Emery, *Great Tombs II*, 9, 130. The walls of other tombs were simply painted white, for example Tomb X. Emery, *Great Tombs I*, 107.
**Brushes**

Brushes were in common use in ancient Egypt and were made up of various vegetable fibres. For painting, bundles of finer fibre, with different degrees of fineness, were bound together at the top with a thin rope, or palm leaf to form a handle. Also used for painting were pieces of fibrous wood bruised at one end until the fibres separated to form bristles. This kind of brush was used exclusively for painting, and ten models were among the tomb painters' outfit. Paints were made using finely ground naturally occurring materials or mineral substances and the use of minerals is one of the reasons the colours remain so well preserved to this day.380

### 3.10 Carrying Baskets

The removal of spoil was undertaken with baskets, with examples found by H. E. Winlock during a 1921 to 1922 excavation season at the Middle Kingdom site of King Mentuhotep at Deir el-Bahari. At the 11th Dynasty temple of Mentuhotep site, 50 baskets still filled with stone chips that had been abandoned by the workers following an interruption to their work were found.381 These baskets were approximately 62cm x 40cm x 40cm when scaled off the published photographs.382 Based on the size of these baskets and the workable carrying capacity of a man, the volume was estimated to be 0.028m³.

The manufacture of baskets for various uses goes back as early as the Neolithic period where most of the techniques originally used continued and enhanced throughout the Pharaonic period.383 Closely twinned bags made of dom palm leaf and grass string may have been used to transport heavy weights.384

The production of basketry required the gathering and preparing of raw materials. Some materials, such as grass, or palm leaf, could be collected all year round, but other materials, such as rushes and sedges, had to be gathered at certain times of the year, dried and stored until needed. The time spent on harvesting and storing required a certain degree of organisation. Twining and weaving required a workspace for the use.

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380 Lucas, and Harris, *Materials and Industries*, 133, 139.
382 D. Arnold, *The Temple of King Mentuhotep at Deir el-Bahari*, (New York 1979), pl. 36c–d. Unfortunately the volume of the baskets was not given in the reports.
of looms. This suggests that twined matting, twined bags and woven matting were made by organised labour.\textsuperscript{385}

Workers may have used leather bags for carrying excavated spoil.\textsuperscript{386} Cerny infers that the sacks referred to the inscription from the reign of Rameses II, “38 leather sacks….right 19 sacks; left 19 sacks. Total 38 sacks”, were for workers carrying out rubbish from the tomb.\textsuperscript{387} The bags, however, may have been used to carry other materials.

\subsection*{3.11 Conclusions}

Without the proper resources and tools, the construction of the smallest pit grave, through to the most elaborate tombs, would have been impossible. Mud bricks were the principal building material employed in the Early Dynastic period, supplemented with timber. Stone was used sparingly at this time. From the surviving mortuary structures, the extent and amount of the materials used can be gleaned, however, the tools and sources of raw materials must, in most instances, be assessed from later periods, hence the use of Pharaonic examples in this chapter. Despite improvements in the technology of certain implements throughout Pharaonic history, a number of tools have remained largely unchanged, even to this day. As such, the evaluation of resources and tools from sources outside the Early Dynastic period should not detract from the validity of this analysis.

The development of tools enabled larger, more complex structures to be attempted as materials became more readily available and easier to procure. Just as the engineering of the tombs displayed clear developments in knowledge, so too the development of tools enabled bigger and better structures to be built. Indeed, the scale of construction was limited only to the wealth and status of the deceased occupant. The evaluation and comparison of the material expenditure from various sites of the Early Dynastic mortuary complexes forms the basis of Chapter 4.

\textsuperscript{385} Nicholson, and Shaw, \textit{Ancient Egyptian Materials and Technology}, 265–266.
\textsuperscript{387} J. Cerny, \textit{A Community of Workmen at Thebes in the Ramesside Period} (Cairo, 1973), 106.
Chapter 4: Material Expenditure of Tombs

By the 1st Dynasty, more than four centuries before the Pyramid Age, monumental architecture was beginning to leave its mark on the ancient Egyptian landscape. The structures built at this time show impressive architectural skills, and also demonstrate a high degree of proficiency by the early designers and the builders who obviously project-managed their construction. Chapter 4 reviews the quantity of material that went into building the tombs of the 1st and 2nd Dynasty kings, elite, and the general population.

4.1 Methodology

The methodology undertaken firstly involved calculating the volume of the substructures in order to determine the total amount of material excavated. Secondly, the total volume of mud bricks (measured in m³) was calculated for both the substructure and superstructure. In order to determine the number of mud bricks used within each tomb structure, the volume of a single mud brick was estimated before the total volume was converted into mud bricks units.

Other items estimated in the construction of the tomb included the:

- Face area of plaster and paint on walls (m²)
- Volume of sand used to build up the false floor (m³)
- Area of reed matting used to strengthen the brick walls as well as used over the false floors and the timber roofs (m²)
- Quantity of limestone used to line, pave and roof the tombs (measured both in m³ and converted into tonnes)
- Quantity of timber beams and planks used to roof and line the tombs.

388 As the material used for the mortar was the same as that used to make the mud brick, the volume of mud bricks was not differentiated between the volumes of mortar consumed. The volume of mortar based on the size of an average mud brick from the Early Dynastic period would result in the quantity of mud bricks published being reduced by approximately 12%. Reducing the quantity of mud bricks (by 12%) would simply mean that the data on the volume of mortar would need to be published. Because the labour calculations incorporate the time taken to carry the raw materials to make the mortar on site and place the mortar by the bricklayers within the brick transportation and bricklaying figures, there has not been an over estimation of the results published here.

389 The size of the bricks used for some tombs was provided in excavation reports. For all other tombs the average size was used for the calculations.

390 The material expenditure is presented for each tomb later in this chapter.

391 The roofing quantities are based on the size and number of beams and planks estimated to have been necessary as part of the engineering analysis undertaken in Chapter 2.
The sites chosen were those that had tombs constructed with mud bricks. As these sites were investigated, any tombs that did not contain mud bricks within the construction were also incorporated into the corpus. The tomb selection criteria were based on analysing the major sites, which contained several sizable mortuary structures dating to the 1\textsuperscript{st} and 2\textsuperscript{nd} Dynasty.\(^{392}\)

4.2 Material Expenditure Analysis

The following is a summary description of the tombs, taken directly from excavation reports. Accompanying the brief description of each tomb is a summary of the material expenditure results from this research.\(^{393}\)

4.2.1 SAQQARA\(^{394}\)

The large mud brick tombs at Saqqara exhibit a steady development from the reign of Aha to the end of the 2\textsuperscript{nd} Dynasty.\(^{395}\) They were comprised of two distinct structural elements: the substructure, which was an open-cut pit roofed with heavy beams, and the superstructure, a large mud brick mastaba, built above ground. A mud brick enclosure wall usually surrounded the superstructure. These subterranean tombs, with their above-ground mud brick superstructures, had been begun to be built by the 2\textsuperscript{nd} Dynasty.

The form of the superstructure itself was generally rectangular and comprised of a continuous series of large and small niches that formed the so-called palace-façade. Its hollow interior was divided into a series of compartments or magazines. The subterranean chambers were hewn into bedrock. At first, there was no stairway entrance to the substructure since the stairway didn’t make its first appearance in tombs until the time of King Den, when the entrance was blocked by a portcullis stone. By the end of the 1\textsuperscript{st} Dynasty, the palace-façade brick panelling was becoming less common. At the same time, there was an increase in the number of subterranean chambers and a reduction in the number of magazines in the superstructure.\(^{396}\) The 2\textsuperscript{nd} Dynasty tombs

\(^{392}\) Whilst new cemeteries are being unearthed every year, the most important criteria for tomb and site selection was that the published material had to be accessible now, in order to be utilised in this research.

\(^{393}\) For plans and elevations of all the tombs, please refer to the Appendix, Volume 2.


\(^{395}\) See Volume 2, Appendix A, for tomb plans and sections, (Figure A1.1 to Figure A1.31).

\(^{396}\) For example Tomb S3338. Emery, *Great Tombs I*.
became, essentially, a series of subterranean galleries and rooms cut into the natural rock.\textsuperscript{397}

\textit{1st Dynasty Tombs}\textsuperscript{398}

\textbf{Tomb S3357}\textsuperscript{399}

The earliest 1st Dynasty tomb at Saqqara is Tomb S3357, ascribed to Hor-Aha by Emery, and would have undoubtedly belonged to one of his high ranking officials. The tomb is situated on top of the high desert directly over the extreme south end of the village of Abusir.\textsuperscript{400} The tomb was constructed on lower ground compared to the tombs of Hemaka (S3035) and Ankh-Ka (S3036), most likely to make full use of the rock strata at this level. Two enclosure walls surrounded the superstructure: the outer measuring approximately 22.0m x 47.8m and 0.75m thick, the inner 18.1m x 43.9m and 0.55m thick. The superstructure measured 15.50m (N) / 15.55m (S) x 41.60m (E) / 41.50m (W); the thickness of the walls averaged 2.5m (2.4m–2.65m) and had an 8:1 batter.\textsuperscript{401} All four sides were decorated with the palace façade panelling, consisting of nine large niches on the long walls and three on the short walls. In front of the each of the large niches four holes were cut in the mud pavement, averaging 20cm diameter by 25cm deep in which stumps of wooden poles, 10cm in diameter, were found in position when first excavated by Emery.\textsuperscript{402} The exterior of the superstructure was originally faced with a thick mud plaster and white gypsum plaster.\textsuperscript{403} The interior of the superstructure was subdivided into 27 magazines. The mud brick walls were not engaged to the main superstructure walls, nor were the internal magazine cross-walls

\begin{itemize}
\item \textsuperscript{397} J. Spencer, \textit{Early Egypt} (London, 1993), 93.
\item \textsuperscript{398} Refer to Table 4.1 for a summary of the material expenditure results of the Saqqara tombs.
\item \textsuperscript{399} W. B. Emery, \textit{Excavations at Saqqara, Hor-Aha} (Cairo, 1939).
\item \textsuperscript{400} Emery, \textit{Hor-Aha}, 10.
\item \textsuperscript{401} Emery, \textit{Hor-Aha}, 12. The dimensions presented here and for subsequent tombs were taken from measurements given in excavation reports, in some instances converted from imperial to metric for consistency. Where measurements were not provided in excavation reports, but tomb plans were, the dimensions were scaled from the plans and elevation drawings. While the degree of accuracy may be questionable from excavation reports that are 50–100 years old, in some cases this was the only information available to the author, as not all sites are undergoing re-excavation today.
\item \textsuperscript{402} Emery believed the postholes were used to hold standards and not the remains of scaffolding footings. Emery, \textit{Hor-Aha}, 10. This would seem logical based on the care taken in the construction of these tombs. Leaving evidence of the building phase would surely have been an unthinkable oversight by the earlier builders and supervisors.
\item \textsuperscript{403} Referred to in the tomb report as ‘lime stucco’: Emery, \textit{Hor-Aha}, 15. Lime was not used in ancient Egypt until the Ptolemaic period, and plaster frequently termed ‘lime plaster’ or ‘lime stucco’ is always gypsum until this later period. A. Lucas and J. R. Harris, \textit{Ancient Egyptian Materials and Industries} (New York, 1999), 76.
\end{itemize}
bonded together as shown on Emery’s plan of the tomb. 404 No subsidiary graves surrounded this tomb.

The substructure consisted of a large rectangular pit measuring 19.1m x 2.9m x 1.35m below ground level; the pit was subdivided into five rooms with the central chamber most likely the burial chamber. The walls of all the chambers were originally faced with mud plaster over which large reed mats were adhered – traces of the reed matting imprint remain on the walls with red and blue colouring faintly visible. The mats on the upper half of the wall were placed horizontally and those on the lower half were placed vertically. 405

Calculations, based on the tomb’s dimensions as reported above, show that construction would have involved excavating 75m³ of material to create the substructure, as well as the manufacture and subsequent laying of approximately 785,500 mud bricks, assuming an original height of 4m. 406 The bricks throughout the construction consisted of black earth mixed with straw and had an average dimension of 23cm x 12cm x 7cm. 407

The upper part of the superstructure was completely denuded such that no evidence of the roofing of the magazines remained. It is probable that the roof was formed by wooden beams and planks similar to the tomb of Hemaka. 408 From the embedded wooden remains in the upper part of the substructure walls, however, evidence of the roof could be seen.

Emery described the remains as follows:

From east to west the rooms were spanned by wooden beams with an average diameter of 10cm, spaced about 15cm apart. Above them placed north to south, were planks with an average width of 25cm and thickness of 12cm. Reed mats were placed above this wooden roofing, probably held in place with a thick coating of mud plaster. 409

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404 Emery, Hor-Aha, Plate 1.
405 Emery, Hor-Aha, 17.
406 Refer to Chapter 3, Tools and Resources Table 3.1 for brick sizes.
407 Emery, Hor-Aha, 18.
408 Emery, Hor-Aha, 15.
409 Emery, Hor-Aha, 17.
Thus, the timber required to roof the magazines of the superstructure and the chambers in the substructure would have consisted of approximately 404 roofing beams, 10cm in diameter by 3.8m length, 383 timber planks (25cm x 12cm of varying lengths).

The floor level of the 27 magazines was raised above ground level, to a height of 1m, by filling it with sand and rubble as evidenced by the fact that the walls were covered with a thick mud plaster above the false floor level. A total wall face area of 2,500m² was plastered, and a further 300m² of mud was laid, forming the mud-packed floor around the enclosure walls. The volume of sand used to build up the false floor in the 27 magazines equated to 255m³.

Timber bonding used in the main superstructure brick walls consisted of two layers of sticks approximately 2cm in diameter, placed in rows about 3cm apart, between the 10th and 16th course of brickwork from ground level. This resulted in a total of approximately 3,805 sticks x 2.0m long per course of bonding for the main walls, and 1,640 sticks x 0.8m long for the 24 large niches (the niches had a depth of 1.2m so the sticks would needed to have been considerably shorter, hence the 0.8m length is assumed). The excavation report makes no comment of timber bonding in the internal magazine walls but if such timber had been used, a total of 1,780 sticks measuring between 0.6m to 0.85m (width of magazine walls) would have been required per course of bonding. Finally, the reed matting used on the walls of the burial chamber and that above the timber roofing came to a total area of 77m² and 296m² respectively.

Tomb S2185
Tomb S2185 was of the same type as the “Menes” tomb at Naqada, although in a more denuded state. The superstructure had the typical palace façade mud brick panelling, which consisted of nine large niches on the long walls and three on the short walls. Measuring approximately 15.3m (N-S) x 39.5m (E-W), the superstructure was surrounded by an enclosure wall measuring 17.6m x 41.3m and 0.52m thick. Quibell’s excavation report states that the “... height of the building was quite considerable,

410 Emery, Hor-Aha, 15.
412 Quibell, Archaic Mastabas, 16.
perhaps as much as 6m, but the boundary wall was very thin and probably did not exceed 1m in height.\textsuperscript{413}

Even though the superstructure walls were thick enough to achieve a height of 6m, an assumed height of 4m was used in calculating the material used; maintaining consistency with all the Saqqara tombs.\textsuperscript{414}

Tomb S2185 had three rows of chambers including side chambers at ground level and a central row of chambers at a lower level, approximately 1.4m deep. This central row was roofed with stone, above which timber beams (8cm in diameter and 30cm apart) had been laid to form the flooring of the upper set of chambers. Stone roofing slabs were only found in chambers \textit{d} and \textit{f}, the slabs being 0.20m–0.32m thick.\textsuperscript{415}

The material expenditure of Tomb S2185 amounted to 81m$^3$ of excavated material to form the substructure; 584,900 mud bricks and 43.3m$^3$ (or 91 tonnes) of limestone was used to roof all seven rooms.

The total face area plastered equated to 1,600m$^2$ for the enclosure wall and the superstructure. The timber roofing over the magazines and substructure equated to 591 beams of 8cm diameter x 4.2m long and 242 beams of 8cm diameter x 3m long. It was assumed that reed mats were placed over the beams without the use of timber planking. The area of reed mats amounted to 287m$^2$. Above the substructure roofing, the false floors were built up using 104m$^3$ of sand.

\textbf{Tomb S3471}

Despite the lack of owner identification, Tomb S3471 can be dated to the reign of Djer. The tomb is almost identical in size to S3357, however no traces of enclosure walls remain around the mastaba as they were most likely destroyed during the construction of the small 3\textsuperscript{rd} Dynasty tombs which surround the 1\textsuperscript{st} Dynasty tomb. The superstructure measured 15.15m (N) / 15.05m (S) x 41.2m (E) / 41.3m (W) and the walls were, on

\textsuperscript{413} Quibell, \textit{Archaic Mastabas}, 16.
\textsuperscript{414} The reason for choosing a height of 4m is that with the exception of Hemaka’s tomb, the superstructures of all the Saqqara tombs are so denuded that the original height was impossible to ascertain. However, Hemaka’s tomb survived to a height of 3.45m, and whilst the top of the superstructure was also eroded, the roofing beams were still visible, so it is unlikely that it would have exceeded a height of 4m.
\textsuperscript{415} Quibell, \textit{Archaic Mastabas}, 16.
average, 2.65m thick with the exception of the west wall which was only 2.0m thick. The structure was denuded, surviving to a height of only 1m. As with Tomb S3357, the superstructure walls were decorated with the palace façade, also consisting of nine large niches and three large niches on the long and short walls respectively. The walls had an 8:1 batter. Timber bonding was noted in the walls of this tomb but unlike Tomb S3357, the brickwork was ruined to a point where the placement of the timber layers could not be ascertained. The 29 magazines within the superstructure had mud brick cross-walls, which were neither bonded together nor engaged to the main walls. The exterior of the superstructure was originally mud plastered, which was then coated with gypsum plaster.\footnote{Emery, Great Tombs I, 13–16.} The roofing of the magazines was most likely similar to that of Hemaka’s tomb.

The substructure consisted of seven rooms cut to varying depths below ground level and separated by mud brick walls. All the rooms were roofed with timber beams of approximately 12cm diameter and planks 40cm wide x 7cm thick. Above this planking, reed mats were place to prevent sand filtering through from the false floors above. The rooms exhibited traces of mud plaster on the walls, but no reed matting was fixed to the walls as seen in Tomb S3357.\footnote{Emery, Great Tombs I, 16.}

In summary, the material expenditure of Tomb S3471 amounted to a total of 206m$^3$ of excavation to form the substructure. This included 772,000 mud bricks (allowing for two enclosure walls of similar dimension to Tomb S3357)\footnote{If no enclosure walls had existed, which is doubtful, the total mud bricks would amount to 711,700 bricks. An original height of 4m was assumed for the superstructure.} and a total wall plastering area of 2,770m$^2$ (of which 746m$^2$ is attributed to the assumed dual enclosure walls). Further, the timber bonding between the mud bricks of the superstructure equated to 1,573 sticks at 2.6m long per course: 504 sticks x 2m long (for the west wall which was only 2m wide) and 1,680 sticks x 1.0m long per course of bonding for the niches. As no timber bonding was noted in the excavation report for the other walls, this was not calculated.

The roofing materials equated to:

- 76 beams (12cm diameter) x 2.8m long

\footnote{Emery, Great Tombs I, 13–16.}
200 beams (12cm diameter) x 3.4m long
40 beams (12cm diameter) x 4.8m long.

The total number of timber planks placed above these beams was:

- 119 planks of 40cm x 7cm at 3.5m long
- 81 planks of 40cm x 7cm at 4.8m long
- 20 planks of 40cm x 7cm at 7.1m long.

Finally, a total area of 282m² of reed matting would have been required to cover the timber roofing planks and 109m³ of sand to create the false floors.

**Tomb S3504**

Tomb S3504 is situated immediately to the south of Tomb S3503 on the edge of the escarpment and can be dated to the reign of Djet from inscribed labels and impressions found in the tomb.419 Emery wrote:

> The general design of the tomb is a development of the type common to the early part of the 1st Dynasty. Its design is a transition from the monuments of S3357, S3471 and S3503 to the more elaborate structures of the middle of the 1st Dynasty of Hemaka (S3035) and Ankh-ka (S3036).420

The tomb comprised of an enclosure wall, measuring 25.45m (N-S) x 56.45m (E-W) and 0.95m thick, which was denuded to a height of 0.73m. A corridor between the enclosure wall and superstructure was stamped-mud, over which a thin layer of gypsum plaster was applied and then painted green.421

The superstructure measured 19.90m (N) / 20.00m (S) x 49.35m (E) / 49.50m (W) and survived to a height of 2.35m. The palace façade panelling was made up of 11 large niches on each of the long sides and four large niches on the short sides. A low bench running around all four sides of the superstructure held life size bull-heads modelled in sun-dried clay over which real horns were placed. The bench was 0.60m wide x 0.45m

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419 Emery, *Great Tombs II*, 5.
high. The bench and superstructure had been mud plastered and painted with white gypsum.\textsuperscript{422}

Within the superstructure there were a total of 43 magazines formed by cross-walls varying in thickness from 0.75m–0.95m. These cross-walls were not bonded to the main walls of the superstructure, but were bonded to each other within the structure. All the magazines had false floors built up with sand.\textsuperscript{423}

The original substructure, before the restoration during the time of Qa’a, was cut into the rock strata, measuring 22.60m (N-S) x 10.20m (E-W) x 3.1m deep. The pit consisted of a central room: the burial chamber, two large rooms on the north and two on the south, and eight small magazines running east and west. All the walls were faced with mud plaster. The burial chamber measured 7.10m x 5.70m and was dug deeper than the adjoining rooms. The walls of the burial chamber had brick pilasters that were faced with timber originally decorated with strips of gold plate embossed in a ‘bound reed’ design. The floor of the burial chamber was originally of timber planking approximately 3cm thick.\textsuperscript{424}

Tomb S3504 also had 62 subsidiary graves placed along the south, east and west sides, outside the enclosure wall. Unlike Tomb S3503, which had individual graves, Tomb S3504 had three long trenches subdivided by mud brick cross-walls forming separate compartments. The average size of the graves in the south trench measured 1.50m x 1.15m, the east trench 1.40m x 0.95m, and the west trench 1.40m x 0.95m. The depths varied from 1.00m–1.70m. The pits were roofed with timber planks which rested on a shelf on each side of the trench above which reed matting was placed to prevent sand from filtering through the woodwork. The mud brick walls were all faced with mud plaster. The graves all had rubble filled mud brick superstructures built over them, measuring on average 1.70m x 1.45m and each superstructure had a small niche at the south end of the east façade.\textsuperscript{425}

\textsuperscript{422} Emery, \textit{Great Tombs II}, 8–9.
\textsuperscript{423} Emery, \textit{Great Tombs II}, 9.
\textsuperscript{424} Emery, \textit{Great Tombs II}, 9–11.
\textsuperscript{425} Emery, \textit{Great Tombs II}, 11.
Returning to the main tomb, a total of 506 m$^3$ of material was excavated to form the substructure and 1,360,200 mud bricks were used. The reed matting placed between the brick courses equated to 386 m$^2$ per course, a total wall area of 3,420 m$^2$ was plastered and 290 m$^2$ of mud-packed floor existed.

The roofing over the different sized magazines would have comprised of the following dimensions:

**Magazines CC, BB, PP, QQ, J, JJ, KK, C and B:**
- 90 beams of 25 cm diameter and 3.0 m long
- 80 planks of 30 cm x 12 cm and average length of 6.3 m.

** Remaining magazines:**
- 122 beams of 25 cm diameter and 2.0 m long
- 41 beams of 25 cm diameter and 2.8 m long
- 192 planks of 30 cm x 12 cm and average length of 3.7 m.

**Rooms CC, BB, PP and QQ of the substructure contained:**
- 35 beams of 25 cm diameter and 2.8 m long
- 32 planks of 30 cm x 12 cm and average length of 6.5 m.

**Burial Chamber:**
- 22 beams of 25 cm diameter and 6.5 m long
- 38 planks of 30 cm x 12 cm and average length of 8 m.

The reed matting over the roof structures equated to 363 m$^2$ for the superstructure and 213 m$^2$ for the substructure.

The subsidiary graves also consumed a large quantity of material, with 286 m$^3$ of material excavated to form the trenches and 94,500 mud bricks used for the superstructure and substructures. The superstructures also require 63 m$^3$ of rubble. The total area plastered equalled 621 m$^2$ and the roofing was comprised of 338 planks with average dimensions of 30 cm x 12 cm x 1.4 m long.

**Tomb S3503**
Tomb S3503 is situated immediately south of Tomb S3500 on the extreme edge of the escarpment and is dated to the reign of Djer. In size and design the tomb conforms to the style of S3357, S2185 and S3471, however the substructure shows marked
differences, namely that it was much smaller and covered a restricted area. Furthermore, the magazines in the superstructure were larger in size but smaller in number, totalling 21 rooms. The magazines all had false floors with reed matting covering the sand filling, but the walls above the false floor had not been plastered. 426 The total amount of sand required to form these false floors equalled 217m³.

The enclosure wall surrounding the superstructure was, in this case, only found on the east side, the other sides presumably destroyed. In addition, the wall had a platform on the west side extending the full length of the superstructure, measuring 42.5m x 0.95m wide. The enclosure wall was 0.65m wide. Both the enclosure wall and platform were faced with mud plaster and covered with white gypsum plaster. Surrounding the superstructure was a stamped mud pavement, covered with white gypsum plaster and then painted red and blue. 427

The superstructure measured 16.00m (N) / 15.75m (S) x 42.60 (E-W), and was found to a surviving height of 2.20m. It had palace façade panelling on all four sides with 9 large niches on the long sides and 3 on the short sides. 428 A total of 613,300 mud bricks were required to construct the tomb, assuming an original height of 4m. 429 The mud brick walls were faced with mud plaster about 2cm thick and then 1cm thick gypsum plaster was applied, before finally being white-washed. Traces of paint decoration were noted on the east side. 430 A total of 1,470m² of wall area was plastered and 415m² of mud packed floor.

As with tombs S3357 and S2185, four postholes were found in the pavement in the front of each of the large niches of the superstructure. Emery subsequently suggested they were used for scaffolding. This seems doubtful based on the care taken in all aspects of the construction. Surely, if the holes were the remains of where scaffolding support posts had been positioned, the builders would not have been so careless as to not fill the holes with mud following the removal of the scaffolding and completion of

426 Emery, *Great Tombs* II, 129.
429 This quantity also allows for the bricks used in the enclosure wall.
the tomb. It stands to reason that Emery’s original suggestion of the holes acting to support standards seems more probable.\textsuperscript{431}

The substructure, a large rectangular pit measuring 14.25m (N-S) x 4.50m (E-W) x 2.90m deep, was cut through bedrock. Mud brick walls were built to ground level to retain the granular strata encountered above the bedrock.\textsuperscript{432} A total of 186m\textsuperscript{3} of material was excavated to form this pit. Two cross-walls running east to west divided the pit into 3 compartments; the outer chambers were then subdivided into two rooms each. Traces of the wooden roof remained and showed that the roof was similar to that of Tomb S3471, and stood 2.45m above floor level.\textsuperscript{433}

The roofing over the substructure was estimated to comprise of:
Burial Chamber:
- 10 beams of 22cm diameter and approximately 4.3m long
- 12 planks of 30cm x 15cm and 5.6m long.

Side Chambers:
- 25 beams of 22cm diameter and approximately 2m long
- 21 planks of 30cm x 15cm and 3.5m long.

The reed matting used over the roofs amounted to 20m\textsuperscript{2}. The walls of all the rooms in the substructure were mud plastered and faint traces of matting remained.\textsuperscript{434}

The roofing above the magazines required a substantially larger quantity of timber:
Magazines A, B, C, D, E, F and G:
- 64 beams of 22cm diameter and 3.8m long
- 70 planks of 30cm x 15cm and average length of 4m.

Magazines H, I, J / K, L, M / N, O and P:
- 64 beams of 22cm diameter and 4.3m long
- 82 planks of 30cm x 15cm and average length of 4m.

\textsuperscript{431}Emery, \textit{Great Tombs II}, 131.
\textsuperscript{432}Emery, \textit{Great Tombs II}, 133.
\textsuperscript{433}Emery, \textit{Great Tombs II}, 133.
\textsuperscript{434}Emery, \textit{Great Tombs II}, 133. The wall area of the substructure rooms was 135m\textsuperscript{2}, which may have equalled the area of reed matting required to face these walls.
Magazines Q, R, S, T, U, V and W:

- 64 beams of 22cm diameter and 3.35m long
- 60 planks of 30cm x 15cm and average length of 4m.

Reed matting placed over the all the magazine roofs equated to 289m².

Although only 20 have survived, 22 subsidiary graves were found outside the enclosure wall on all four sides of the tomb. The pit graves were lined with mud bricks and roofed with wood. Differences in the construction of these graves suggest they were not all built at the same time.⁴³⁵

The total volume excavated for the 20 surviving subsidiary graves equated to 75m³, or 3.7m³ per grave. A total of 6,700 mud bricks were used, equating to 335 bricks per grave. The roofing of these 20 graves amounted to 306 timber beams placed side by side of 15cm diameter x 2.4m long (allowing for a 20cm overhang on either side). Local timber would have been used to roof the subsidiary graves.

Tomb S3503 was accompanied by a boat burial which required 15,400 mud bricks and 42m³ of sand fill.

**Tomb S3507**

Although Tomb S3507 can be dated to the reign of Den, it is of the pre-stairway type found in the earlier half of the 1st Dynasty, and therefore presumably built before S3506, S3035 and S3036.⁴³⁶

An enclosure wall, measuring 22.25m (N-S) x 44.35m (E-W) was found to a surviving height of 1.45m surrounding the superstructure. The walls of the enclosure wall had a curved batter and were faced with white gypsum plaster.⁴³⁷ A gateway at the south end of the east wall of the enclosure measured 1.64m wide and opened to a court, 4.50m x 2.65m. The walls of the gateway were vertical and faced with white gypsum plaster. The corridor between the enclosure wall and superstructure was paved with packed mud.

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⁴³⁶ 'Inscribe material strongly suggests that the tomb is the burial place of Queen Her-nit, who may have been consort to Djer, who died, and old woman, early in the reign of Den who arranged her burial' Emery, *Great Tombs III*, 73; An ivory vase found within the tomb grave goods had the inscription 'she who is united with the two lords’ which is the title of a queen, Emery, *Great Tombs III*, 93; and the same inscription occurs on similar ivory vases from Abydos, Petrie, *Royal Tombs II*, 9–10.
⁴³⁷ Emery, *Great Tombs III*, 75.
originally painted green. The superstructure measured 15.85m (N) / 15.80m (S) x 37.9m (E) / 37.75m (W) and the walls were found to a surviving height of 2.5m. The exterior of the superstructure had the palace façade panelling made up of eight large simplified niches on the long walls and three on the short sides. The façade was mud plastered, 2cm thick, finished off with white gypsum plaster; it was painted yellow with the inner recess of the large niches painted red. A bench, measuring 0.45m wide and 0.25m high with mud ‘bull-heads’ placed on top, ran along all four walls of the foot of the panelled façade. Faced with mud plaster and painted white, the bull-heads had real horns placed in front of the small niches. There was no evidence that heads were placed in the large niches.

The superstructure was divided into 21 magazines by cross-walls, 0.65m thick, bonded to the main walls of the superstructure. The walls of the magazine were not plastered, but the floors were raised to a height of 1.25m with sand.

The substructure consisted of a deep rectangular pit with a rock cut stairway descending only half the depth of the pit. The pit measured 5.25m (N-S) x 3.15m (E-W) x 4.75m deep from ground level. Timber beams for the roofing were embedded in the soft gravel strata and were spaced 30cm apart. At a depth of 2.25m, a cut-in shelf supported a secondary roof which stretched from the foot of the descending stairway to two rock cut pilasters in the east and west walls. These pilasters were spanned by a limestone lintel carved with a frieze of seated lions. The lintel was 25cm deep and supported a stone flag roof that covered the south area of the burial chamber. The substructure was covered by a rectangular tumulus of sand and rubble, encased with a single layer of mud bricks. The tumulus measured 10.5m x 9.2m and had a maximum height of 1.1m.

The material excavated to form the substructure was 80m$^3$ and a total of 464,600 mud bricks were used to build this tomb. Reed bonding was placed between every fifth or sixth course in the brickwork. The reed matting required for the brick bonding equated to 450m$^2$ per course. A total face area of 1,040m$^2$ was plastered and painted, and 565m$^3$
of sand was used to form the false floors. The mud packed floor around the enclosure wall measured 350m².

The material expenditure for timber and stone differed between the upper and lower roofs. Material expenditure for the upper roof was:

- 10 beams of 25cm diameter x 3.95m long
- 16 planks of 40cm x 25cm and 3m long (or 8 planks at 6m long).

Material expenditure for the lower roof was:

- 5 beams of 25cm diameter x 3.95m long
- 8 planks of 40cm x 25cm and 3m long.

A total of 4.2 tonnes of limestone was used to form the stone lintel and roofing flags.  

Although no roofing information was available on the magazines, if we assume a similar configuration to that of Hemaka’s tomb, the following timber would have been required:

- 463 beams (12cm diameter) x 3.9m long
- 94 beams (12cm diameter) x 3.7m long
- 219 planks of 40cm x 7cm at 5.4m long
- 33 planks of 40cm x 7cm at 6.7m long.

**Tomb S3506**

Tomb S3506, dated to the reign of Den, was built in two distinct stages. The first construction stage consisted of a large rectangular rock-cut pit which was accessed by a staircase on the east side. The whole structure was unroofed, open to the sky. The walls and floor were faced with white gypsum plaster.

The second stage involved additions to the structure. In the pit, a series of brick walls forming recesses were built, reducing the floor area to 11.70m x 5.25m. These deep recesses were roofed with timber at a height of 2.15m above floor level. The floor was then covered with sand on which a timber floor was placed. The wall surfaces and the

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442 The stone lintel measured 25cm in depth, but no other dimensions were published in the excavation report, Emery, *Great Tombs III*, 77; The stone flags were therefore estimated to be approximately 40cm x 40cm x 1.47m in length.

interior of the recesses were faced with mud plaster with no trace of gypsum plaster. Further work in the pit included raising the floor of the surrounding gallery using brickwork into which timber beams and planks were embedded to form the roof, covering the entire substructure.

The gallery was also subdivided into a series of small magazines and each magazine was roofed separately with wooden planks. The main stairway entrance to the gallery was blocked by brickwork, but the main entrance to the substructure contained a unique structure forming the door jambs and lintel – a gateway built of three cut limestone slabs, 0.37cm thick. The entire gateway was filled with mud bricks behind a wooden door which was painted red. The side walls of the landing between the last step and the descending stairway had wooden panelling painted yellow. 444

An enclosure wall surrounded the superstructure and measured 28.5m (N-S) x 67.0m (E-W). The wall was 1.15m thick and was covered with white gypsum plaster as was the corridor pavement which varied in width (3m N; 2.65m S; 3.65m E and 2m W). 445

In the east and north corridors between the superstructure and the enclosure wall, ten subsidiary graves were built. The graves were built separately and were, on average, 2.15m x 1.6m and 1.25m deep. They were brick lined and roofed with wooden planks. Above the roof, the grave was filled with rubble up to ground level and a low superstructure was built above this with pressed mud. 446

The superstructure built over the pit measured 19.50m (N) / 19.60m (S) x 47.50m (E) / 47.60m (W) and the wall thickness averaged 4.30m. The palace façade panelling consisted of 13 large niches on the long walls and five large niches on the short walls. These niches were formed with small bricks (15cm x 7cm x 7cm) similar to those in the tomb of Hemaka; larger bricks were used throughout the rest of the superstructure (23cm x 13cm x 7cm). The exterior walls of the superstructure were faced with thick mud plaster on which a white gypsum plaster finish was applied. Surrounding the superstructure, a low bench, 0.50m wide x 0.23m deep, was constructed but no mud bull-heads were found. 447

445 Emery, Great Tombs III, 40.
446 Emery, Great Tombs III, 41–42.
447 Emery, Great Tombs III, 41.
The interior of the superstructure was not divided into a series of magazines as seen in earlier tombs, but instead, shallow buttresses 0.85m wide at 4m spacing on the long walls and 2m on the short walls, were built. The interior of the superstructure was filled with sand and rubble.\textsuperscript{448}

The second phase of construction showed signs of rapid construction. A total of 725m\textsuperscript{3} of material was excavated to form the pit, and 1,156,400 bricks: the intricate niches were built using 80,400 small mud bricks (17cm x 7cm x 7cm) and the rest of the structure from 1,076,000 standard sized bricks (23cm x 13cm x 7cm). The total face area plastered during the first building stage equalled 237m\textsuperscript{2} for the walls and 122m\textsuperscript{2} for the floor. The second stage consisted of plastering an area of 207m\textsuperscript{2}. The area of walls plastered for the stairway was 52m\textsuperscript{2}. The superstructure and bench comprised a total plastered area of 1,207m\textsuperscript{2} and the enclosure wall 425m\textsuperscript{2}.

The roofing consisted of a stairway that used 15, 2m long beams with a 30cm diameter as well as a burial pit with three 16cm-long beams of 90cm x 35cm, and 72, 4.3m long planks of 40cm x 20cm.

The ten subsidiary graves consisted of 50m\textsuperscript{3} of excavated material, 3,500 mud bricks and 125 timber planks (20cm x 10cm x 2m long). The plastered walls equalled 40m\textsuperscript{2}. Tomb S3506 was also accompanied by a boat burial which consumed 83m\textsuperscript{3} of excavated material, 7,000 mud bricks and 75m\textsuperscript{3} of sand fill.

**Tomb S3035**\textsuperscript{449}

Hemaka was appointed Royal Chancellor, the head of the Treasury,\textsuperscript{450} and the size of his tomb reflected his position and status. The superstructure measured 26.0m (N-S) x 57.3m (E-W). The exterior walls had a slight inward batter of 1:26 and palace façade panelling with the longer walls comprising 14 niches, the shorter walls with six. Like Tomb S3506, two sizes of bricks were used in Hemaka’s tomb. The intricate niches were of a smaller size (17cm x 5cm x 5cm) compared with the bricks used for the rest of the superstructure and substructure (23cm x 13cm x 5cm). The superstructure was

\textsuperscript{448} Emery, *Great Tombs III*, 41.
\textsuperscript{449} W. B. Emery, *Excavations at Saqqara, The Tomb of Hemaka* (Cairo, 1938).
faced with a thick layer of mud plaster, which was white-washed. Streaks of red paint on the white-wash, in imitation of wood, were found on the walls of some of the niches. The interior of the superstructure was subdivided into 45 magazines; the cross-walls were not bonded to the main superstructure walls, nor were they connected to each other. The floor in some of the magazines was raised with sand, creating a false floor, while five of the magazines in the south east corner were connected by doors 1.5m high with light wooden lintels, 10cm thick.

The magazines were roofed with beams 15cm in diameter placed into the brick walls. Roughly hewn planks 7cm thick were placed above the beams laid longitudinally over which reed matting was placed. Above the matting alternate layers of brick headers and stretchers were laid.

Hemaka’s tomb had a ramp and stairway leading to the substructure – the first to do so in Saqqara. The ramp and stairway measured 7.15m in width, leading to three subterranean rooms. The stairway had been blocked in three places by portcullis stones which had been lowered into place through grooves cut into the walls. The pit measured 9.5m x 4.9m and had a total depth of 8.3m from ground level. At the bottom of the rock stratum, 5m above the floor of the pit, a wide ledge was cut on all four sides (0.9m wide x 0.7m high). On the northern and southern sides, three rectangular recesses cut at the base of the ledge were evident, presumably for architraves supporting the roof. Brick walls supported the gravel stratum above the rock.

The subterranean rooms were cut into solid rock with doorways leading from the pit. Room 1 (most likely the burial chamber) measured 7.7m x 4.8m and 3.1m high; Room 2 measured 3.75m x 5.35m x 1.85m; and Room 3 measured 3.80m x 3.40m x 1.8m. The walls were covered with a thick gypsum plaster.

Hemaka’s tomb was to be one of the largest tombs built at Saqqara, as demonstrated by the material consumed. The total volume excavated equated to 835m³. A total of

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451 Emery refers to the white wash as Sulphate of Lime. Chemically, gypsum is calcium sulphate (sulphate of lime), Lucas and Harris, *Materials and Industries*, 79.
400,000 small mud bricks were used to form the niches, and 2,959,500 normal sized mud bricks were used elsewhere.\footnote{The mud brick volume was calculated for a height of 4m.} A total wall face area of 1,440m$^2$ was plastered. Finally, the timber roof over the magazines and pit consisted of approximately 425 roofing beams that were approximately 15cm in diameter and 2.6m long, 566 timber planks (14cm x 7cm by 3.2m in length) and 412m$^2$ of reed matting. The fill placed within the magazines to form the false floors equalled 824m$^3$.

**Tomb S3036**\footnote{Emery, *Great Tombs* I.}

Ankh-Ka was a high official during the reign of King Den. The tomb’s substructure was entered via a stairway, one of the first to do so.\footnote{Hemaka’s tomb also introduced a stairway entrance into the substructure, but it is difficult to say with complete accuracy which tomb was constructed first – Ankh-ka’s or Hemaka’s – as they were both high officials during Den’s reign.} The superstructure measured 21.2m (N) / 22.0m (S) x 41.0m (E) / 40.2m (W) and had typical palace façade panelling. However, the niches were much shallower than those of earlier tombs. The interior of the superstructure was subdivided into 32 magazines by a series of cross-walls that were bonded to each other but not to the main superstructure walls. These cross-walls were approximately 80cm thick. The floor of the magazines was packed to a height of 1.85m with sand over which a single layer of bricks was placed. Above the bricks the walls had been plastered.\footnote{Emery, *Great Tombs* I, 73.} Surrounding the superstructure was an enclosure wall (29.1m x 47.2m), with thickness from 1.3m (north wall) up to 1.65m (south and east walls). The western wall was 1.5m thick. Outside the enclosure wall a trench running parallel to the eastern wall only contained the remains of trees planted at regular intervals.\footnote{Emery, *Great Tombs* I, 74.}

Ankh-Ka also incorporated a stairway leading down into the substructure of his tomb. The stairway was brick lined until it reached the rock strata 3.5m below the surface. Both the brick walls and rock were covered with white gypsum plaster. Two portcullis stones were positioned inside the stairway to seal the tomb.\footnote{Emery, *Great Tombs* I, 73.}

The substructure comprised of the burial pit (4.8m N-S x 8.55m E-W x 6.5m depth) and two pairs of subsidiary rooms flanking the northern and southern sides of the pit. The roofing over the substructure was different to those early tombs in that the timber planks
were placed below the timber beams. The approximate size of the beams was 30cm diameter and the planks 45cm wide x 14cm thick.\textsuperscript{463}

The tomb had 560m\(^3\) of material excavated, 1,754,200 mud bricks, and a wall and floor plastered area of 2,500m\(^2\) and 240m\(^2\) respectively. The timber roofing consisted of approximately 344 roofing beams each with a 30cm diameter by 3.8m length, 322 timber planks (45cm x 14cm by 3.8m long) and 433m\(^2\) of reed matting. The sand fill forming the false floors equated to 835m\(^3\). Reed matting between the brick courses equated to 656m\(^2\) per course. This matting was placed at every sixth course and if the mastaba reached a maximum height of 4m, a total of 3,300m\(^2\) would have been required.

**Tomb X**

Tomb X belonged to a high official named Nes-ka, with the title of Treasurer. The superstructure was a solid mud brick construction devoid of the palace façade panelling seen in the earlier tombs and measured 12m \(\text{(N-S)}\) x 26m \(\text{(E-W)}\). The exterior walls were mud plastered and painted white. A ramp and stairway on the east side of the tomb led to the two magazines and the burial pit (6.24m x 3.75m). The walls of the burial chamber were faced with thick white gypsum plaster. On the north, east and west sides, wide shelves were cut 3.35m above the floor level which may have supported the roof.\textsuperscript{464}

The total volume excavated to form the burial pit and the two magazines equated to 180m\(^3\). A total of 858,000 black mud bricks were consumed, each measuring 24cm x 10cm x 5cm.\textsuperscript{465} The plastering of walls equalled 52m\(^2\) for the stairway, 15m\(^2\) for Magazines A and B, 68m\(^2\) for the burial chamber and 304m\(^2\) for the superstructure.

The roof consisted of:

- 15 planks of 30cm x 15cm and 1.8m long to roof the magazines
- 31 planks of 30cm x 15cm and 1.8m long to roof the stairway
- 11 beams of 20cm diameter x 4.5m long to roof the burial chamber
- 13 planks x 30cm x 15cm and 7.2m long, placed above the beams of the burial chamber.

\textsuperscript{463} Emery, *Great Tombs* I, 74.
\textsuperscript{464} Emery, *Great Tombs* I, 107.
\textsuperscript{465} Emery, *Great Tombs* I, 108.
Tomb S3338

The superstructure of Tomb S3338 consisted of a rubble filled brick mastaba with all four sides being plain rather than having the palace façade panelling. There was also no trace of either mud or gypsum plaster.\textsuperscript{466}

The superstructure measured 14.00m (N) / 13.80m (S) x 30.50m (E) / 30.40m (W) and the thickness of the main walls were 3.30(N) / 3.30(S) / 3.10(E) / 2.30(W). A descending passage, starting under the northern end of the superstructure, led southward to a large rectangular pit which formed the burial chamber. Entrance to the pit from the passage was blocked by a portcullis stone. The sides of the entrance were shelved to support stone roofing blocks. Two magazines were situated under the superstructure on the east and west sides of the passage. Magazine A measured 2.25m x 1.40m and 1.10m deep from floor level to roofing shelf. Magazine B measured 2.00m x 1.50m and 1.15m from roofing shelf. Rock cut shelves, 1.10m above floor level, supported a wooden roof, evidence of which remains. The burial chamber was 6.50m x 3.75m and 6.25m below ground level and just like the magazines on all four sides, wide shelves were cut to support the roof 3.55m above the floor level. Six rock cut emplacements were cut in the east and west shelves to receive wooden beams or stone architraves.\textsuperscript{467}

The total volume excavated to form the substructure equated to 324m\textsuperscript{3} with a total of 479,400 mud bricks used to form the superstructure. Assuming stone beams had been placed to roof the stairway, based on a 9.1m length and 1.68m span including the shelf, and using slabs similar in size to those used in the later Tomb S3121 (0.6m x 1.0m x 1.6m), a total of nine slabs would have been required, equating to 18 tonnes of limestone. For the magazines and burial pits, where evidence of timber roofing was found,\textsuperscript{468} the total number of beams required was estimated to be seven planks of 45cm x 15cm and 2.8m long for the magazines, and three 4.8m long planks of 60cm x 50cm or nine 8.0m long planks of 60cm x 50cm for the burial chambers. The rubble fill over the roof equalled 262m\textsuperscript{3} of material.

\textsuperscript{466} Emery, Great Tombs I, 125.  
\textsuperscript{467} Emery, Great Tombs I, 125.  
\textsuperscript{468} Emery, Great Tombs I, 125.
**Tomb S3111**

Tomb S3111 was assigned to Sabu, a high official during the reigns of Den and Anedjib. The superstructure measuring 12.10m (N)/ 12.00m (S) x 29.25m (E)/ 29.10m (W) had palace façade panelling that consisted of eight large niches on the long sides and three on the short sides. The interior of the superstructure was lined with bricks and supported by buttress walls 0.5m wide, similar to Tomb S3506. No magazines were built within the superstructure of this tomb.469

The substructure consisted of a large pit cut into the gravel and rock strata 2.55m deep, which was subdivided by brick walls to form seven rooms. The pit measured 10.45m x 6.0m, including the shelves. A total volume of 160m³ was excavated to form the pit. The pit walls cut into the soft gravel were retained by mud brick walls. The rooms were faced with mud plaster and roofed with timber beams and planks. The burial chamber, rooms E, C and D had sockets cut into the walls to support the roof.470

A total of 188,200 mud bricks were used. These bricks were of dark black earth mixed with straw and measured 26cm x 12cm x 7cm.471 A wall face area of 770m² was plastered and the false floors within the magazines required 154m³ of sand fill.

A total of 63m² of reed matting was required and the roofing consisted of various beam and plank configurations due to the varying size of the rooms. These included:

- 4 beams of 20cm diameter and approximately 5.8m long
- 38 planks of 30cm x 10cm and 1.5m long
- 17 planks of 30cm x 10cm and 2.8m long
- 18 planks of 30cm x 10cm and 3.8m long.

**Tomb S3038**

Tomb S3038 can be dated to the reign of Anedjib and belonged to Nebtka. The tomb underwent three construction phases: Period A, Period B and Period C. Due to the uniform size, texture and colour of the bricks used in all three phases, no great interval of time would appear to have passed between these alterations.472

472 Emery, *Great Tombs* I, 82.
Period A. The first construction involved excavating a rectangular pit which was then bounded on the north and south by subsidiary rooms, built at a higher level than the pit itself with mud brick walls. The northern room was made to accommodate a series of built-in grain bins. The usual entrance stairway descended from the east side into the pit and a second stairway led to an upper storey built above the substructure. The superstructure consisted of a rectangular block of brickwork with vertical sides which just covered the burial pit and the subsidiary rooms. On the north, south and west sides, banks of sand and rubble were placed against the walls to form a foundation and core for a series of steps arranged in pyramidal form. The eastern side of the superstructure was not stepped, but had a vertical façade, with a high narrow terrace in front of it. The whole structure was covered with a fine textured plaster. The burial pit walls and the rock below them were covered with a thick yellow plaster. The subsidiary rooms were built as granaries.\textsuperscript{473} The superstructure measured 22.70m x 10.55m and was comprised of steps, eight on each side of the structure with the exception of the eastern side, which was vertical. The whole superstructure was covered with fine mud plaster.\textsuperscript{474}

The material expenditure for Period A consisted of 291m\textsuperscript{3} of excavated material, 168,700 mud bricks and 573m\textsuperscript{2} of plastered wall face area. The roofing timber comprised of approximately:

- 26 beams of 18cm diameter and 5.6m long
- 32 planks of 30cm x 15cm and 8.6m long
- 37m\textsuperscript{2} of reed mats.

Period B. Construction Phase 2 involved only two alterations: the construction of brick terraces around the stepped superstructure and the raising of the already existing terrace between the stairways and the south east corner.\textsuperscript{475} The material expenditure during Period B involved the placement of an additional 59,000 mud bricks.

Period C. The construction activity to Tomb S3038 during Period C turned this tomb into the usual palace façade mastaba. The area enclosed by the panelled walls was filled with sand to the height of the retaining walls of the pit and subsidiary rooms, and the northern and southern stairways led up, from ground level, to the magazines built on the

\textsuperscript{473} Emery, Great Tombs I, 85.
\textsuperscript{474} Emery, Great Tombs I, 84.
\textsuperscript{475} Emery, Great Tombs I, 87.
filling. The two stairways leading down to the upper and lower storeys of the burial pit were left unaltered. The final measurements of the superstructure were 13.85m (N) / 13.75m (S) x 37.00m (E) / 36.80m (W) and the entire structure was covered with white plaster.⁴⁷⁶ The interior of the superstructure, where the steps and terraces were situated, was filled with sand to a height of 2m and then paved with a single layer of mud bricks.⁴⁷⁷

The burial pit was considerably reduced in area through the construction of thick brick walls along the east, south and west sides, as well as subdivided by other brick walls into five rooms. The walls were covered with fine white gypsum plaster and a painted dado of yellow.⁴⁷⁸

The extent of the modifications and changes are more apparent with the additional materials used in the construction.

Period C resulted in an additional 376,300 mud bricks being used in the sub- and superstructure. The new brick work meant that more plastering would be required; the superstructure and stairs required an additional wall area of 1,155m² to be plastered. The total volume of sand used to fill the interior of the superstructure equated to 459m³.

**Tomb S3505**

Dated to the reign of Qa’a,⁴⁷⁹ the overall structure of S3505 is the largest in plan area in North Saqqara.⁴⁸⁰ Emery stated: “...amongst 1st Dynasty buildings it is unique in its advance in design towards the general conception of the pyramid complex of later times”.⁴⁸¹

The tomb consisted of a mud brick superstructure with palace façade panelling on three sides, with the west wall having simplified panelling.⁴⁸² The walls of the superstructure had been faced with a gypsum plaster and then painted with elaborate geometric

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⁴⁸⁰ The tomb of Hemaka consumed a greater number of mud bricks but had a smaller plan area based on the surviving structure.
⁴⁸² Emery, *Great Tombs III*, pl. 9.
patterns in red, white, black, blue-green and yellow. Surrounding the panelled façade was a low bench with mud bull-heads. On the north side of the superstructure stood what has been interpreted as a funerary temple, consisting of 14 rooms connected by passages. The superstructure and the funerary temple were enclosed in the main walls of the funerary temple. Surrounding these, a high enclosure wall with a gateway opposite the doorway to the funerary temple was built.\footnote{Emery, Great Tombs III, 6.}

The enclosure wall measured 65.2m (N-S) x 40.0m (E-W), a base thickness of 2.10m and wall height as found was 1.6m with a 3:1 batter. The outer walls of the combined structure of the superstructure and funerary temple had a uniform design with a batter of 4:1 on the outer face and vertical sides in the interior. The entire structure measured 58.45m (N-S) x 33.60m (E-W) and was 3.0m thick. The walls were faced with mud plaster, but subsequent to this, the builders strengthened the walls with a mud brick skin wall 20cm thick, rising from the base to a height of 1.2m. The whole exterior of the structure was then covered with a thick white gypsum plaster. The superstructure consisted of massive brick walls retaining a filling of packed rubble which covered the whole area of the interior and measured 24.00m (N) / 24.30m (S) x 35.20m (E) / 35.00m (W), with a wall thickness of 5.80m / 5.15m / 6.00m / 5.75m respectively.\footnote{Emery, Great Tombs III, 6.}

The funerary temple covered an area of approximately 600m$^2$. Of the 14 rooms, all had mud packed floors covered with a thick layer of white gypsum plaster, with the exception of Room 7 which was paved with stone. The largest room, Room 10, had walls covered with reed matting adhering to the mud plaster.\footnote{W. Z. Wendrich wrote: ‘The walls of the funerary chapel in the 1$^{st}$ Dynasty tomb S3505 at Saqqara, were not made of reeds, but of a much more flexible grass matting, in which bundles of grass were made into a fabric by widely spaced rows of twinning. Since S3505 was thought to be an elite tomb, the occurrence of simple twined grass matting as wall cover for the chapel is surprising.’ Nicholson and Shaw, Ancient Egyptian Materials and Technology, 257.} The walls of Rooms 7 and Room 8 were originally painted yellow with a black dado, 16cm deep. All other rooms were faced with white plaster.\footnote{Emery, Great Tombs III, 10.}

The substructure of the tomb was entered via a passage under the east corridor, running north to south and turning at right angles to the west. Rock-cut shelves on each side of the passage supported wooden beams and planks for the roofing, traces of which were
found when the tomb was excavated. The substructure consisted of two magazines on the north and south of the passage to the burial chamber. The burial chamber measured 5.00m x 8.70m and had a maximum depth from ground level of 5.75m. Wide shelves on all four sides of the chamber were cut 3.10m above the floor level to support a wooden roof. Two rock cut emplacements were cut in the east and west walls to receive wooden beams which measured approximated 60cm x 60cm. The roofing planks that rested on these beams were 30cm thick x 90cm wide.487

This large funerary complex consumed a large quantity of materials. A total of 460m$^3$ of material was excavated to form the substructure. The mud bricks used totalled 2,014,700 – the second highest number after the tomb of Hemaka. The total plastered area equated to 2,600m$^2$ of wall and 530m$^2$ of mud packed floor. The reed matting in Room 10 would have covered an area of 58m$^2$. The rubble fill within the interior of the superstructure was estimated to be 1,040m$^3$.

The roofing of the complex varied in dimensions for the corridor, magazines and burial chamber.

Roofing of the corridor included:
- 30 planks of 60cm x 30cm and 1.3m long.

Roofing of the magazines included:
- 5 planks of 60cm x 30cm and 2.0m long for Magazine A
- 6 planks of 60cm x 30cm and 2.8m long for Magazine B.

Roofing of the burial chamber included:
- 2 square beams 60cm x 60cm, approximately 9.5m long (allowing for overhang)
- 10 planks of 90cm x 30cm and 5.8m long.

**Tomb S3500**

The last tomb of the 1st Dynasty built at North Saqqara, dated to the reign of Qa’a is S3500.488 The tomb had a plain brick superstructure with an elaborate niche on the south end of the east face. The interior of the superstructure was divided by a series of cross-walls into 6 large rooms which were filled with sand, and one contained a

488 This is assuming no additional tombs are found in the future, and the dating of tombs does not change as new material is discovered.
magazine, which was a rectangular pit with mud brick walls rising 0.50m above ground level. It had originally been roofed with wooden planks supported by thin beams. An enclosure wall surrounded the superstructure and an entrance gateway existed in the south-west corner. A passageway under the east side of the enclosure descended down steps to two small magazines before coming to a large rectangular pit. The sides of the pit were shelved and rough stone retaining walls were built to hold the soft gravel strata above the rock. The passageway had three gates separated by grooves which supported two limestone portcullises. All three gates had stone lintels.

The enclosure wall measured 23.35m (N-S) x 37.10m (E-W) and the thickness at the base varied from 0.80 to 1.28m. The superstructure measured 15.85m (N) / 15.90m (S) x 31.60m (E) / 31.90m (W) and the main walls were 2.80m (N-S) and 2.60m (E-W) thick. Both structures were faced with white gypsum plaster.

Tomb S3500 had a total volume of 365m$^3$ excavated to form the burial pit and small magazine. The number of mud bricks used in constructing the tomb came to 601,000 units and the total area plastered was 1,010m$^2$. The rubble fill placed within the superstructure equalled 273m$^3$. The roofing of the magazines was estimated to include:

- 14 beams of 11.3cm diameter and 2.8m long
- 18 planks of 15cm x 6cm and 3.1m long.

Although no information is available on the roof of the burial chamber, it was estimated that 14 planks measuring 30cm x 60cm and 8.1m in length would have been required.

2nd Dynasty Tombs

Tomb S3121

Tomb S3121 was built on the side and partly on top of the escarpment. Dated to the 2nd Dynasty, it consisted of a superstructure with plain walls, bound corridors on the north and west-east sides, and an inner superstructure within which five magazines existed.
The superstructure was of trapezoidal shape and measured 13.60m (N) / 15.75m (S) x 19.10m (E) / 18.90m (W). Two offering niches were placed on the west wall of the inner superstructure. The walls were built vertically and originally faced with mud plaster over which a thin layer of white gypsum plaster was applied.\(^{494}\) The corridor walls and niches bore traces of painted decorations but the magazines were only faced with mud plaster.\(^{495}\)

A doorway in the north corridor led to a sloping passage descending southwards to a series of five steps which led to the subterranean burial chamber. The lower portion of the walls of this chamber had been cut into solid rock, the upper walls, cut in the softer gravel stratum, needed to be retained with walls built of roughly dressed stone which, originally faced with mud plaster, bore the marks of copper chisels. The burial chamber measured 3.5m (N) / 3.6m (S) x 4.5m (E) / 3.5m (W) and was 2.15m high.\(^{496}\) The passage leading to the burial chamber had been roofed with large blocks of hard limestone, with an average size of 2.0m x 1.0m x 0.6m.\(^{497}\)

Smaller in size compared to the massive mud brick mastaba tombs from the middle of the 1\(^{st}\) Dynasty, this tomb required the excavation of 64m\(^{3}\) of material, a total of 108,000 mud bricks and a face area of 363m\(^{2}\) mud plastered.\(^{498}\) The rubble placed over the roof was estimated to be 23m\(^{3}\).

**Tomb S3120**\(^{499}\)

Tomb S3120 was built on the side of the escarpment after Tomb S3121. The superstructure was trapezoidal and similar to S3121, with the exception that it only had three magazines in the inner superstructure. The superstructure measured 10.00m (N) / 8.80m (S) x 13.20 (E) / 11.40 (W), and had plain sides. The west wall of the corridor of the inner superstructure had two offering niches. The walls were faced with mud plaster and covered with white gypsum plaster while the flooring consisted of packed mud and bricks.\(^{500}\)

\(^{495}\) Emery, *Great Tombs I*, 117.
\(^{496}\) Emery, *Great Tombs I*, 118.
\(^{497}\) Emery, *Great Tombs I*, 118.
\(^{498}\) It was assumed that the superstructure of Tomb S3121 was built to a height of only 2m.
\(^{499}\) Emery, *Great Tombs I*.
\(^{500}\) Emery, *Great Tombs I*, 121.
The subterranean burial chamber was accessed through a stairway in the floor of the east-west corridor which turned at right angles to the south. The stairway leading to the burial chamber had brick walls and wooden beams with mud packing above forming the roof. The remains of the timber beams were found in sockets in the walls so their position was ascertainable. The average beam diameter was 20cm. The burial chamber was cut in the side of the rock-face at a depth of 6.0m below ground level and measured 2.85m / 3.50m x 3.90m / 3.30m and a height of 1.85m. The walls were originally faced with white gypsum plaster.501

Tomb S3120 consumed 82,400 mud bricks. 280m² of wall area was plastered and 35m³ of material was excavated in constructing the substructure.502 The volume of material placed over the roof was only 13m³ of rubble.

**Tomb S3024**

Tomb S3024 consisted of a rectangular mud brick superstructure filled with rubble. The substructure was entered via a stairway descending east-west and turning south. There were two magazines at the end of the stairway and the burial chamber was beyond these rooms. The substructure was cut into rock.503 The total volume of material excavated to create the substructure equated to 290m³. The mud bricks consumed in the superstructure equalled 188,800 and the plastered wall face equated to 167m².504 The rubble fill within the superstructure equalled 145m³.

502 It was assumed that the superstructure of Tomb S3120 was built to a height of only 2m.
504 It was assumed that the superstructure of Tomb S3024 was built to a height of only 2m.
Subterranean 2nd Dynasty Tombs

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume (m³)</th>
<th>Bricks (units)</th>
<th>Plaster (m²)</th>
<th>Rubble Fill (m³)</th>
</tr>
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<td>S2498</td>
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<td>120</td>
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<tr>
<td>S2406</td>
<td>88</td>
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<td>374</td>
<td>255</td>
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Subterranean 2nd Dynasty Royal Tombs

<table>
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<tr>
<th>Tomb</th>
<th>Volume (m³)</th>
<th>Bricks (units)</th>
<th>Plaster (m²)</th>
<th>Rubble Fill (m³)</th>
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<td>Ninetjer</td>
<td>1800</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</table>

Summary of Results – Saqqara

The results of volume excavated and mud bricks used in the Saqqara tombs were graphed in order to establish any discernable trends (see Graph 4.1). The graph illustrates that those buried in North Saqqara during the early to mid 1st Dynasty were afforded considerable resources, most likely provided by the kings they served.

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506 The height of the superstructures was assumed to be 4m.
507 The height of the subterranean galleries was assumed to be 2m, see C. Lacher, “Das Grab des Hetepsechemui/Raneb in Saqqara”, MENES, Studien zur Kultur und Sprache der ägyptischen Frühzeit und des Alten Reiches 5 (2008), 431.
508 From Lacher’s reconstruction of Hetepsekhemwy’s superstructure (Lacher, Das Grab des Hetepsechemui/Raneb in Saqqara, 430–431), the volume of bricks was estimated to total 1,600m³ (based on 122m x 48m x 4m high superstructure – the mud brick walls were assumed to have been 5m thick). Assuming one brick equalled 0.002016m³ (24cm x 12cm x 7cm) the total number of bricks consumed by Hetepsekhemwy’s tomb equated to approximately 793,650 units.
510 Based on the available plan of this tomb it was not possible to calculate the number of bricks due to lack of evidence of a superstructure. In Chapter 6, Tomb Construction, the superstructure proposed by the author is a mud brick mastaba of the same size as that of Hetepsekhemwy and in the style of the earlier elite superstructures. This was done in order to provide comparative construction times only of equivalent style tombs for the first and third kings of the 2nd Dynasty – Hetepsekhemwy and Ninetjer. It must be stressed that there is presently no evidence on the type of superstructure built for this tomb. The tomb of Ninetjer is currently being reinvestigated by the German Archaeological Institute, led by Field Director, Claudia Lacher who has indicated that no remains of a superstructure have been located. In a forthcoming manuscript of the tomb of Ninetjer, C. Lacher has designed five different reconstructions of the superstructure, basing them on diverse historical lines, including Abydos-tumulus-type and the Saqqara-mastaba-type. However, she cautions, that as long as no remains have been found, one should not assume anything. Personal communication with C. Lacher.
The size of the tombs built for two high-ranking officials during Den’s reign, Hemaka (S3035) and Ankh-Ka (S3036) were exceptionally large, as was Tomb S3035 (dated to the reign of Qa’a). This is reflected in the spikes on the graph, indicating a large number of mud bricks were consumed in the construction of these tombs. The intermediary periods between Den and Qa’a saw a drop in the size of the tombs and this is also reflected in the tombs of the kings themselves, as discussed later in this chapter.

The elite tombs which followed the 1st Dynasty structures were small in comparison. The quantity of mud bricks gradually increased before falling, but never reached 1,000,000 units. It is possible, although purely speculative, that one of the reasons for the reduction in tomb size was the kings, now being buried at Saqqara, had greater control over the tombs built by their officials, and because of this, the type of grand structures built early in the 1st Dynasty were scaled back markedly to ensure a clear distinction between the king’s position and that of his officials.

One thing is certain, however, the size of the kings’ tombs were not compromised. Hetepsekhemwy, the first king of the 2nd Dynasty, built an enormous subterranean gallery tomb, and while nothing remains of his superstructure, it would undoubtedly have been impressive.

The estimated total material that went into the construction of each of the Saqqara tombs is summarised in Table 4.1.
<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume Excavated (m³)</th>
<th>No. of Mud Bricks</th>
<th>Total Area Plastered (m²)</th>
<th>Vol. of Sand False Floor (m³)</th>
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Table 4.1. Saqqara tombs – material expenditure summary

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<tr>
<th>Subsidiary Graves</th>
<th>Number of Graves</th>
<th>Volume Excavated (m³)</th>
<th>No. of Mud Bricks</th>
<th>Total Area Plastered (m²)</th>
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<td>4</td>
<td>3,000</td>
<td>10</td>
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</table>

Table 4.2. Saqqara subsidiary graves – material expenditure summary

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511 The number of mud bricks tabled is based on 4m high superstructures with the exception of tombs S3121, S3120 and S3024, which were taken to be 2m high.
513 No superstructure was found for the tomb of Ninejet. Lacher, *Tomb of King Ninejet*, 217.
514 Tomb S3503 was accompanied by a boat burial, containing 15,400 mud bricks and 42m³ of sand fill.
515 The tomb was originally flanked by 22 subsidiary graves, however only 20 have survived.
516 Tomb S3506 was accompanied by a boat burial as discussed earlier: 83m³ of excavated material, 7,000 mud bricks and 75m³ of sand fill.
4.2.2 HELWAN\textsuperscript{517}

The Helwan cemetery, on the east bank, features medium-sized mastaba tombs and thousands of smaller graves in contrast to the large mortuary structures of the elite across the Nile River at North Saqqara.\textsuperscript{518}

During the 1\textsuperscript{st} Dynasty, the substructures of the tombs were typically pit burials, ranging from small oval pits to larger rectangular substructures. They were either single roomed or subdivided by mud brick walls to form multiple chambers. By the middle of the 2nd Dynasty subterranean gallery tombs also began to be built.\textsuperscript{519} The size and number of subterranean chambers varied from a single chamber to a complex structure made up of a series of galleries and rooms.\textsuperscript{520} The good limestone in the Memphite region was ideal for underground tunnelling and therefore subterranean tomb construction, which made this area the focal point for early developments in stone working and quarrying as seen by the large amount of limestone employed in tomb chambers of the 1\textsuperscript{st} and 2\textsuperscript{nd} Dynasty tombs at Helwan.\textsuperscript{521} Large slabs of limestone were used to line, pave and, in some instances, roof the tombs.\textsuperscript{522}

Remains of superstructures at Helwan, though rare, have survived, if only a few bricks high.\textsuperscript{523} Even where no traces of the superstructure remain, the spatial distribution of the surrounding tombs may point to the existence of one.\textsuperscript{524} The exterior of the superstructure varied between simple rectangular niches on the east or west side, to the more elaborate palace façade panelling as seen at Saqqara, only here, it existed on a

\textsuperscript{517} Refer to Table 4.3 for a summary of the material expenditure results of the Helwan tombs.


\textsuperscript{519} See Volume 2, Appendix C, for tomb plans and sections. (Figure C1.1 to Figure C1.33)

\textsuperscript{520} Köhler, \textit{BACE} 11, 83–92; Köhler, \textit{Archéo-Nil} 13, 16–27; Köhler, \textit{Helwan I}.


\textsuperscript{522} It is possible that the stone at Helwan was used as a substitute for the timber lining of the elite tombs at Saqqara (see W. Wood, “The stone tombs of Helwan”, \textit{JEA} 73 (1987) 59–70). The stone used in the Helwan tombs may have been less prestigious than imported cedar, but it would have been just as expensive to acquire (see Köhler, \textit{Helwan I}).

\textsuperscript{523} Köhler, \textit{Archéo Nil} 18, 113–130.

\textsuperscript{524} Köhler, \textit{Helwan I, 25}.
smaller scale. These superstructures were built of solid mud bricks or filled with mud brick debris, sand and rubble, and in most cases, inaccessible.

The Helwan cemetery contained burials belonging to common and low ranking officials, however, a few of the tombs are still notable in size as evidenced by the amount of material that went into the construction. The larger Helwan tombs are briefly described below along with a breakdown of the materials used in the construction of each tomb.

**Tomb 1473.H.2**

Dated to Naqada IIIC (Dyn 1) the tomb was originally mislabelled as 1374.H.2. The superstructure had the palace façade panelling on all four sides (elaborate niches were built on three sides and small niches on the fourth side) and was surrounded with an outer enclosure wall. The descent into the substructure of the tomb was via a mud brick staircase, running straight from west to east, where it ended at the burial chamber. There were two magazines, one to the south of the burial chamber and one on a higher level to that of the burial chamber.

Tomb 1473.H.3 was one of the largest tombs at Helwan from the Early Dynastic period, with 310m$^3$ of material excavated to form the substructure. The quantity of mud bricks equated to 177,500 and this number of mud bricks assumed a solid brick structure. However, the interior of the superstructure may have resembled that of Tomb Op 4/1. A total wall face area of 530m$^3$ was plastered. The enclosure wall measured approximately 17.8m x 12.4m and was 1.0m thick. The superstructure measured 14.1m x 8.5m. A maximum height of 2m was assumed. The total timber used for the roof, based on the engineering requirements, equated to 27 beams of 30cm diameter and 3m

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525 For example, Helwan Tomb 1473.H.2. Saad, *Saqqara and Helwan*, Plate 53; Note: the tomb is mislabelled as Tomb 1374 in the photograph on Plate 53, but correctly labelled on the overall site plan in the same publication.


527 I would like to thank E. C. Köhler for providing the dating for the Helwan tombs and for advising on the mislabelling of Tomb 1473.H.2.


529 This total was broken down whereby 54,500 mud bricks were used to build the retaining walls in the substructure and 123,000 in the superstructure and enclosure wall.

530 The interior of Tomb Op 4/1’s superstructure was not a solid mass of mud bricks but a series of mud brick cross-walls. The voids were filled with sand and rubble. Köhler, *Archéo Nil* 18, 7.

531 A height of 2m was used for all the Helwan superstructures based on the fact that they would have been just over the height of a tall person, whilst not built to the excesses seen in the Saqqara tombs. Furthermore, the maximum height of 2m was chosen due to the structural capacity of the brick walls (based on the thickness of the walls) within the superstructure of Tomb Op 4/1.
length as well as timber planks, 30cm x 12cm of which 15 needed to be 3.2m long, and ten 5.5m long, based on the size of the chambers. A total of 27m² of reed matting would have been needed to cover the timber roofs.

**Tomb 185.H.4**

Tomb 185.H.4 also dated to Naqada IIIC (Dyn 1) had a rectangular form cut in gravel with three magazines on the south, which were built of mud bricks. Ledges for the roof had been excavated on the east and west walls, 0.7m thick, and 1.9m from floor level. The burial place measured 3.4m from north to south, 2.5m from east to west and 2.2m from the bottom of the burial place to the top of the ledges.\(^{532}\)

The total volume excavated to form the pit of the tomb was 69m³, and only 1,700 mud bricks were estimated to have been used in the substructure. There was no mention in the excavation report that the walls had been plastered. As the tomb was unfinished, it is possible this was not deliberate.\(^{533}\)

The timber roofing required was estimated to be:

- 14 beams of 20cm diameter and 3m long
- 13 planks of 20cm x 15cm and 4m long for the burial chamber
- 13 planks of 20cm x 15cm and 2m long for the magazines
- 13.2m² of reed matting placed above the timber planking.

**Tomb 762.H.5**

Tomb 762.H.5, dated to Naqada IIIC (Dyn 1) is rectangular and built of mud bricks, measuring 2.4m (N-S) x 1.6m (E-W) and 1.6m from floor to ledge + 1.9m ledge to ground level. The substructure consisted of a burial chamber and four magazines, two of which were situated to the north and two to the south. A boat grave measuring 10m long and about 1.2m wide was also found to the north of Tomb 762.H.5.\(^{534}\)

The total volume excavated to form the substructure equalled 65m³ and 9,500 mud bricks were used to line the tomb walls. There was no evidence of the walls having been

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\(^{532}\) Saad, *Helwan*, 7.

\(^{533}\) Saad, *Helwan*, 7.

\(^{534}\) Saad, *Helwan*, 42.
plastered.\textsuperscript{535} If they had, however, the total area of plastering would have equated to 23m$^2$.

It was assumed the timber roofing of the burial chamber and the magazines would have comprised of beams and planks of various dimensions.

The burial chamber would have included:
- Six beams of 20cm diameter and 2.6m long
- Five planks of 30cm x 12cm and 3m long.

The magazines would have included:
- Four beams of 20cm diameter and 2.6m long
- 12 planks of 30cm x 12cm and 1.5m long
- 7.1m$^2$ of reed matting.

**Tomb 68.H.4**

The substructure of the tomb (dated to IIIC), cut in gravel, is rectangular and lined with mud bricks. The pit measured approximately 3.8m (N-S) x 2.8m (E-W), and was made smaller through the mud brick retaining walls. The resulting chamber measured 2.5m (N-S) x 1.2m (E-W) and 1.6m deep, with no other rooms built.\textsuperscript{536} The total volume excavated to form this tomb was 39m$^3$ and a total of 7,700 mud bricks were consumed in lining the tomb.

A ledge, 0.4m wide, was constructed on top of the east and west walls at a height of 1.6m where timber beams rested – traces in the form of brown powder still remained in holes where those wooden beams were inserted. The sides of the tomb from the ledges upwards were built up to the ground level. The overall height came to 3.6m. The space from the timber roof to ground level was filled with gravel after the body was buried. No evidence remained of a superstructure.\textsuperscript{537}

The roofing to cover this tomb, based on the roofing analysis undertaken in Chapter 1, may have consisted of five rectangular (19cm x 15cm) beams by 2m long which supported the top planking of six planks (20cm x 12cm) by 3m long. The reed matting,

\textsuperscript{535} Saad, *Helwan*, 42.
\textsuperscript{536} Saad, *Helwan*, 7.
\textsuperscript{537} Saad, *Helwan*, 7.
if used, equalled 3m$^2$. Like the earlier tombs, no evidence remained of plaster on the walls.

**Tomb 9.H.1**

Tomb 9.H.1 was one of the larger tombs, by Helwan standards, measuring 11.0m x 5.4m with a stairway perpendicular to the main tomb measuring 8.6m x 2.0m. The substructure consisted of a central burial chamber with two magazines on either side. The depth of the overall pit was assumed, based on photographs of the tomb, to be 3.6m (2m from floor to ledge + 1.6m ledge to ground level). The tomb had mud brick retaining walls and the main chamber had subsequently been lined with limestone slabs. The volume excavated was 195m$^3$, a total of 34,100 mud bricks, and 10.6m$^3$ of limestone was used to line the walls and pave the floor. The roof of the burial chamber also had two large stone slabs. If the four magazines had also been roofed with limestone slabs, a further 2.7m$^3$ of limestone would have been required, resulting in a total of 28 tonnes of limestone used in this tomb.

**Tomb 649.H.5**

Tomb 649.H.5 was also a large tomb, with the remains of a superstructure above the burial chamber and magazines of the tomb. A staircase descended into the substructure, which was made up of a burial chamber and four small magazines formed by cross-walls. The outer walls of the superstructure walls measured approximately 21.8m x 12.8m and 1.0m thick, the superstructure measured approximately 11.2m x 8.6m. A boat grave measuring 13.5m x 1.5m wide was found to the east of the tomb. The excavated substructure measured 8.0m x 3.3m and 4m deep with the total material excavated equalling 139m$^3$. The total number of mud bricks used was approximately 106,700 units of which only 21,000 were used in the substructure. This highlights an important fact: the majority of bricks went into the superstructure of these tombs, and since few traces of the superstructures remain, the analysis and comparison of the material expenditure of the Helwan tombs may be slightly misleading. This issue will be reviewed later in this chapter.

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538 Köhler, Archéo-Nil 18, Figure 8.
539 Saad, Helwan, 28.
540 The density of limestone used to convert the calculated volume into tonnes was taken to be on average 2.1 tonnes per m$^3$. Köhler, Helwan I, 25.
541 Saad, Helwan, 41–42.
The total face area requiring plastering of Tomb 649.H.5 equated to 320 m², and the roofing was assumed to consist of 17 beams of 30 cm diameter and 3 m long, 11 planks (30 cm x 12 cm) by 3.2 m long over the burial chamber, and 27 planks (30 cm x 12 cm) by 1.8 m long. A total of 14 m² of reed mats would have covered the roof.

**Tomb 559.H.2**

The substructure of the tomb was entered via a straight staircase built with mud bricks, containing 21 regular steps measuring 6.4 m x 1.8 m wide. At the fifth step from the end of the staircase there are two grooves opposite each other in the walls of the staircase; at the last step, there are two similar grooves. These grooves mark the positions where two portcullis stones would have rested. In the space between the two portcullises, two magazines were constructed on each side of the steps. There were no communicating doors to the magazines, only niches. The burial chamber was rectangular and lined with mud bricks. In the south-east corner a small chamber with a small door on the west side was built, possibly to house the body of the deceased. The pit measured 4.8 m x 3.4 m and 3.8 m deep. The height from floor to the ledge where the roof was placed was 2.25 m. ⁵⁴²

The total volume excavated equalled 90 m³ and 14,600 mud bricks were used in the substructure. A total face area of 77 m² was plastered. The roofing over the main chamber may have consumed nine beams of 20 cm diameter by 3 m long and 12 planks of 30 cm x 15 cm and 4 m long. The total area of reed matting equalled 9 m². The roofing over the stairs could have been made up of 32 beams of 20 cm diameter and 1.8 m long.

**Tomb 1371.H.2** ⁵⁴³

As with a majority of the Helwan tombs, no remains survive of the superstructure. A staircase leading to the substructure ran from west and then turned south. A stone portcullis was found blocking the entrance to the passage on both sides of which two magazines were constructed. The magazines contained large actual granaries made from pottery. At the end of the passage, another portcullis stone blocked the entrance to the burial chamber, which was paved with three slabs of white limestone. According Zaki

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⁵⁴² Saad, *Helwan*, 107; Köhler, *Archéo-Nil* 18, Figure 1.
Saad, this tomb was for one of the officials who lived during the reign of King Anedjib. This tomb was large with the substructure, excluding the stairs, measuring approximately 11.1m x 4.5m. The tomb was not a true rectangle however, and the excavated material to form the pit equalled 191m$^3$. Mud brick retaining walls lined the substructure resulting in a total of 45,200 mud bricks. The walls of the tomb had been white-washed, a total area of 128m$^2$. Finally, the roofing consisted of eight rectangular beams of 33cm x 17cm and 3.5m long; ten planks 30cm x 15cm by 9m long (or most likely 20 planks at 4.5m long); and 24m$^2$ of reed mats. Eight tonnes of limestone was used in the portcullis and stone pavement.

**Tomb 1502.H.2**

The substructure of Tomb 1502.H.2 was entered via a staircase which originally ran straight from north to south, but was later changed so the bottom section of the steps ran west before meeting up with the original steps. Two magazines, one to the east and another to the west, were positioned at the end of the stairway passage before the burial chamber. Four large pottery granaries were placed in the magazines to the east. The burial chamber was blocked with a limestone portcullis and paved with limestone slabs, all covered with a layer of white-washed plaster. The walls were built with mud brick, plastered and finally white-washed. The tomb was roofed with large beams of wood – large, burnt traces of which were found on the walls. A boat grave was also found to the south of the tomb.

The total volume excavated equalled 148m$^3$ for the substructure and stairs. A total of 21,300 mud bricks were used in the substructure and 86m$^2$ of face area was covered with white-washed plaster. The total reed matting used over the burial chamber and magazines amounted to 12m$^2$. The roofing, as with other tombs, was assumed to be comprised of a burial chamber, magazines and stairway.

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545 Saad, *Helwan*, 110.
The burial chamber included the following materials:

- Two rectangular beams of 24cm x 30cm and 3m long (spanning almost 2m with 50cm on either side of ledge)
- Seven planks of 30cm x 15cm and 4.2m long.

The magazines included the following material:

- Ten planks of 30cm x 15cm and 2.0m long.

The stairway included the following material:

- 41 beams of 20cm diameter and 1.5m long.

**Tomb 1.H.3**

One of the larger tombs in Helwan, Tomb 1.H.3, measured approximately 23.0m x 11.3m. The burial chamber was hewn in gravel and then built up with mud brick walls on all four sides. The mud brick walls were encased with large white limestone slabs placed one beside the other. The substructure and stairs were formed by excavating a total volume of 365m$^3$ of material. The total number of mud bricks used for the retaining walls in the substructure was 51,000, with the superstructure (assuming it was of solid mud brick) equalling 187,500. A total of 24 tonnes of limestone was used to line the burial chamber.

The burial chamber was roofed with big timber beams and then covered with wooden planks. A total of 5 square beams measuring 30cm x 30cm and 4.6m in length would be required to span the burial chamber. Further, 12 timber planks of 30cm x 15cm and 6.5m in length would have been placed above these beams. Then, above the stairs, a total of 110 timber beams placed side by side, 20cm in diameter and 2m long, would have been necessary if this passage had been roofed.

**Tomb 60.H.1**

Tomb 60.H.1, accessed via a straight mud brick lined staircase, was originally protected by two portcullis stones. The excavated pit measured approximately 13.1m x 5.2m and the height, as scaled from photographs, was estimated to be 2.5m–3.0m. This
resulted in a total volume of $41m^3$ of material being excavated. The burial chamber substructure measured 3.5m x 2.0m and was retained by mud brick walls. Above the substructure, remains of the superstructure walls exist, their complete size estimated to be 14.9m x 7.3m and 27cm thick. These dimensions suggest that a total of 54,500 mud bricks would have been required for the both the superstructure and substructure, with the substructure only requiring 1,800 bricks. The builders of this tomb also utilised 26 tonnes of limestone for lining the burial chamber walls, the portcullis and the roofing.

**Tomb 701.H.3**

A staircase, running east to west and then turning south, led to a passage that ended with a portcullis stone blocking the entry to the burial chamber. Three mud brick magazines were on either side of the staircase. The excavated pit forming the substructure measured almost 9m x 4m, with the burial chamber reduced to 4.17m x 2.4m and 5.43m below ground level.\(^{553}\) This resulted in a total of $242m^3$ of material being excavated (including the stairs), and 12,600 mud bricks being used to form the walls of the magazines and burial chamber. The main walls of the burial chamber were assumed to have been plastered resulting in a face area of $40m^2$.

The roofing was estimated to have consisted of:

- 13 beams of 30m diameter and 3m long over the burial chamber
- Ten beams of 30cm diameter and 2m long over the corridor to the burial chamber
- 28 planks of 30cm x 15cm and 5m long over the magazines (although it is probable that small size timbers were used to roof the magazines)
- $39m^2$ of reed matting.

**Tomb Op1/1\(^{554}\)**

A staircase running from north to south led to the two magazines and a burial chamber that formed the substructure. Two portcullis stones (which are still in place) served to protect the entrance to the tomb. The tomb substructure, excluding the stairs, measured approximately 9.9m x 5.6m. The total volume excavated to form the substructure and stairs equated to approximately $229m^3$.

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\(^{553}\) Saad, *Helwan*, 173.

\(^{554}\) Originally labelled 40.H.3 by Saad who first excavated this tomb. Re-excavated and published by Macquarie University, Köhler, *Helwan I*. 
Tomb Op1/1 was lined and paved with stone slabs, totalling approximately $43m^3$ or 90 tonnes of limestone.\footnote{555} Behind the stone slabs, smaller masonry blocks were laid horizontally which were joined by a “pinkish orange mud mortar”.\footnote{556} The time and energy expended in quarrying these stone slabs and finally dressing the surface would have been considerable.

While no evidence remains of the superstructure, spatial distribution of the surrounding tombs was used to determine its size. The superstructure would have measured approximately 20m x 10m,\footnote{557} and assuming it was solid and that it reached a maximum height of 2m, would have contained approximately 145,000 mud bricks.\footnote{558} It was also estimated that the roof of Tomb Op1/1 comprised of 19 timber beams, 20cm in diameter and 6m long,\footnote{559} with 11 planks 30cm x 15cm and 8m long placed above the beams.\footnote{560}

**Tomb 385.H.4**

A descent from the north cut in gravel leads down to a flight of mud brick steps running to the substructure where two magazines and a burial chamber once made up Tomb 385.H.4. The burial chamber was lined with stone slabs and measured 5.22m (N-S) x 4m (E-W) and 1.85m + 2.3m from the floor to ground level. Ledges were built on the east (1.3m wide) and west (0.6m wide) side of the burial chamber, where the roof rested. No traces of a superstructure survived.\footnote{561}

The substructure of the tomb measured approximately 9.3m x 5.9m and 1.85m + 2.3m high, equating to 120m$^3$ of material being excavated. A total of 11,300 mud bricks were used in the substructure and 31 tonnes of limestone. Assuming the roof was made of timber, the burial chamber, magazine and stairway would have required specific dimensions.

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\footnote{555}{The volume calculated differs from that presented in the tombs’ publication were the calculated stone volume was 35m$^3$–40m$^3$. Köhler, *Helwan I*, 25.}

\footnote{556}{Köhler, *Helwan I*, 24.}

\footnote{557}{Köhler, *Helwan I*, 25.}

\footnote{558}{Based on brick sizes 23cm x 15cm x 8cm.}

\footnote{559}{Köhler, *Helwan I*, 25.}

\footnote{560}{Above the majority of roofs, reed mats would have been placed to ensure the sand forming the false floor was contained.}

\footnote{561}{Saad, *Helwan*, 9–11.}
For the burial chamber, roofing requirements would have been:

- 14 beams of 30cm diameter and 5.2m long
- 14 planks of 30cm x 15cm and 6.2m long.

For the magazine and stairway, roofing requirements would have been:

- 18 beams of 30cm diameter and 2.0m long
- 24 planks of 30cm x 15cm and 1.5m long
- A total area of 31m² would require reed matting.

**Tomb 426.H.4**

Tomb 426.H.4 had a stairway running from south to north, cut in gravel 6.5m long, which finished at a passage 1.8m long and 1.05m wide where two magazines, one on the east and one on the west, were positioned before the burial chamber. The burial chamber was blocked with a limestone portcullis. The burial chamber was lined with mud brick walls and measured 3.5m (N-S) x 2.35m (E-W) and 2.1m high. At this height four ledges were cut into the gravel, 0.4m wide, where a timber roof rested. Above the ledges were built walls on all four sides and then the whole area above the roof was filled with rubble.

The excavated pit measured approximately 7.3m x 4.0m, and the total volume excavated equalled 134m³. Of the 128,300 mud bricks required, following a plan area based on spatial distribution which suggested a size of 14m x 8m, and an assumed height of 2m, 81,200 mud bricks would have been used in the superstructure.

In terms of roofing then, the builders of Tomb 426.H.4 would have required:

- 17 beams of 30cm diameter and 3.2m long
- 11 planks of 30cm x 15cm and 4.2m long for the burial chamber
- 11 planks of 30cm x 15cm and 3.6m long for the magazines
- 21m³ of reed matting.

**Tomb 653.H.4**

Tomb 653.H.4 occupied an area of 48m (N-S) x 24m (E-W). The total volume excavated was 1,620m³ – the greatest volume of any of the Helwan tombs. The

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562 Saad, Helwan, 12–13.
563 Saad, Helwan, 18.
substructure was a large rectangular pit accessed by a staircase 17.5m long and 1.7m–1.2m wide. The substructure measured 25.3m x 7m and 6.2m–6.6m in depth. Along the sides of the substructure there are a total of 17 holes on the east side, 17 holes on the west, and eight holes on the south. In front of every two holes on the east side there is a hole forming a triangle with the two others. In one of the ground-level holes on the south-west corner, traces of wood were found. It is possible these holes were for timber posts which may have formed timber compartments.564

Based on the engineering analysis conducted on the roofing structure, the roof was estimated to be comprised of 27 beams of 59cm diameter and approximately 8m long, as well as 62 planks of 30cm x 15cm and 8.4m lengths. The total area of the roof would have required approximately 177m² of reed matting.

**Tomb 680.H.5**

The superstructure of Tomb 680.H.5 measured 11m x 6.6m with an enclosure wall apparent; the enclosure wall measured approximately 16.5m x 9.7m with 1.0m thick walls.565 A staircase in the south, 4.2m long and 0.8m wide, was cut roughly in gravel leading to a rectangular burial chamber cut in soft rock. Around the burial chamber, evidence of 0.3m wide ledges were cut to support the roof, and above these ledges, mud brick walls were built up to ground level. The chamber measured 4.5m x 1.8m and was approximately 1.8m (from floor to ledge) + 2.4m (from ledge to ground level). To the south, a boat grave measuring 9.5m x 1.3 was built.566

Considering these dimensions, the total volume excavated form Tomb 680.H.5 was 56m³, 83,600 mud bricks were used within the superstructure and enclosure wall, approximately 4,400 of which were used in the substructure walls along the ledges. Assuming the height of the superstructure was 2m and the enclosure wall 1.5m, the plastered walls would have equalled 241m².

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564 Köhler, *Archéo Nil* 18, 113–130. It is unlikely the postholes were used to simply support the roof as the posts were placed along the perimeter of the roof span.
565 Saad, *Helwan*, 42.
566 Saad, *Helwan*, 42.
The roofing, assumed to be made up of four rectangular timber beams measuring 31cm x 15cm and 2.4m long, above which six timber planks of 31cm x 15cm and 5.1m long sat, would have only required 8m² of reed matting.

**Tomb 150.H.5**

A north to south stairway, 6.8m long and 1.3m wide, led to the burial chamber measuring 7.5m (N-S) x 3.2m (E-W) and 2.2m + 2m high. There were two 0.5m wide ledges on the east and west walls where wooden beams bearing the roof would have rested.\(^\text{567}\) The floor of the burial chamber has five holes on the east and west sides, which probably held wooden posts for compartments or pillars to support the roof.\(^\text{568}\) The burial chamber measured 7.5m x 3.2m, with a brick retaining wall 0.5m thick. Remains of the brick walls above ground level in a rectangular shape indicate a superstructure which measured 14.8m from north to south and 7.2m from east to west.

A total of 115m³ of material was excavated to form the substructure, 1,500 mud bricks were used in the substructure and approximately 43,000 mud bricks were used in the superstructure. A total of 88m² of wall area was plastered.

The roofing structure consisted of six beams (40cm diameter and 4.2m long), 11 planks (30cm x 15cm and 8.5m long), as well as ten vertical posts (40cm diameter and 2.2m high). The reed matting used above the timber roof, if indeed any was used, would have equalled 24m².

**Tomb 1.H.4**

Tomb 1.H.4 originally had a mud brick superstructure. In the northwest corner of the superstructure was a small chapel facing west. The substructure of the tomb was accessed by a staircase leading to the burial chamber. Cut in gravel, the chamber measured 4.3m (N-S) x 2.6 (E-W) and 3.4m deep. There were two ledges on the east and west sides on which traces of the wooden beams used to support the roof were found.\(^\text{569}\)


\(^{568}\) For comments on the strength of the roof, refer to Chapter 2, Engineering of the Early Dynastic Tombs.

\(^{569}\) Saad, *Helwan*, 5–6.
The material excavated to form the substructure was calculated to be 53m$^3$. The superstructure, which measured approximately 15.4m x 6.8m and was 0.8m thick, would therefore have required a total of 24,000 mud bricks. The total height of the superstructure was assumed to be 2m. The roofing was assumed to consist of 11 beams, 30cm in diameter and 3.6m in length, and the plastered walls would have covered 136m$^2$.

**Tomb 407.H.4**

Cut in gravel, the stairway leading down to the substructure measured 7.5m. At the end of the descent, a door leading to the inside of the tomb had been sealed with bricks and plastered with mud. The door opened to a passage running east to west measuring 3.4m long, 1m wide and 2m high. At the end of the passage, a door to the north led to a magazine (0.6m x 1.8m x 2m high) and a door to the south led to the burial chamber. A third door in the east wall of the passage led to a second magazine (2.0m x 1.05m x 2m high). The burial chamber, measuring 8.10m x 3.85m x 2m high, had mud brick walls retaining the gravel cut.$^{570}$

The total volume excavated equated to 272m$^3$. A total of 21,400 mud bricks were used for the substructure. A superstructure, based on spatial distribution, was assumed to measure approximately 13.5m x 9.7m and 2m high with an enclosure wall of 19m x 13.5m x 1.5m high and 80cm thick. Such a structure would have consumed an additional 100,600 mud bricks. The mud brick walls in the burial chamber were lined with timber planks and the floor was paved with timber.

Based on traces of wood found on the ledges, the roof was clearly made up of timber beams and planks. These ledges were built to the ground level and the whole area was filled with rubble. The roofs of the burial chamber and magazines would have had a total of 49m$^2$ of reed matting and consisted of a range of beams and planks.

The burial chamber would have had:

- 21 beams of 30cm diameter and 4.5m long
- 27 planks of 30cm x 15cm and 9m long.

The magazines would have had:

- 12 beams of 30cm diameter and 3.3m long
- Nine planks of 30cm x 15cm and 4.5m long.

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$^{570}$ Saad, *Helwan*, 11–12.
**Tomb 355.H.4**

Saad reported that the substructure of Tomb 355.H.4 was almost square, measuring approximately 4.13m x 4.04m, and the depth of the tomb from the surface of the ground to the floor of the burial place was 2.9m. The length of the stairway leading to the substructure measured 3.6m and 0.6m wide.\(^{571}\) Therefore, the total volume excavated to form this substructure and stairs was calculated to be 45m\(^3\).

At the end of the descent were two grooves for the portcullis. Beyond the portcullis doorway was a magazine built with mud bricks measuring 0.55m (N-S) x 0.7m (E-W) and 0.8m + 0.7m deep. The burial place located to the south measured 2.5m x 1.9m x 1.7m + 0.5m deep. The ledges were 0.3m wide and above them another wall was built up to the ground level, 0.5m high. The first two ledges were for the placement of timber beams for the roof.

The mud brick walls acted as retaining walls, and formed ledges on which the roof was placed. These walls were constructed out of 8,100 bricks. If the walls of the burial chamber had been plastered, this would have equated to 15m\(^2\).

Finally, the roofing dimensions were calculated to be constructed from:

- Seven beams of 30cm diameter and 2.5m long
- Seven planks of 30cm x 15cm x 3m long
- 22 beams of 20cm and 1m long used over the magazines and stairs
- 5m\(^2\) of reed mats.

**Tomb 480.H.3**

The tomb was made up of two small chambers with no evidence of mud brick walls.\(^{572}\) The total volume excavated equated to 13m\(^3\). The roof of the tomb was found collapsed but it was calculated that the roof of one of the chambers would have consisted of ten beams, 20cm in diameter and 2.2m long; and the other chamber, 14 beams of the same diameter, but 1.4m long.

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\(^{571}\) Saad, *Helwan*, 8–9.

**Tomb 499.H.2**

Tomb 499.H.2 composed of stairs built of mud brick, which were flanked on both sides by two magazines. The stairs ended at an opening for a portcullis stone, which led to the burial chamber. The entire structure was rectangular and measured 6.0m x 3.1m.\(^{573}\) The volume excavated to form this substructure equated to 65m\(^3\), a total of 11,500 mud bricks were used to line the stairs, form the magazines and act as retaining walls around the burial chamber.

The roof was estimated to comprise of:

- Seven beams of 20cm diameter and 3m long for the burial chamber
- 11 planks of 20cm x 15cm and 3.6 long also for the burial chamber
- Eight beams of 20cm diameter and 1.4m long for the stairs and magazines
- 19m\(^2\) of reed matting.

**Tomb 553.H.2**

Tomb 553.H.2 consisted of a stairway starting from north to south before turning 180 degrees, only after four steps, to run south to north. The remaining five steps descended to the burial chamber, access to which was possibly blocked by two portcullis stones as evidenced by the grooves in the wall on the plan of the tomb.\(^{574}\) The burial chamber measured 3.0m x 2.2m and was approximately 2.94m deep. The stairs measured 2.5m x 1.74m. The cutting which formed this substructure was retained with mud brick walls, which were, on average, 40cm thick.\(^{575}\) The total volume thus excavated was 31m\(^3\) and a total of 7,000 mud bricks were used. If the mud brick walls of the burial chamber and stairs had been plastered, a 22m\(^2\) face area would have been covered.

The roofing would have comprised of:

- Six beams of 20cm diameter and 2.2m long for the burial chamber
- Seven planks of 20cm x 15cm and 3.0m long also for the burial chamber
- 13 beams of 20cm diameter placed side by side and 1.5m long for the stairs
- 7m\(^2\) of reed matting.

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\(^{574}\) Saad, *Helwan*, pl. XXXVI, XLIV.

\(^{575}\) Saad, *Helwan*, 107.
**Tomb 505.H.4**

Tomb 505.H.4 was a subterranean tomb and dated to the 2nd Dynasty. A stairway led down to a portcullis beyond which a chamber was cut into the rock, on each side of which (two in the east and two in the west) were magazines. The chamber measured 2.3m x 1.55m and 2.5m high. Beyond this chamber a doorway communicated with a second chamber measuring 5.3m x 2.3m x 2.5m high. On the east side there were three magazines and on the west a single room measuring 1.2m x 1.65m. The subterranean gallery continued to a third chamber measuring 2.6m x 2.4m x 2.5m high where, on the east side, there were two more magazines. The main chambers were approximately 2.5m high, the magazines and side rooms only 1.0m high. All the walls of the chambers and the roof were mud plastered and white-washed with gypsum.576

The total volume excavated to form the subterranean tomb equated to 91m$^3$. No mud bricks were used, but the area of all the walls that had been mud plastered and white-washed equalled 147m$^2$. Being subterranean, a roof was unnecessary.

**Tomb Op2/1**

Tomb 25.H.4 was re-excavated by Macquarie University and designated Op2/1.577 The subterranean tomb was accessed via a stairway cut in gravel left open without a roof. At the bottom of the stairs, two magazines were cut and behind a portcullis stone ahead of the magazines a corridor ran east to west. On the west side of the north wall a door led to a small square chamber in the east wall of which was another door. This door communicated with a rectangular chamber measuring 2.3m x 1.4m x 2.25m high. The burial place, measuring 0.8 x 1.3 x 0.95m high, was at the north end of the chamber, on a higher level than the floor. The walls of the descent, chambers and roof were all plastered with yellowish mud (Tafl) and then white-washed.578

The total volume excavated was 27m$^2$ and based on spatial distribution of the surrounding tombs, the quantity of mud bricks required (if a superstructure had in fact once existed), amounted to approximately 29,000 units. The area of wall plastered equated to 82m$^2$.

Tomb 810.H.3
Tomb 810.H.3 was also subterranean. The total volume of material excavated to form the stairway and burial chamber equated to 54m$^3$.

Tomb 25.H.5
The descent from north to south into the subterranean rooms was comprised of 22 rough steps cut in gravel, measuring 15m x 0.8m. The steps ended in a rectangular space 2.75m (N-S) x 1.25m (E-W) and 7.8m high to ground level. The passage leading to the burial chamber had once been blocked by a portcullis stone. The burial chamber measured 5.9m (N-S) x 1.65m (E-W) and 1.85m high. At the end was another door, 0.8m wide and 1.25m high, leading to a chamber measuring 3.1m (N-S) x 0.95m (E-W) and 1.25m high. To the west of this chamber was the burial place, 2m (N-S) x 0.9m (E-W) and 1.25m high. In total, 73m$^3$ of material was excavated to form this subterranean tomb, with no other evidence of plastering or painting of the walls cut into the natural rock.

Tomb Op4/1
Tomb Op4/1 was excavated by Macquarie University from 1998 to 2000. Of great importance is the fact that the mud brick superstructure survived, in some parts, to a height of 1.6m. The overall superstructure measured 22m x 11m. This mastaba was not of solid mudbrick, but consisted of irregular internal cross-walls. These internal compartments were found filled with material consisting of mud bricks, mud brick debris, sand and rubble. This method of construction would have saved considerably in the quantity of mud bricks used and labour expended, as it would have been far quicker to fill these compartments with rubble than build a solid mud brick superstructure.

Approximately 51,400 mud bricks were used in the superstructure, and 112m$^3$ of material was excavated to form the substructure. By way of comparison, if the

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579 Saad, *Helwan*, 172.
580 Saad, *Helwan*, 27.
581 Based on groves on both sides of the wall where the portcullis slab would have slid into place.
582 Saad, *Helwan*, 27.
584 Köhler, *BACE* 11, 85.
superstructure had been built of solid mud bricks, a total of approximately 175,400 bricks would have been required.


<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume (m³)</th>
<th>Mud Bricks (units)</th>
<th>Plaster (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op4/15</td>
<td>15</td>
<td>8,000</td>
<td>38</td>
</tr>
<tr>
<td>Op4/19</td>
<td>13</td>
<td>26,000</td>
<td>55</td>
</tr>
<tr>
<td>Op4/35</td>
<td>11</td>
<td>25,200</td>
<td>63</td>
</tr>
</tbody>
</table>

**Additional Subterranean Tombs**

<table>
<thead>
<tr>
<th>Excavation Season</th>
<th>Tomb</th>
<th>Volume Excavated (m³)</th>
<th>Basic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946-47</td>
<td>419</td>
<td>14.0</td>
<td>Natural rock cut + 1 underground chamber</td>
</tr>
<tr>
<td>1944-45</td>
<td>314</td>
<td>26.8</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>644</td>
<td>19.0</td>
<td>Natural rock cut</td>
</tr>
<tr>
<td>1944-45</td>
<td>568</td>
<td>14.0</td>
<td>Natural rock cut</td>
</tr>
<tr>
<td>1945-46</td>
<td>303</td>
<td>60.2</td>
<td>Large subterranean rock cut</td>
</tr>
<tr>
<td>1945-46</td>
<td>322</td>
<td>44.8</td>
<td>Large subterranean rock cut</td>
</tr>
<tr>
<td>1945-46</td>
<td>278</td>
<td>31.2</td>
<td>Large subterranean rock cut</td>
</tr>
<tr>
<td>1945-46</td>
<td>216</td>
<td>25.8</td>
<td>Natural rock cut + 1 underground chamber</td>
</tr>
<tr>
<td>1945-46</td>
<td>168</td>
<td>21.1</td>
<td>Natural rock cut + 1 underground chamber</td>
</tr>
<tr>
<td>1945-46</td>
<td>189</td>
<td>19.2</td>
<td>Natural rock cut + 1 underground chamber</td>
</tr>
<tr>
<td>1945-46</td>
<td>202</td>
<td>15.5</td>
<td>Natural rock cut + 1 underground chamber</td>
</tr>
<tr>
<td>1944-45</td>
<td>809</td>
<td>37.7</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>263</td>
<td>34.6</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>767</td>
<td>21.1</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>845</td>
<td>20.9</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>812</td>
<td>20.4</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>671</td>
<td>17.6</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>43</td>
<td>16.4</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>719</td>
<td>13.7</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>813</td>
<td>13.3</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>488</td>
<td>12.4</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>768</td>
<td>10.6</td>
<td>Natural rock cut with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>471</td>
<td>80.0</td>
<td>Large subterranean with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>672</td>
<td>43.8</td>
<td>Large subterranean with stairs</td>
</tr>
<tr>
<td>1945-46</td>
<td>45</td>
<td>43.5</td>
<td>Large multi chamber subterranean tomb</td>
</tr>
<tr>
<td>1944-45</td>
<td>665</td>
<td>42.6</td>
<td>Large subterranean with stairs</td>
</tr>
<tr>
<td>1944-45</td>
<td>494</td>
<td>36.5</td>
<td>Large subterranean with stairs</td>
</tr>
<tr>
<td>1946-47</td>
<td>345</td>
<td>28.0</td>
<td>Large subterranean tomb</td>
</tr>
</tbody>
</table>

Table 4.3: Helwan – additional subterranean tombs

**Summary of Results – Helwan**

The results of the volume excavated and mud bricks used were graphed (Graph 4.2). An average height of 2m was assumed for the superstructures of the Helwan tombs based

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585 These tombs were excavated by Macquarie University. The plans of these tombs were provided by the director of excavations, E. C. Köhler.

586 The height of the superstructures was assumed to be 2m.

587 The volume of material expenditure was calculated from the plates published by Z. Saad, as detailed plans were not printed. Saad, *Saqqara and Helwan*; Saad, *Helwan.*
on the capacity of the free standing walls based on the superstructures not being of solid mud brick.588

Graph 4.2. Helwan tombs material expenditure

The results illustrate the amount of material excavated to be fairly constant, with the exception of Tomb 653H.4. The number of mud bricks used, however, appears erratic. The reason being that few tombs have surviving superstructures, so it was not always possible to estimate, through spatial distribution, the amount of mud bricks that may have been used in the superstructure. For graves where later tombs were built over the original tomb, no original ‘footprint’ of the substructure remained. So a different approach was taken in order to estimate the quantity of bricks used as explained below.

For tombs where the superstructure survived, even in a denuded state, or where the remains could be ascertained based on spatial distribution, the ratio of mud bricks used in the superstructure to those used in the substructure was analysed. The results indicated that the substructure constituted, on average, 30% of the total mud bricks used for the tombs with larger substructures; smaller tombs averaging only 3%. Using these percentages, the volume of bricks potentially used to build the superstructures was

588 The superstructure of tomb Op 4/1 had walls which were approximately 0.20m–0.25m thick. Based on robustness calculations, if the wall had no lateral restraint, it was capable of achieving a maximum height of 1.5m. If one end of the wall was restraint, the maximum height would equate to 2.2m (0.20m thick) – 3.0m (0.25m thick).
extrapolated and the results graphed.\textsuperscript{589} Unfortunately, the results remain up and down and the trend towards earlier tombs being larger is unchanged.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{helwan_tombs_material_expenditure_graph.png}
\caption{Helwan tombs material expenditure – with additional extrapolated superstructure mud brick usage}
\end{figure}

\textsuperscript{589} For the purpose of this exercise, the quantity of mud bricks used for the enclosure walls was removed from the calculations to reduce the degree of error from this extrapolation. Furthermore, those tombs, which did not have mud brick in the substructure, were also excluded in the extrapolation.
The total estimated material which went into the construction of each of the Helwan tombs is summarised in Table 4.4.\textsuperscript{590}

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume Excavated (m\textsuperscript{3})</th>
<th>Mud Bricks (units)</th>
<th>Total Area Plastered (m\textsuperscript{2})</th>
<th>Limestone (Tonnes)\textsuperscript{591}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1473H.2</td>
<td>310</td>
<td>177,500</td>
<td>530</td>
<td>-</td>
</tr>
<tr>
<td>185H.4</td>
<td>69</td>
<td>1,700</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>762H.5</td>
<td>64</td>
<td>9,500</td>
<td>23</td>
<td>-</td>
</tr>
<tr>
<td>68H.4</td>
<td>39</td>
<td>7,700</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>9H.1</td>
<td>195</td>
<td>34,100</td>
<td>79</td>
<td>28</td>
</tr>
<tr>
<td>649H.5</td>
<td>139</td>
<td>106,700</td>
<td>330</td>
<td>-</td>
</tr>
<tr>
<td>559H.2</td>
<td>90</td>
<td>14,600</td>
<td>77</td>
<td>1</td>
</tr>
<tr>
<td>1371H.2</td>
<td>191</td>
<td>45,200</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>1502H.2</td>
<td>148</td>
<td>21,300</td>
<td>86</td>
<td>4</td>
</tr>
<tr>
<td>1H.3</td>
<td>365</td>
<td>238,500</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>60H.1</td>
<td>41</td>
<td>54,500</td>
<td>-</td>
<td>26</td>
</tr>
<tr>
<td>701H.3</td>
<td>242</td>
<td>12,600</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>Op1/1</td>
<td>229</td>
<td>145,000</td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td>385H.4</td>
<td>120</td>
<td>11,300</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>426H.4</td>
<td>134</td>
<td>128,300</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>653H.4</td>
<td>1,620</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>680H.5</td>
<td>56</td>
<td>83,600</td>
<td>241</td>
<td>-</td>
</tr>
<tr>
<td>150H.5</td>
<td>115</td>
<td>44,500</td>
<td>88</td>
<td>-</td>
</tr>
<tr>
<td>1H.4</td>
<td>53</td>
<td>24,000</td>
<td>136</td>
<td>-</td>
</tr>
<tr>
<td>407H.4</td>
<td>272</td>
<td>122,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>355H.4</td>
<td>45</td>
<td>8,100</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>480H.3</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>499H.2</td>
<td>65</td>
<td>11,500</td>
<td>34</td>
<td>-</td>
</tr>
<tr>
<td>553H.2</td>
<td>31</td>
<td>7,000</td>
<td>22</td>
<td>-</td>
</tr>
<tr>
<td>505H.4</td>
<td>91</td>
<td>-</td>
<td>147</td>
<td>-</td>
</tr>
<tr>
<td>Op2/1</td>
<td>27</td>
<td>29,000</td>
<td>82</td>
<td>2</td>
</tr>
<tr>
<td>810H.3</td>
<td>54</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>25H.5</td>
<td>73</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Op4/1</td>
<td>112</td>
<td>51,400</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Op4/2</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Op4/15</td>
<td>15</td>
<td>8,000</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>Op4/19</td>
<td>13</td>
<td>26,000</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Op4/35</td>
<td>11</td>
<td>25,200</td>
<td>63</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4.4. Helwan material expenditure summary

**Saqqara versus Helwan**

A comparison of the volume excavated and the quantity of mud bricks used in the construction of the tombs at Saqqara and Helwan provides a clear picture of the scale of the mortuary structures at these two sites (Graph 4.4). Notably, the majority of the Saqqara tombs are enormous, while only a few of the larger Helwan tombs have

\textsuperscript{590} The value of mud bricks is based on original results without the added extrapolated figures presented in Graph 4.3.

\textsuperscript{591} The density of limestone used to convert the volume into tonnes was taken to be on average 2.1 tonnes per m\textsuperscript{3}, Köhler, *Helwan I*, 25.
substructures of comparable size. Furthermore, the use of stone in these early structures is more prolific at Helwan.

Helwan Cemetery Complex
The large majority of the 10,258 Helwan tombs excavated by Zaki Saad were not published. We are, however, fortunate that detailed plans of the site, drawn to scale, and published by Saad, allow an (albeit cursory) analysis of most of the tombs. Of the five plates publish, 4,743 tombs could be established. The volume of material excavated in each of these tombs, regardless of whether it was a pit, mudbrick lined, or subterranean gallery tomb was calculated. However, the depth of the tombs was not recorded, and despite the larger tombs and subterranean tombs undoubtedly being deeper than the smaller pit tombs, for the purposes of this research, the depth of all tombs was calculated at an average depth of 2m. As dating of these tombs was also not possible, the tombs were placed in order of type: pit tomb, mud brick lined, rock cut with underground chamber and subterranean gallery tombs. The results were graphed and the following results produced.

592 Saad, Saqqara and Helwan; Saad, Helwan.
593 Note: These tombs span from the Early Dynastic Dynasty to the Old Kingdom and in some instances tombs of the Middle Kingdom.
594 These graphs can be viewed in larger scale with accompanying data tables in Volume 2, Appendix 3 - CD.
These results show, firstly, that pit tombs cut into the gravel made up the majority of the tombs (also evident by looking at the five plates published by Zaki Saad).\textsuperscript{595} The tombs in each graph were positioned in order of the style of the tomb: pit tombs cut in gravel; pit tombs lined with mud bricks; pit tombs cut in rock with a small subterranean chamber; and subterranean gallery tombs. The graphs show a trend towards the tombs gradually increasing in size. This is one of the reasons that the tombs in the latter part of the graphs are larger.

\textsuperscript{595} Saad, \textit{Saqqara and Helwan}; Saad, \textit{Helwan}.

Graph 4.5. Material expenditure – Helwan (Plate IV) Season 1942
Graph 4.6. Material expenditure – Helwan (Plate IV) Season 1943–1944

Graph 4.7. Material expenditure – Helwan (Plate V) Season 1943–1944
Graph 4.8. Material expenditure – Helwan (Plate I) Season 1944–1945

Graph 4.9. Material expenditure – Helwan (Plate I) Season 1945–1946
Graph 4.10. Material expenditure – Helwan (Plate II) Season 1945–1946

Graph 4.11. Material expenditure – Helwan (Plate III) Season 1945–1946
Graph 4.12. Material expenditure – Helwan (Plate II) Season 1946–1947

Graph 4.13. Material expenditure – Helwan (Plate III) Season 1946–1947
4.2.3 ABYDOS

Leaving the Memphite region and travelling south to Abydos, site of the royal tombs, the material expenditure analysis brought out some interesting results. The royal tombs in Abydos do not compare visually to the grand mud brick mastabas built at Saqqara; this is one of the reasons that some earlier scholars believed the Abydos structures to be cenotaphs rather than tombs in their own right. It is now an accepted fact that the surviving substructures at Abydos are the royal tombs of the 1st Dynasty kings and two 2nd Dynasty kings. The following material expenditure analysis of the royal tombs and funerary enclosures reveals the true scale of construction, not to be overshadowed by the Saqqara structures.

1st Dynasty Royal Tombs

Tomb B0

Tomb B0 measures approximately 5m x 6m at the top and 4m x 5m at the bottom of the pit, excavated to a depth of 1.9m. Approximately 20cm below the desert level on the south of the pit edge, minor traces of wood, brick and plaster were found.

Tomb B1/2

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume Excavated (m³)</th>
<th>Mud Bricks (units)</th>
<th>Plaster (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>34.4</td>
<td>5,800</td>
<td>34.1</td>
</tr>
<tr>
<td>B2</td>
<td>18.6</td>
<td>4,350</td>
<td>24.4</td>
</tr>
</tbody>
</table>

Tomb B7/9

Tomb B7, which Petrie assigned to King Ka, is a pit tomb with sloping sides measuring 6.0m x 3.25m and 2m deep. The tomb was lined with mud brick walls of single brick thickness, approximately 28cm thick. This single skin of brickwork was not sufficient to retain the sandy strata of the excavated pit, resulting in the long walls of the...
tomb overturning due to the pressure of sand behind the wall.\textsuperscript{604} The short walls remained upright due to the (possibly unintentional) effect of the long walls acting as buttress supports. A total of $37\text{m}^3$ of material was excavated to form the pit and approximately 5,700 mud bricks were used to line the tomb. A total face area of $35\text{m}^2$ was plastered. Tomb B9 was of the same construction as B7, requiring $33\text{m}^3$ to be excavated to form the pit, 3,600 mud bricks and a total face area of $34\text{m}^2$ was plastered.

**Tomb B17/18**

Tomb B17/18 was ascribed to Narmer. The burial chamber B18, measured $3.35\text{m} \times 5.6\text{m}$ and $2.8\text{m}$ deep. B17 was the accompanying magazine.\textsuperscript{605} A total material volume of $35\text{m}^2$ and $53\text{m}^2$ was excavated to form the pits of tombs B17 and B18 respectively. The mud brick walls lining both pits equated to 6,740 for B17 and 8,950 for B18, plastered face areas of $21\text{m}^2$ and $50\text{m}^2$ respectively.

**Aha – B10/15/19, 13/14, B16**

Aha was the first king to build a tomb complex of substantial size. The tomb was made up of three independent subterranean chambers and 35 subsidiary chambers. B10 measured $4.56\text{m} \times 7.52\text{m}$ at the base of the pit and $3.4–3.5\text{m}$ deep. Mud brick walls lined the chamber and were battered, the dimensions of which are summarised in Table 4.5.\textsuperscript{606}

<table>
<thead>
<tr>
<th></th>
<th>North Wall</th>
<th>South Wall</th>
<th>East Wall</th>
<th>West Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>B10</td>
<td>1.80–1.85m</td>
<td>(ca. 1.50m)</td>
<td>(1.85–2.10m)</td>
<td>1.70–1.80m</td>
</tr>
<tr>
<td></td>
<td>4–5°</td>
<td>5–7°</td>
<td>5–7°</td>
<td>6–7°</td>
</tr>
<tr>
<td>B15</td>
<td>1.50–1.75m</td>
<td>1.60m</td>
<td>1.90–2.00m</td>
<td>1.90–2.10m</td>
</tr>
<tr>
<td></td>
<td>6–7°</td>
<td>4–5°</td>
<td>9–11°</td>
<td>5–6°</td>
</tr>
<tr>
<td>B19</td>
<td>1.50–1.75m</td>
<td>1.60m</td>
<td>1.60m</td>
<td>1.60–1.70m</td>
</tr>
<tr>
<td></td>
<td>3–5°</td>
<td>5–7°</td>
<td>7–8°</td>
<td>5–6°</td>
</tr>
</tbody>
</table>

Table 4.5. Mud brick wall dimensions and wall batter for Aha tomb chambers B10, B15 and B19\textsuperscript{607}

B15, presumed to be the royal burial chamber, measured $4.52\text{m}–4.57\text{m} \times 7.55\text{m}–7.62\text{m}$ and $3.6\text{m}$ deep.\textsuperscript{608} The thickness of the mud brick walls lining the chamber are presented in Table 4.5. There were postholes on floor of the long walls used to support the timber shrine. In addition, holes for the roofing beams were found 3.8m above floor

\begin{itemize}
  \item Petrie, *Royal Tombs II*, 7.
  \item Engel, *Archéo-Nil* 18, 37.
  \item Kaiser and Dreyer, *MDAIK* 38, 215.
  \item Kaiser and Dreyer, *MDAIK* 38, 215.
  \item Kaiser and Dreyer, *MDAIK* 38, 215.
\end{itemize}
level. The roof of B15 formed a dense sequence of about 20 cross beams, 15–20cm diameter spaced at 15–35cm, placed along the longitudinal wall.\textsuperscript{609}

B19 measured 4.43m–4.51m x 7.48m–7.51m with the mud brick walls being battered in the same manner as the earlier tombs. The chamber was 3.50m–3.60m deep.\textsuperscript{610} Trailing B10, B15 and B19, were a total of 35 subsidiary chambers labelled B13, B14 and B16. The total timber consumed for the roofs of these 35 chambers was estimated to be 346 beams, 15–20cm diameter spaced at 15–35cm.

The postholes within the three chambers, B10, B15 and B19, vary in size. Postholes measured 40cm–50cm in diameter and 90cm–95cm deep; the remains of wooden posts ca. 25cm diameter, were found \textit{in-situ} in B10 and B19. Smaller postholes of 25cm and 40cm–45cm diameter were also found.\textsuperscript{611} The postholes were placed along the perimeter of the chamber meaning their purpose as roof supports would have been superfluous. Petrie suggested the postholes may have been used as backing for a large wooden shrine, and not roof supports.\textsuperscript{612}

The total material expenditure for Aha’s tomb structures was:

<table>
<thead>
<tr>
<th>Aha Tomb Complex</th>
<th>Volume Excavated (m\textsuperscript{3})</th>
<th>Mud Bricks (units)</th>
<th>Plastered Wall Area (m\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>B10, B15, B19</td>
<td>1,075</td>
<td>318,500</td>
<td>270</td>
</tr>
<tr>
<td>B13/14, B16</td>
<td>886</td>
<td>190,200</td>
<td>780</td>
</tr>
<tr>
<td>TOTAL</td>
<td>\textbf{1,961}</td>
<td>\textbf{508,700}</td>
<td>\textbf{1,050}</td>
</tr>
</tbody>
</table>

\textbf{Djer}

Djer chose a grander design for his tomb, the style being markedly different to that of his predecessor, Aha. The tomb increased in size as did the number of subsidiary chambers, with a total of 330 chambers ascribed to Djer.\textsuperscript{613}

Djer’s tomb consisted of an almost square subterranean pit, lined with thick mud brick walls. The excavated pit forming the king’s chamber measured ca. 17m x 18m, with the

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\textsuperscript{609} Kaiser and Dreyer, \textit{MDAIK} 38, 216, 218, Abb 2.

\textsuperscript{610} Kaiser and Dreyer, \textit{MDAIK} 38, 215.

\textsuperscript{611} For full details on positioning of postholes see Kaiser and Dreyer, \textit{MDAIK} 38, 218.

\textsuperscript{612} Petrie, \textit{Royal Tombs II}, 7; Kaiser and Dreyer, \textit{MDAIK} 38, 218.

\textsuperscript{613} Of the 334 chambers, 318 were listed as subsidiary graves and 16 as subsidiary chambers, Engel, \textit{Archéo-Nil} 18, 38. Recent excavations showed that Djer’s tomb had 330, and not 334, subsidiary graves (forthcoming \textit{Rundbrief DAI}, 2012). For consistency, the single term chambers will be used when discussing the burials and chambers surrounding the structures of the tomb complex.
brick walls lining the pit approximately 2.6m thick.\textsuperscript{614} The depth of the chamber was ca. 2.7m.\textsuperscript{615} A large wooden shrine (ca. 10.5m x 8.60m) was supported by mud brick division walls of store chambers, on three sides of the chamber.\textsuperscript{616} Beneath the shrine, the floor consisted of a layer of mud bricks, 7.6cm thick on a sub-base of 12.7cm thick sand. The division brick cell walls had rough unplastered ends with the imprint of wood grain lining the chamber, still visible on the mud mortar adhering to the bricks.\textsuperscript{617}

The total volume excavated to create the substructure of the tomb was 782m\textsuperscript{3} and contained approximately 180,000 mud bricks. The total volume excavated for the 318 subsidiary graves and 16 magazines was 2,400m\textsuperscript{3} equating to approximately 8m\textsuperscript{3} for each chamber. The total number of bricks used to line the 330 chambers was approximately 479,000 or 1,400 per chamber. The quantity of plaster was also substantial with a total face area of 330m\textsuperscript{2} for the main tomb and 3,705m\textsuperscript{2} for the subsidiary chambers.

Whilst the superstructures of royal tombs have not survived, it is probable these tombs were covered over by a tumulus mound (Fig. 4.1). The remains of a tumulus mound was found over the tomb of Djet. The tumulus mound in the reconstruction was shown to be covering the burial chamber, with the subsidiary chambers covered individually. When calculating the quantity of materials consumed, it was assumed that the mound covered the burial chamber but did not extend beyond the thick mud brick retaining walls of the substructure, as evidenced by the tumulus remains found in Djet’s tomb.\textsuperscript{618}

\textsuperscript{614} G. Dreyer, “Abydos/ Umm el-Qaab”, \textit{Rundbrief DAI}, 2006, 13.
\textsuperscript{615} G. Dreyer, “Abydos/ Umm el-Qaab”, \textit{Rundbrief DAI}, 2008, 18.
\textsuperscript{616} Dreyer, \textit{Rundbrief DAI}, 2008, 18.
\textsuperscript{617} ‘...moreover the cast of the grain of the wood could be seen on the mud mortar adhering to the bricks’, Petrie, \textit{Royal Tombs} II, 8.
Fig. 4.1. Proposed tumulus cross-section\textsuperscript{619}

The additional number of bricks consumed by the tumulus mound and mud brick flat plane equated to 99,600 units.\textsuperscript{620} The total surface area to be plastered equalled 364m\textsuperscript{2} and 378m\textsuperscript{3} of sand and rubble filled the mound. Similarly, the mound over the subsidiary chambers consumed 23,000 extra mud bricks, an additional 700m\textsuperscript{2} of wall area was plastered and 350m\textsuperscript{3} of sand and rubble formed the mound.

As discussed above, there were five brick cell walls on the long walls and four on the northern short wall. These contained timber impressions of the column posts forming the timber frame of the timber shrine, which Petrie recorded to measure 5 inches x 9 inches.\textsuperscript{621} The quantity of timber used in building of the frame of the timber shrine was estimated to be approximately 14 post columns, ca. 13cm x 23cm and 2.5m long.\textsuperscript{622} Five beams measuring ca. 30cm x 30cm x 9m placed longitudinally and four transverse beams also 30cm x 30cm, built into the mud brick walls would have acted as supports for the roof of the shrine.\textsuperscript{623} The beams along the perimeter would have totalled ca. 38m

\textsuperscript{619} Based on tomb reconstruction of Qa’a by Engel, \textit{Archéo-Nil} 18, 32–33. Remains of the tumulus placed over the burial chamber were found for the tomb of Djet. The tumulus was below ground level and as such, still considered part of the substructure. Dreyer, \textit{Rundbrief DAI}, 2008, 17–19.

\textsuperscript{620} For the purpose of estimating materials and total construction time, the mound was presumed to cover the burial chamber but not extend beyond the thick mud brick retaining walls of the substructure. The assumptions made in calculating the amount of material consumed to build the mound were that the mud brick ‘Flat Plane’ was 20cm thick (two bricks high) and the mound was filled with sand/rubble and lined with mud bricks.

\textsuperscript{621} ‘The beams on which the wooden planking of the sides rested were 9 x 5 inches’, Petrie, \textit{Royal Tombs} II, 8.

\textsuperscript{622} The beam dimensions have been converted and rounded up for clarity from 12.7cm x 22.5cm.

\textsuperscript{623} This is based on the timber shrine being of similar design to the reconstruction of Den’s shrine. The reason for choosing four transverse beams was due to the four brick cell walls on the north wall. It is
along the external frame of the shrine (adjacent to brick walls) and ca. 30m along the internal frame of the shrine. Additional timber joists placed perpendicular to the brick walls along each post column, equalled 14 in number and were estimated to be 5.1cm x 25.4cm and approximately 2.5m high.

A total of 166 timber planks (23cm x 13cm and approximately 2.5m long) would have been required if the walls of the shrine had been lined with such planks of timber. If the shrine was lined with matting or fabric, the wall area to be covered would equate to approximately 100m². A total of 45 planks (23cm x 13cm thick x 8.6m long) was estimated to be required for the roof and an equal number for the base of the shrine.

The total number of beams required to roof the main tomb was approximately 40 beams of 12–24cm diameter spanning 11.8m, spaced at 15–20cm centres. If timber planks had been placed above the beams a total of 51 planks measuring an assumed 23cm wide x 13cm and 12.8m long, placed side by side, would have been required.

Roofing requirements for the 330 chambers, with an average size of 1.7m x 1.3m, would have equated to approximately 2,000 beams of 15cm diameter placed 10-15cm apart, and 2.0m long, allowing for sufficient overhang.
Djet

The tomb of Djet consisted of a large chamber measuring ca. 9m x 12m and “2.3m to the roof and then 1.1m more to the top of the retaining wall”, bounded by thick brick walls. Brick cell division walls extended out around three sides the chamber to support the timber shrine, similar to Djer’s tomb. A total of 223 subsidiary chambers accompanied the tomb; on the north a line of small tombs about 1.5m deep, and on the south a triple line of tombs of the same depth. These burials were all built of mud brick and coated with mud plaster. The floor was sand, coated with mud.

The total volume excavated for the tomb was 450m³ and contained approximately 121,200 mud bricks – a significant decrease in material expenditure when compared to the tomb of Djer. The remains of a tumulus mound was found over the tomb of Djet. The subsidiary chambers also decreased in size. The total volume excavated for the 223 burials was 970m³. The total number of bricks used was approximately 227,300.

Brick cell walls, built around the burial chamber, and reducing in size to ca. 6m x 9.2m, supported a timber shrine, were faced with plaster and white-washed on both sides. The end of the brick cell division walls were exposed, showing rough brickwork. These cell walls, built after the main brick perimeter walls, were finished and plastered. The recesses were coloured red-pink and after the division walls were built and the walls underwent a second plastering.

Three timber floor beams, part of the frame for the timber shrine, measured 23cm–27.4cm wide and 17.8cm–19cm thick and ca. 6m long. Timber planks were placed on these beam to form the floor of the shrine. The planks measured 5cm – 6cm and been the length of the chamber, ca. 9m long. The timber planks were coated with a layer of mud plaster 1.3cm–1.8cm thick. The floor of the tomb was mud plastered and white-washed and the floor beams had evidently been positioned before the mud floor turned hard, as they were embedded 6.4cm into the floor.

requirements for the roofing of these pit chambers. It is understood by the author that the subsidiary chambers did vary in size, as is clearly evident in the plan of the tomb.

633 Petrie, Royal Tombs I, 8–10, pl. LXI; G. Dreyer, et. al., “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 5./6. Vorbericht”, MDAIK 49(1993), 57.
634 Of the 223 subsidiary chambers, 204 were graves and 19 were magazines, Engel, Archéo-Nil 18, 38.
637 Petrie, Royal Tombs I, 9.
The total area mud-plastered and white-washed equated to 703m$^2$ for the main tomb (allowing for the second plastering) and 2,056m$^2$ for the subsidiary burials. With an average thickness of 1.5cm, a total of 7.2m$^3$ of plaster would have been required for the main tomb and 21m$^3$ for the accompanying subsidiary chambers.

A total of 30 beams would have been required to roof the main chamber. The beams were estimated to be spaced at 27cm centres and were 27cm in diameter and 9.8m long. As with the subsidiary chambers from Djer’s tomb, those accompanying Djet’s tomb were most likely roofed with local timbers. Roofing requirements for the 223 burials, with an average size of 1.6m x 1.5m, would have equated to approximately 1,190 beams of 15cm diameter placed 10–15cm apart, and 2.0m long, allowing for sufficient overhang.

The quantity of timber used to build the timber shrine based on a similar design to that of Den’s tomb, and as assumed for the tomb of Djer as discussed earlier, was as follows. There were six brick division walls on the long walls and four on the northern shorter wall. Impressions of ‘upright timber’ on the end of the mud brick division walls were found. The quantity of timber used in building the frame of the timber shrine was estimated to be approximately 22 post columns, ca. 13cm x 23cm and 2.3m long. Six beams measuring ca. 30cm x 30cm x 12m placed longitudinally and two transverse beams also 30cm x 30cm, built into the mud brick walls would have acted as supports for the roof of the shrine. The beams along the perimeter would have totalled ca. 30m along the external frame of the shrine (adjacent to brick walls) and ca. 22m along the internal frame of the shrine.

The wall area of the shrine equalled 70m$^2$, which had been lined with “upright planks 3.5 inches thick, which stood 3 to 4 inches out from the wall, or from the back of the beams”. This would result in a total of 9cm thick planks x 23cm wide (based on the minimum width of the floor beams provided by Petrie), a total of 123 planks would have been required to line the timber shrine of Djer’s tomb.

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638 The beam dimensions are based on those used on the tomb of Djer as Petrie recorded the thickness of the planks and not beams, which were 3.5 inches thick (10cm), Petrie, *Royal Tombs* I, 8–9.
639 Based on the timber shrine being of similar design to the reconstruction of Den’s shrine, Dreyer, *MDAIK* 54, Abb. 32.
640 Dreyer, *MDAIK* 54, Abb. 31, Abb. 32.
Merneith

Merneith, mother and regent to her son, Den, had a tomb also built at Abydos. The substructure of the tomb measured approximately 16.5m x 14.0m and 2.7m deep.\textsuperscript{642} The excavated pit was lined with thick mud brick retaining walls that were plastered 0.64cm–2.5cm thick. Eight long narrow chambers enclosed the central chamber, reducing the floor space to 6.4m x 9.0m.\textsuperscript{643} The mud brick walls were 1.22m–1.32m thick and the eight narrow chambers measured 1.22m wide x 4.06m–5.46m long and 1.98m deep.\textsuperscript{644} The material excavated to form the substructure equated to 500m\textsuperscript{3}. A total of 281,800 mud bricks were used and 513m\textsuperscript{2} of mud plaster.

Brick pilasters constructed against the plastered walls of the burial chamber suggest they may have been an afterthought.\textsuperscript{645} At the edge of one of the narrow chambers, a cast of plaited palm-leaf matting was left on the mud mortar. Above this level, the bricks were set irregularly, thus revealing the mode of finishing the roof of the tomb.\textsuperscript{646}

Merneith had 49 subsidiary chambers accompany the tomb, which required in total, 326m\textsuperscript{3} of material to be excavated and 122,500 mud bricks. The plastered walls equated to an area of 496m\textsuperscript{2}.

Petrie found a “small piece of wood on the floor” suggesting a timber shrine was also present. The remains of upright posts within pilasters, which Petrie considered to be an “afterthought”, no doubt supported the shrine.

The estimated quantity of timber used to roof the substructure amounted to approximately 41 beams of 27cm diameter and 15m long, spaced at 27cm centres and 231m\textsuperscript{2} of reed matting covering the roof area (16.5m x 14.0m), over which bricks were laid and the sand tumulus placed above to complete the substructure. If planks had been placed over the beams an estimated 52 planks of 27cm x 13cm and 17.5m long positioned side by side would be required.\textsuperscript{647}

\textsuperscript{642} Petrie, Royal Tombs I, 8.
\textsuperscript{643} Petrie, Royal Tombs I, pl. LXI.
\textsuperscript{644} Petrie, Royal Tombs I, 10.
\textsuperscript{645} Petrie, Royal Tombs I, 11.
\textsuperscript{646} Petrie, Royal Tombs I, 11.
\textsuperscript{647} As explained for the tomb of Djer, it is not possible to ascertain if planking was placed over the timber beams.
Roofing requirements for the 49 burials, with an average size of 1.8m x 1.2m, would have equated to approximately 588 beams of 15cm diameter placed side by side, and 2.2m long, allowing for sufficient overhang. Unlike the roof of the main tomb, which was most likely imported cedar from Lebanon, these subsidiary chambers would have been covered with local timbers.

**Den**

Den was the first king of the 1st Dynasty to incorporate a stairway leading to the burial chamber. This development led to the introduction of the portcullis, made of wood for Den’s tomb, and that of his successors. A stone portcullis was not introduced in Abydos until Qaa’s tomb. Den’s high officials, Hemaka (Saqqara Tomb S3035) and Ankh-Ka (Saqqara Tomb S3036), also incorporated stairs leading to the substructure of their tombs, which were blocked off by a stone portcullis. Similarly, the first Dynasty tombs, M06 and M07 of Abu Rawash dated to the time of Den also contained a stone portcullis. Such use may have been the stimulus for the increase in quarry activities and greater use of stone in later times. Whether they built their tombs first – and stairs were subsequently adopted by Den’s builders – is impossible to establish. Also, unique to Den’s tomb was a granite stone floor, where several large slabs of red and black granite were found *in situ*, and some discarded pieces.

The scale of Den’s tomb increased dramatically from that of his predecessors, and even his successors, with the sole exception being Khasekhemwy, last king of the 2nd Dynasty.

The excavated substructure of Den’s tomb measured 23.8m x 14.9m at the top and 7m deep, around which thick mud brick retaining walls lined the pit. Due to the soft *gebel*, the pit was cut with sloping walls. This meant the walls were much thinner at the base compared to the top. The brick chamber was thus reduced to 15.8m x 8.9m.

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648 The use of cedar enabled greater roof distances to be spanned and would have been ideal for the larger main chambers compared with the smaller subsidiary graves, where local timbers would have sufficed.
649 Personal communication, G. Dreyer.
650 Personal communication, Y. Tristant.
654 Dreyer, *MDAIK* 54, 142.
The side chamber internally measured 4.5m x 1.5m. The brick walls were plastered over to a height of 6.6m above the granite floor. The granite base was surrounded on all sides with mud bricks. Dreyer wrote:

According to impressions of wooden beams and posts in the north-eastern corner of this brick-layer, and holes for fixing beams in the western and eastern walls, this chamber contained a large wooden shrine of 24 x 12 x 7 cubits. Remains of reeds show that the walls were covered with matting, supported by a wooden scaffold.

The top of the walls were plastered flat, and a coat of mud plaster was spread out 20cm lower than the walls on the native marl, far beyond the outer rows of subsidiary chambers.

Den’s tomb had 3,008m³ of material excavated and a total of 492,500 mud bricks. A total estimated face area of 1,464m² was plastered. For the roofing beams, the wooden shrine placed within the burial chamber was estimated to have consumed two beams of 19.3m length and 5 beams of 11.4m length, 30cm x 30cm in cross-section. Due to the remains of a beam hole in the north wall, with the lower edge corresponding exactly to the top of the beam holes in the east and west walls, it is likely that over the long pole distances, fixed beams were attached.

Strong external 30cm x 30cm columns of the shrine were approximately 0.75m distance from the walls on the granite floor, only secured in the brick layer embedded woods which were connected to the outer frame for mounting the reed mat covering. The reed matting was estimated to have covered and area of approximately 186m². Similarly, the lining requirements for facing the walls of the timber shrine was

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656 For full details of side chamber see G. Dreyer,“Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 3./4. Vorbericht”, *MDAIK* 46 (1991), 73–78.
657 Dreyer, *MDAIK* 54, 142.
660 The mud brick walls of Den’s burial chamber although quite thick at the top taper toward the bottom of the pit. G. Dreyer, *MDAIK* 54, pl. 9b.
661 Dreyer, *MDAIK* 54, 142–145, Abb. 32.
662 Dreyer, *MDAIK* 54, 142–145, Abb. 32.
estimated to be 148m² of matting or 147 planks measuring an assumed 25cm wide x 7.6cm thick and 4m long.\footnote{663}

From the timber impressions found on the long sides, the position of the external column posts, with alternating narrow and wide intervals, was formulated in the reconstruction. It is conceivable that the posts should form, in addition to their main function, as supports, a type of niche structure of the shrine. The regular structure may not, however, have continued on the narrow side.\footnote{664} The post columns, 28 in total, measuring 30cm x 30cm were estimated to be 4m in height. The beams along the perimeter would have totalled ca. 47m along the external frame of the shrine (adjacent to brick walls) and ca. 38m along the internal frame of the shrine.\footnote{665} Additional timber joists placed perpendicular to the brick walls along each post column, also equalling 28 in number, were estimated to be 7.6cm x 58cm and approximately 4m high.

The roofing over the main chamber was estimated to have consumed 30 beams of 30cm diameter spaced 24cm–30cm apart, and approximately 11m long. Over the roofing beams, a layer of matting was placed before a layer of mud bricks.\footnote{666} The reed matting was estimated to cover an area of 140m² and the mud brick volume to be 10m³ or 4,500 additional mud bricks.\footnote{667}

The staircase leading to the king’s burial chamber was roofed with timber beams, 10cm in diameter, and reed mats and bricks, similar to the main chamber. The entrance of the niche was covered, 4.72m above the floor level, with beams of 15cm diameter.\footnote{668}

Of the 153 subsidiary chambers accompanying the tomb,\footnote{669} a total volume of 1,190m³ of material was excavated, 200,000 mud bricks were used and 2,371m² of area plastered. This equates to 7.7m³ of excavated material and 1,307 mud bricks per grave.

\footnote{663}{The assumed plank dimensions are based on the sizes of planks used as joists found by Petrie during his excavation of the tomb, Petrie, \textit{Royal Tombs} II, 10; The timber shrine, however, may not have been lined with timber at all. Due to lack of evidence it can to be stated definitively that the shrine was lined with timber. Remains of reeds show the walls were covered with matting supported by the timber frame of the shrine, Dreyer, \textit{MDAIK} 54, 166.}
\footnote{664}{Dreyer, \textit{MDAIK} 54, 142–145, Abb. 32.}
\footnote{665}{Dreyer, \textit{MDAIK} 54, Abb. 31.}
\footnote{666}{Whilst no remains of the roof were found, due to the passage of time, the roof reconstruction was assumed to be similar to that found for the tomb of Qa’a. Personal communication, G. Dreyer.}
\footnote{667}{Mud brick size: 24.5cm x 12cm x 7.5cm. Spencer, \textit{Brick Architecture in Ancient Egypt}, 14.}
\footnote{668}{Dreyer, \textit{MDAIK} 54, 146.}
\footnote{669}{The 153 chambers consisted of 142 graves and 11 magazines. Engel, \textit{Archéo-Nil} 18, 38.}
The task of constructing the subsidiary chambers was, in itself, a huge undertaking. Assuming local timbers were used to roof these chambers, a total of 595 beams of 20cm diameter, spaced 10-20cm apart, would have been required.

Anedjib

The tomb of Anedjib was small compared to his predecessors; the excavated pit measured approximately 15.4m x 7.4m and the stairway entrance, descending from the east, measured 5.7m x 4.6m wide. The doorway at the base of the stairs was blocked by planks and bricks. The tomb was accompanied by 65 subsidiary chambers.

The pit was retained with mud brick walls nearly 1.5m thick and separated by a cross-wall to form two chambers. One of the chambers opened from the stairs measuring 7.0m x 4.5m and the smaller chamber, presumably the burial chamber, measured 2.7m x 4.5m. The walls had all been plastered. The floor of the chambers would have been finished with planks of wood laid flat on sand, without any supporting beams as in the earlier tombs. These planks were 5cm thick, and were cut to order before fitting into the tomb, based on the length being too long in several places.

The timber roof was presumably supported by the timber shrine, which in turn was supported by posts. The base of one post remained in place at the N-E corner and measured 10cm x 43cm. Pilasters were not built against these walls. The roof was positioned approximately 1.83m above floor level, the walls were finished up to a height of 1.98m, above which they became rougher and sloping.

The tomb of Anedjib had a total of 320m³ of material excavated to form the substructure, 121,800 mud bricks and 297m² of plastered wall area. A total of 65 subsidiary chambers accompanied this tomb, resulting in an additional 270m³ of material being excavated and 54,050 mud bricks being used. The plastering of the walls equalled a total of 663m² or approximately 9m² per grave.

670 The assumed quantity is based on an overall length of 237m for the combined graves.
671 Petrie, Royal Tombs I, 12.
672 Petrie, Royal Tombs I, 12–13.
673 Petrie, Royal Tombs I, 12. The timber floor planks were most likely part of the timber shrine in the burial chamber. The length of the timbers exceeding the floor plan area suggests that as the timber shrine was built in conjunction with the construction of the mud brick walls based on evidence from other tombs, e.g. Qa’a, where the frame of the shrine is, in parts, embedded into the brickwork and not prefabricated and lowered into place like a timber box.
674 Petrie, Royal Tombs I, 13.
The timber flooring of the main tomb required approximately 20 planks of wood, 50cm wide x 5cm thick and 4.5m long. A total of 18 roofing beams (22cm diameter placed 55cm apart and 5m long) were estimated to have been required to roof the two chambers. Finally, the 65 subsidiary chambers would have required a total of 188 timber beams of 20cm diameter spaced 10-15cm apart.

Semerkhet

The style of the substructure in Semerkhet’s tomb was different to those of his predecessors. The overall tomb, including the surrounding subsidiary chambers that encircled the main chamber, measured ca. 26m x 18m and 4m deep. The burial chamber measured 16.5m x 7.5m and 3.5m deep, with the pit retained by 1.5m thick mud brick walls. The surrounding five chambers were 0.9m–1.2m deep. The burial chamber was entered via a sloping passage, on the northern corner of the tomb, cut into the natural sand.

The timber floor of the shrine placed within the burial chamber consisted of wooden planks acting as ledges, 20cm wide by 25.4cm high forming the ground-plan frame. Petrie found the hieroglyph sign for “north” cut into one of the planks when he excavated the tomb, proving the timber planks had been prepared elsewhere and transported to the site.

Overall, the tomb appears to have been built hastily, with the brick walls being of poor quality and only a few of the subsidiary chambers plastered (and those that were, were

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676 The beam dimensions are those used for the calculations undertaken in Chapter 2, and are based on data from the excavation reports. Because some of the tombs had no recorded data on beam dimensions due to the denuded state of the tomb, averages from tombs where data was available was used.
677 Re-excavation of the tomb of Semerkhet by the German Archaeological Institute found some irregularities with the plans published by Petrie. For example, the whole north area of the tomb published by Petrie is actually far less regular, G. Dreyer, et al. “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 13./14./15. Vorbericht”, *MDAIK* 56 (2000), 119; G. Dreyer, “Report on the 20th campaign of reexamining the royal tombs of Umm el-Qaab at Abydos 2005/2006”, *ASAE* 82 (2008), 50.
678 Engel, *Archéo-Nil* 18, 39.
680 ‘Only in the corner by the entrance was the wooden flooring preserved; several beams and much broken wood was found loose in the rubbish….The floor, where it yet remains, is made like the others; beams, 8 inches and 10 high, form the frame on which the planks of the floor rest on recessed ledges. There has been a wider shallower cutting also at each side of the corner, as if some skin of finer wood had been laid over it.’ Petrie, *Royal Tombs* I, 13, pl. LXVI.
very irregular). Furthermore, the amount of mortar was used sparingly between the brick, and not consistent with other constructions. It is possible the king died earlier than anticipated, requiring the speedy completion of his tomb.\textsuperscript{681}

Semerkhet’s substructure had 750m\(^3\) of material excavated and approximately 287,100 mud bricks were used. The total face area plastered in the main chamber and stairs equated to 403m\(^2\). The 69 subsidiary chambers had a total of 527m\(^2\) plastered, assuming they had all been plastered.\textsuperscript{682} The total volume of material excavated equated to 260m\(^3\), and 72,500 mud bricks were consumed.

There were no signs of holes for roofing beams and no evidence to the level of the roof.\textsuperscript{683} The roofing of the main chamber may have consisted of 65 planks of 25.4cm x 20cm and 8m length over the burial chamber, placed above the supporting beams.\textsuperscript{684} The roofing over the 69 subsidiary chambers would have consisted of approximately 315 beams of 20cm diameter and may have been covered with reeds.\textsuperscript{685} Only sparse remains survive of the roofing beams placed in the north direction.\textsuperscript{686}

Based on the photographic evidence of Petrie’s excavation on the location of the preserved floor of the timber shrine, it would have occupied a floor plan area of ca. 14m x 5m.\textsuperscript{687} The quantity of timber required for the roof of the shrine was thus estimated to equal 20 planks (25.4cm x 10cm thick x 14m long), with an equal number for the base.

The timber used in building the frame of the timber shrine, based on a similar construction to the reconstruction of Den’s shrine,\textsuperscript{688} amounted to one large beam measuring ca. 30cm x 30cm and 16m length placed longitudinally and six transverse beams also 30cm x 30cm and 6m long, embedded into the brickwork to support the shrine. It is possible such beams served to support the roof of the main chamber. The material requirements to line of the shrine with either timber, matting or fabric would have equated to an area of 106m\(^2\). The beams along the perimeter of the shrine would have totalled ca. 38m. The height of the shrine was assumed to be 2.8m, as the depth of

\begin{footnotesize}
\textsuperscript{681} Dreyer, MDAIK 56, 119, 129.
\textsuperscript{682} The use of Taffl as plaster was used in some subsidiary graves, whilst several chambers were never plastered. Dreyer, MDAIK 62, 128.
\textsuperscript{683} Petrie, Royal Tombs I, 13.
\textsuperscript{684} The planks may have been thinner, but the calculations undertaken to determine the roof capacity were based on these dimensions.
\textsuperscript{685} Engel, Archéo-nil 18, 34.
\textsuperscript{686} Dreyer, MDAIK 56, 120.
\textsuperscript{687} Petrie, Royal Tombs I, pl. LXVI. 4.
\textsuperscript{688} Dreyer, MDAIK 54, Abb. 32.
\end{footnotesize}
the burial chamber was 3.5m, making allowances for the roof of the tomb and sand tumulus covering, which was part of the substructure.689

Qa’a

Qa’a was the last king of the 1st Dynasty and his tomb shows a more developed stage than the others.690 The tomb complex occupied an area of approximately 30m x 20m and 4m deep.691 A stairway descended into the tomb, from which four magazines projected out, two to the east and two to the west. The walls of the magazines were thickened, resulting in a wide ledge on the top of the brick walls. These ledges would have served to support the roof. The tomb had a total 39 subsidiary chambers.692

Beyond these magazines was the burial chamber. The measurement of the burial chamber was 10.80m–10.95m x 5.80m and 4m deep to the tumulus.693 The timber shrine consisted of large timber beams forming the frame along the base, 25cm–33cm deep and 22cm wide and recessed, so as to hold in place timber planks for the flooring.694 The large beams also had mortice holes to hold in place vertical posts.695 These vertical posts served to support the timber shrine and act as scaffolding for matting, fabric or leather. The timber shrine was built simultaneously with the mud brick walls meaning the beams forming the frames are embedded in the brickwork.696

Of the tomb’s construction, Petrie wrote:

The whole building is hasty and defective. The bricks were mostly used too new, probably less than one week after being made. Hence the walls have seriously

689 These estimates are all highly speculative based on the reconstruction of shrines of other tombs, namely Den and Qa’a. What can be said however with some certainty is that these timber shrines were complex in construction and would have taken time to integrate with the mud brick structure. This will be discussed in the subsequent chapters.

690 Petrie, Royal Tombs I, 14; E. M. Engel, Das Grab des Qa’a in Umm el-Qa’ab: Architektur und Inventar Dissertation – microfiche (Göttingen, 1997).

691 Engel, Das Grab des Qa’a, 5.

692 The subsidiary chambers consisted of 21 graves and 18 magazines. Engel, Archéo-Nil 18, 39.

693 Engel, Das Grab des Qa’a, 6.

694 Along the inner edges of the mud brick walls squared timber with rectangular cross-section (21cm x 28cm) of varying lengths formed the timber shrine frame. These timbers were to receive on the outer edge with a heel approximately 4cm high, at irregular intervals, rectangular holes (20cm x 12cm x 12cm) behind which slightly offset in pairs, round holes of 5cm diameter were drilled through, presumably to lock the vertical posts in place with wooden pegs. On the north and the centre of the chamber, the remains of a wooden construction were found. For full details see, Engel, Das Grab des Qa’a, 11, Fig 11a–11d.

695 Engel, Das Grab des Qa’a, 79 – 86, Abb. 54, Abb. 55.

696 Engel, Das Grab des Qa’a, 86–87.
collapsed in most of the lesser chambers; only the one great chamber was built of firm well-dried bricks.\(^{697}\)

The roof of the burial chamber consisted of beams approximately 30cm in diameter, orientated in an east-west direction. Imprints show that the beams were spaced 0–0.3m apart.\(^{698}\) The roofs of the magazines and the smaller subsidiary chambers consisted of wooden beams of irregular shape and smaller diameter, quite possibly of local timber.\(^{699}\) The roofing was approximately 0.5m below ground level, above which sand was placed to fill the void, thus forming a subterranean tumulus lined with mud bricks and plastered.\(^{700}\)

The building of this tomb involved 640m\(^3\) of material being excavated to create the main chamber and 844m\(^3\) for the 39 subsidiary chambers. A total of 341,000 mud bricks were consumed in the main tomb and 137,500 in the subsidiary chambers. Likewise, the plastered wall area equalled 303m\(^2\) and 648m\(^2\) respectively.

The roofing for the burial chamber was comprised of 20 beams of ca. 30cm diameter and approximately 6.5m long. It is possible that timber planks were placed above these, and if so, an estimated 22 planks measuring 25cm x 6cm thick and 11m long positioned side by side would have been needed.\(^{701}\) An estimated 64m\(^2\) of reed matting would have been required to cover the roof of the main chamber.

The timber forming the frame along the base measured ca. 25cm–33cm deep and 22cm wide. A total of 102 timber planks, 25cm x 6cm and approximately 5.8m long would have been required if the walls of the shrine had been lined with such planks of timber.\(^{702}\) If the shrine was lined with matting, fabric or leather, however, the wall area to be covered would equate to approximately 120m\(^2\). A total of 98 planks (22cm x

\(^{697}\) Petrie, *Royal Tombs* I, 14–15. The tomb of Qa’a was re-excavated by the German Archaeological Institute, led by Günter Dreyer. It was found to have been built over a series of stages, Dreyer, *MDAIK* 52, 57–66; Engel, *Das Grab des Qa’a*, 76–94.

\(^{698}\) Engel, *Das Grab des Qa’a*, 9, for spacing of beams according to imprints found.

\(^{699}\) Engel, *Archéo-Nil* 18, 32.

\(^{700}\) Engel, *Das Grab des Qa’a*, 11, 84.

\(^{701}\) Engel, *Das Grab des Qa’a*, 85, Abb. 57.

\(^{702}\) Due to archaeological evidence, the lining of the timber shrines is speculative. The shrines were covered at the base, but whether they were covered with wood, matting, fabric, or a combination of these is inconclusive for most of these tombs, as will be presented. Personal communication based on the tomb of Qa’a, E-M. Engel.
13cm thick x 5.8m long) was estimated to be required for the roof and base of the shrine.

The roofing for the subsidiary chambers was estimated to have required approximately 213 beams of 20cm diameter and of lengths varying to suit the size of the chambers. These beams would have been spaced approximately 20cm apart. These beams would have been sourced from local timbers; the roofing of the royal chamber would have been the only roof made from imported cedar.703

2nd Dynasty Royal Tombs

Peribsen

The 2nd Dynasty kings chose to be buried at Saqqara, presumably to be closer to the centre of political power.705 The last two kings broke with tradition and returned to Abydos to be buried.

The design of Peribsen’s tomb, however, was different when compared with those of his 1st Dynasty predecessors. The tomb maintained the same series of small cells separated by mud brick walls, but in place of a central wooden chamber, a brick chamber and a free passage which communicated with the cells was built around it. The overall excavated pit was 18.0m x 15.0m and 2.5m deep.706 The middle encirclement of which brick walls projected out on the east and west sides, measured 13.0m x 9.85m, the central chamber measured 7.80m x 4.15m.707 Peribsen’s tomb had 660m³ excavated to form the substructure, and 171,000 mud bricks with a total face area of 590m² would have been plastered.

Khasekhemwy

The last king of the 2nd Dynasty, Khasekhemwy, built a massive mud brick tomb that differed greatly from his predecessors. It was first excavated and recorded by Petrie in

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703 Engel, Archéo-Nil 18, 32.  
704 Unlike some of the earlier tombs built by his predecessor, Peribsen’s tomb never underwent different building phases but was built in one stage. Also, due to the bad quality of the plastering, the tomb appears to have been built hastily, Dreyer, MDAIK 62, 98–102.  
705 Personal communication with E. C. Köhler.  
707 Dreyer, MDAIK 62, 99.
the early 1900s\textsuperscript{708} and most recently, the German Archaeological Institute’s excavation team led by Günter Dreyer re-excavated a number of the royal tombs at Abydos, including that of Khasekhemwy.\textsuperscript{709} Dreyer’s revised plan of the tomb documented various building stages and new details of the stone built burial chamber.\textsuperscript{710} During the final excavation season, Dreyer and his team discovered the tomb pit extended a further 28m beyond the entrance to the south.\textsuperscript{711}

The whole structure was built of mud bricks, measuring 68m long and 12m wide in the middle, over which a massive sand tumulus was placed, measuring approximately 35m.\textsuperscript{712} Some of the brick walls had collapsed or were crushed due to the enormous weight of the sand above. Petrie first wrote that the walls had collapsed due to the use of fresh bricks,\textsuperscript{713} however, it has since been suggested by Dreyer that the “collapse must have been caused instead by an extra pressure from above the middle chambers, most probably from an artificial mound above desert level of the existing 5m of sand filling of the pit”.\textsuperscript{714}

The central chamber was dug to a depth of 1.8m and was lined and paved with limestone blocks. The chamber measured 5.25m x 3.20m, however, the brick walls were 2.3m high.\textsuperscript{715} The stone lined chamber may have been roofed with small stone slabs, resting on the timber shrine in the chamber.\textsuperscript{716} The sand tumulus above Khasekhemwy’s tomb may also have been lined with limestone slabs.\textsuperscript{717}

The surface of the stone chamber was smoothed with a coating of a thin layer of fine grained plaster; red vertical paint marks found particularly on the east wall with some traces on the floor, most likely transferred from the timber shrine. A wooden shrine, 2.65m x 4.70m and presumably 1.5m high was placed in this stone chamber.\textsuperscript{718}

\textsuperscript{708} Although it should be noted that Amélineau did excavate Khasekhemwy’s tomb, it was Petrie who first published it, Petrie, \textit{Royal Tombs} II, 13.
\textsuperscript{710} Dreyer, \textit{MDAIK} 59, 67–138.
\textsuperscript{711} Dreyer, \textit{MDAIK} 62, 111, 128.
\textsuperscript{712} Dreyer, \textit{MDAIK} 59, 110; Fig. 17.
\textsuperscript{713} Petrie, \textit{Royal Tombs} II, 12.
\textsuperscript{714} Dreyer, \textit{MDAIK} 59, 138.
\textsuperscript{715} Dreyer, \textit{MDAIK} 59, 138.
\textsuperscript{716} Dreyer, \textit{MDAIK} 59, 128.
\textsuperscript{717} Dreyer, \textit{MDAIK} 59, 110; Fig. 17.
\textsuperscript{718} Dreyer, \textit{MDAIK} 59, 108.
The chambers had the remains of postholes on the top of the walls where wooden roof beams were lodged into the mud plaster.\textsuperscript{719} The holes were small in diameter, 10cm–20cm and spaced at a distance of 25cm. Generally, the beam impressions showed a small diameter next to a large diameter suggesting that tapering branches had been used.\textsuperscript{720} Based on the reconstruction of the roof,\textsuperscript{721} and using beams of 20cm diameter\textsuperscript{722} spaced 25cm apart to estimate the quantity consumed, a total of approximately 890 beams (average 2m length), would have been required to cover the 58 chambers and corridors of Khasekhemwy’s tomb, as well as 22 beams of approximately 5.6m length for the burial chamber.

The burial chamber and subsidiary chambers of Khasekhemwy’s tomb lie 3.6m from floor level to the top of the mud brick walls. This means the substructure required 4,536m\textsuperscript{3} of material to be excavated in order to create the substructure. However, from floor level to desert ground level, the total depth is 13m,\textsuperscript{723} meaning 24,900m\textsuperscript{3} of sand may have been removed. A total of 528,600 mud bricks were used and 2,460m\textsuperscript{2} of wall face area was plastered. The stone used in the central chamber equated to 34 tonnes.

The quantity of mud bricks may be seen to be rather low compared with the structures built at Saqqara. The royal tombs at Abydos did not have large mud brick superstructures compared to those built in Saqqara. Instead, a tumulus mound was built over the substructure, as discussed earlier. The role of royal superstructures was to be assumed by the funerary enclosures built approximately 2km north of the tombs.

\textit{Funerary Enclosures}\textsuperscript{724}

The quantity of mud bricks calculated for each of the funerary enclosures assumes the structures were 5m high, with the exception of Khasekhemwy, whose structure has survived to its original height of 11m. Five meters was chosen due to the possible conservatism employed by the builders of Khasekhemwy’s structure; having 5m thick walls but built to a height of 11m, the walls of the structures of his predecessors being

\textsuperscript{719} G. Dreyer, “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 13./14./15. Vorbericht”, \textit{MDAIK} 56, pl. 14c.
\textsuperscript{720} Dreyer, \textit{MDAIK} 59, 112.
\textsuperscript{721} Dreyer, \textit{MDAIK} 59, 113; Fig. 18 (b).
\textsuperscript{722} The timber beam would have been 20cm on one end tapering down to 10cm on the other end.
\textsuperscript{723} Dreyer, \textit{MDAIK} 59, 111, Fig. 17.
\textsuperscript{724} See Volume 2, Appendix B, for funerary enclosure plans. (Figure B1.11 to Figure B1.17)
Ist Dynasty Funerary Enclosures

Aha

Three funerary enclosures have been attributed to Aha, each of a different size. The three enclosures had individual subsidiary chambers surrounding the four sides of each enclosure. The largest enclosure measured 33m x 22m and the two smaller enclosures were almost equal in size, measuring 17m x 12m and 15.7m x 10.5m. The exterior walls had palace façade panelling; a simple niching pattern ran along the northwest, southwest and southeast walls, and a complex niching pattern in the southeast wall of the largest structure. A low bench ran along the entire wall, and a circular feature built of unshaped limestone rocks covered with mud has been reconstructed to have been placed in each of the corners of the enclosures.

The largest of the three funerary enclosures had six subsidiary chambers, two on each side of the long walls, and one on each side of the short walls. The two smaller enclosures had one grave on each side, with the exception being the side where the two structures were parallel to each other; in this case, only one grave had been built. Within the enclosures, cult chapels that consisted of three rooms with white-wash plastered walls existed.

Despite the small size of each of the three individual funerary enclosures Aha built, the combined total number of bricks used equated to 1,323,300 mud bricks and 1,645m² of plaster, assuming the structures were 5m high. The accompanying subsidiary chambers had a combined 35,600 mud bricks. Roofing of the subsidiary chambers consisted of

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725 It should be noted that the thickness of the walls of the funerary enclosures would have enabled these structures to be built higher than this, based on robustness calculations. This height was chosen based on the assumption that the kings would want to build their superstructures higher than those at Saqqara (assumed to be 4m). It has been suggested that the height of Djer’s funerary enclosure may have been built to a height of 8m–9m; see D. O’Connor “New Funerary Enclosures (Talberzirke) of the Early Dynastic period at Abydos”, JARCE 26 (1989), 74. For the purposes of calculating the quantity of mud bricks consumed and the labour subsequently expended in the construction of these structures, all funerary enclosures, with the exception of Khasekhemwy’s, was assumed to have been built to 5m for the reasons mentioned above.


727 Bestock, Archéo-Nil 18, 48.

728 Bestock, Archéo-Nil 18, 48–49.

729 Bestock, Archéo-Nil 18, 49.
wooden beams topped with reed matting.\textsuperscript{730} The total timber consumed for the roofs of these 13 chambers was estimated to be 143 beams, 15–20cm diameter spaced at 15–20cm.

**Djer**

The funerary enclosure ascribed to Djer, lying east of Peribsen’s structure, measured 53.8m x 96.2m.\textsuperscript{731} The northwest and southwest walls had simple niching, the northeast wall, facing the cultivation, exhibited a pattern of deep niches between a regular number of shallow niches. There were two gateways, one in the east and one in the north, with the eastern gateway similar to that of the large Aha enclosure. Another common feature was a continuous bench that ran along the exterior base of the walls. The overall width of the wall and bench was 3.25m. The enclosure was surrounded on all four sides by 269 subsidiary chambers. Unlike those around Aha’s enclosure, which were constructed as individual pit chambers, the chambers surrounding Djer’s enclosure were built by excavating long trenches, and lined with mud brick retaining walls. The chambers were finally subdivided by mud brick cross-walls.\textsuperscript{732}

Djer’s funerary enclosure consumed a total of 2,144,300 bricks based on a 5m high structure plus 268,700 bricks for the subsidiary chambers. The plastered walls equated to 3,380m\textsuperscript{2} for the main structure and 893m\textsuperscript{2} for the surrounding chambers. Roofing of the 269 subsidiary chambers, with an average requirement of ten beams per chamber, would have equated to approximately 2,690 beams of 15cm diameter placed 10-20cm apart, and 2.0m long, allowing for sufficient overhang.

**Djet**

No structural remains of a funerary enclosure have been found belonging to Djet, although, based on the surviving 154 subsidiary chambers forming a rectangular frame, the size of the funerary structure can be extrapolated. Based on the size of the rectangle formed by these chambers, the size of Djer’s funerary enclosure would have been approximately 90.0m x 47.5m.\textsuperscript{733}

\textsuperscript{730} Bestock, *Archéo-Nil* 50.  
\textsuperscript{732} Bestock, *Archéo-Nil* 18, 51–52.  
\textsuperscript{733} Bestock, *Archéo-Nil* 18, 52.
Djet built a smaller structure, using only 1,979,700 mud bricks with 3,124m² of wall area plastered. An additional 110,200 mud bricks were used in the construction of the subsidiary chambers. The wall area of the 154 chambers equalled 612m² for plastering. Roofing of the 154 subsidiary chambers, was estimated to require 1,540 beams of 15cm diameter placed 10-20cm apart.

**Merneith**

Merneith built a smaller enclosure to that of her predecessor, measuring approximately 66.5m x 25.5m, with walls 1.8m thick and having a regular simple niching. On the exterior, a low bench ran only one brick course high and 45cm deep. A total of 79 subsidiary chambers were found on three sides of the enclosure, however, due to the heavy disturbance of the area, it is quite possible that many more have been destroyed.⁷³⁴ Of the surviving subsidiary chambers, and assuming a height of 5m for the funerary enclosure, a total of 63,900 and 1,152,900 mud bricks would have been used respectively. The plastered walls equated to 305m² for the chambers and 2,160m² for the enclosure. Roofing of the 79 subsidiary chambers, was estimated to require 790 beams.

**Den**

No funerary enclosure has yet been found which can be attributed to Den.

**Unidentified Funerary Enclosures**

Two unidentified funerary enclosures, Unidentified 1 and Western Mastaba which are not associated with inscriptions bearing royal names, are probably from the 1st Dynasty. The first measures approximately 67.0m x 37.5m, has a bench running along the exterior wall, and a simple niche palace façade panelling. The overall wall thickness including the bench measures 3.2m. The Western Mastaba measures 69.2m x 30.7m and also has a bench running along the four sides. The niche pattern is similar to the other known enclosures.⁷³⁵

The total number of bricks used for the Unidentified 1 and Western Mastaba structures equated to 1.22 million and 1.93 million, respectively. The plastered wall areas likewise equalled 2,400m² and 2,311m².

Lying between the Western Mastaba and Khasekhemwy’s funerary enclosures are 14 boat graves. The boats were encased in mud brick thus forming superstructures, each running parallel to the other.\(^{736}\) A total of 350,560 mud bricks were used and \(83\text{m}^2\) of plaster.

**2\(^{nd}\) Dynasty Funerary Enclosures**

The walls of the 2\(^{nd}\) Dynasty funerary enclosures had neither benches nor the low circular features on the four corners, as seen in some of the 1\(^{st}\) Dynasty structures. Furthermore, the northern gateways of the 2\(^{nd}\) Dynasty enclosures were more elaborately built than those of the 1\(^{st}\) Dynasty and were not bricked up. No subsidiary chambers were associated with these later enclosures.\(^{737}\)

**Peribsen**

Peribsen’s enclosure measured 108m x 55m and had the thinnest walls of any known enclosure, measuring only 1.5m thick. Robustness calculations, however, show that walls 1.5m thick would have enabled this structure to achieve a maximum height of 9.2m. Whether this funerary enclosure was built to this great height, one can only speculate. Assuming the height of the funerary enclosure was 5m, a total of 1,033,500 bricks would have been required.\(^{738}\)

A chapel was built in the interior eastern corner and measured 12.3m x 9.5m. It had three rooms consistent with 1\(^{st}\) Dynasty funerary enclosures.\(^{739}\)

**Khasekhemwy**

The final enclosure built at Abydos was constructed by Khasekhemwy, the last king of the 2\(^{nd}\) Dynasty.\(^{740}\) Known less formally as the Shunet ez-Zebib, it is the only funerary

\(^{736}\) Bestock, *Archéo-Nil* 18, 55.

\(^{737}\) Bestock, *Archéo-Nil* 18, 56.

\(^{738}\) A 9.2m high mud brick structure would have consumed a total of 2.8 million bricks.

\(^{739}\) The estimated number of mud bricks includes those used in the chapel, Bestock, *Archéo-Nil* 18, 56.

\(^{740}\) Khasekhemwy had previously built a large mud brick enclosure at Hierakonpolis that measured 64.4m x 74.7m and had a large gateway at the southern end of the east wall. The structure survives to a height of approximately 9m, although was suggested that it most likely lost a 1m through weathering The bricks in the first phase where slightly thinner than those of the second phase, measuring on average 26.5cm x 12.5cm x 6.75cm and those of the second phase measuring 26.5cm x 12.5cm x 8.75cm. Friedman, R. F. “New Observations on the Fort at Hierakonpolis” in Hawass, Z. H. and J. Richards (eds.), *The Archaeology and Art of Ancient Egypt. Essays in Honor of David B. O’Connor.* ASAE 36. Cairo: 309–336; J. E. Quibell, and F. W. Green, *Hierakonpolis* II (London, 1902), 20. This structure at
The enclosure still standing to its original full height of nearly 11m. The walls are approximately 5.5m thick at the base and taper gently towards the top. The enclosure measured 126m x 65m with an eastern gateway. The exterior of the walls were decorated with the regular pattern of vertical niches, and coated with a layer of mud plaster and white-wash. Outside the main wall, a lower perimeter wall existed. This wall was unique to Khasekhemwy’s enclosure, measuring 137m x 78m and 2.6m thick at the base. The cult chapel, built within the enclosure, also of a grander scale than those of the earlier funerary enclosures, had at least nine chambers.

The enormity of this construction can be discerned from the size of the structure described above. And the material expenditure that would have been required in such a large scale project leaves no doubt as to the skill these early builders possessed, not only from an engineering perspective, but also from a project management perspective. The funerary enclosure consumed a total of 10.2 million mud bricks and 9,860m² of plaster. This would have required a very well organised crew of workers for making and transporting the bricks, ensuring sufficient water for the mortar and an able brick laying crew. The labour force will be reviewed in the subsequent chapters.

Summary of Results – Abydos

The following three graphs summarise:

1. The volume of material excavated to create the substructure of the royal tombs, splitting the main tombs and the subsidiary chambers in order to determine the effort afforded to each (Graph 4.14).
2. The total number of bricks used, once again dividing the quantity consumed by the main tomb and those of the subsidiary chambers (Graph 4.15).
3. The total number of bricks for all three mortuary structures: tombs, subsidiary chambers and funerary enclosures (Graph 4.16).

These graphs illustrate the following:

10m high would have consumed approximately 4.8 million bricks as calculated by the author (or 12,373m³). The excavators estimated a total of 4 million bricks, (using average brick size 25 x 13 x 8.5cm) – see R. Jaeschke, “Fortifications”, Nekhen News Volume 17 (2005), 23–25; N. Hampson and R. Friedman, “Mapping the Fort and More”, Nekhen News Volume 12 (2000), 20–21.

741 Bestock, Archéo-Nil 18, 57.
742 Bestock, Archéo-Nil 18, 57.
1. **Graph 4.14 - Volume of material excavated.** With the exception of Khasekhemwy, Den’s tomb was the largest, perhaps because he chose to transfer a large number of resources which had previously been directed at the subsidiary chambers into building his own tomb. If one looks at the resource distribution between tombs and subsidiary chambers for Aha, Djer and Djet, resources are clearly focused on the subsidiary chambers, rather than the kings’ tombs. Although the 1st Dynasty tombs of Den’s predecessors where significantly smaller in scale, the trend of focusing resources on the tombs continued. Even at the tomb of Qa’a, which indicates there was a 50% distribution of resources between the tombs and graves, it is possible that the majority of the ‘graves’ may have in fact been chambers for the king’s use.

The resource distribution for the 2nd Dynasty tombs of Peribsen and Khasekhemwy were shown to have no subsidiary chambers. The various chambers constructed within the tomb were part of the main structure, therefore no distinction was made.

2. **Graph 4.15 – Quantity of mud brick units.** The total number of bricks used to build the tombs, excluding the funerary enclosures, highlights the large scale of Den’s tomb with the exception of Khasekhemwy. Obviously, Den’s reign must have seen Egypt experience a period of wealth, evidenced by both the king’s own tomb, and those of his officials discussed earlier.743

3. **Graph 4.16a – Total quantity of mud brick units.** The additional materials used in constructing the funerary enclosures emphasise the huge scale of Khasekhemwy’s funerary enclosure, dwarfing all other structures.

Unfortunately, no funerary enclosure has yet been found belonging to Den. Presuming his funerary enclosure was the same size, if not larger than that of Djer, his mud brick consumption would have outstripped his 1st Dynasty predecessors (Graph 4.16b).744 The size of tombs built by Den’s high officials at Saqqara indicate that this was an affluent period, as the sheer volume of materials and labour required to erect such elaborate structures would have been a considerable economic drain to the society. Perhaps this is why the later kings of the 1st Dynasty chose, or more

743 Tombs ascribed to the reign of Den include S3507, S3506, and those of Hemaka (S3035) and Anhk-Ka (S3036).
744 O’Connor, *JARCE* 26, 59.
likely were driven, to down-size their building activities, as seen in the reduced size of some of the later 1st Dynasty tombs at Saqqara.

By the time of Khasekhemwy, however, the economic stress must have eased. Khasekhemwy’s mud brick structures consisted of the enclosure he built at Hierakonpolis, his tomb at Abydos and the accompanying funerary enclosure at Abydos. These structures together would have consumed a total of 15.2 million bricks. This, of course, excludes any other building projects he may have initiated such as temples and palaces.

Graph 4.14. Volume excavated – Abydos tombs
Graph 4.15. Mud bricks used – Abydos tombs excluding funerary enclosures

Graph 4.16a. Mud bricks used – Abydos tombs and funerary enclosures
Graph 4.16b. Mud bricks used – Abydos tombs and funerary enclosures (with assumed funerary enclosure for Den)
The total estimated material used in the construction of the royal tombs at Abydos is summarised in tables below.

<table>
<thead>
<tr>
<th>Tomb - Substructure</th>
<th>Subsidiary Graves/ Chambers – Substructures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tombs</td>
<td>Vol Excavated (m³)</td>
</tr>
<tr>
<td>B1</td>
<td>34.4</td>
</tr>
<tr>
<td>B2</td>
<td>18.6</td>
</tr>
<tr>
<td>B7</td>
<td>37</td>
</tr>
<tr>
<td>B9</td>
<td>33</td>
</tr>
<tr>
<td>B17</td>
<td>35</td>
</tr>
<tr>
<td>B18</td>
<td>53</td>
</tr>
<tr>
<td>Aha B10/ B15/B19 Subsidiary Chambers B13/14 B16</td>
<td>1,075</td>
</tr>
<tr>
<td>Djer</td>
<td>782</td>
</tr>
<tr>
<td>Djet</td>
<td>450</td>
</tr>
<tr>
<td>Merneith</td>
<td>500</td>
</tr>
<tr>
<td>Den</td>
<td>3,008</td>
</tr>
<tr>
<td>Anedjib</td>
<td>320</td>
</tr>
<tr>
<td>Semerkhet</td>
<td>750</td>
</tr>
<tr>
<td>Qa’a</td>
<td>640</td>
</tr>
<tr>
<td>Peribsen</td>
<td>660</td>
</tr>
<tr>
<td>Khasekhemwy</td>
<td>4540 / 24900</td>
</tr>
</tbody>
</table>

Table 4.6. Material expenditure total – Abydos tombs

<table>
<thead>
<tr>
<th>Funerary Enclosures</th>
<th>Tomb</th>
<th>Subsidiary Chambers</th>
<th>Boat Grave</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mud Bricks</td>
<td>Plaster (m²)</td>
<td>Number</td>
</tr>
<tr>
<td>Aha</td>
<td>1,323,300</td>
<td>1,645</td>
<td>35,600</td>
</tr>
<tr>
<td>Djer</td>
<td>2,144,300</td>
<td>3,380</td>
<td>269</td>
</tr>
<tr>
<td>Djet</td>
<td>1,979,700</td>
<td>3,124</td>
<td>154</td>
</tr>
<tr>
<td>Merneith</td>
<td>1,152,900</td>
<td>2,160</td>
<td>79</td>
</tr>
<tr>
<td>Unidentified 1</td>
<td>1,220,000</td>
<td>2,400</td>
<td>–</td>
</tr>
<tr>
<td>Western Mastaba</td>
<td>1,933,600</td>
<td>2,311</td>
<td>–</td>
</tr>
<tr>
<td>Peribsen</td>
<td>1,033,500</td>
<td>3,366</td>
<td>–</td>
</tr>
<tr>
<td>Khasekhemwy</td>
<td>10,200,330</td>
<td>9,860</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 4.7. Material expenditure summary – Abydos funerary enclosures

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745 The funerary enclosure consumed approximately 1,583,000 mud bricks, and the boat graves an estimated 350,600.
Abydos versus Saqqara

For clarity, the results discussed below have been separated into the volume excavated and the number of mud bricks used.

The total volume excavated for the tombs at Abydos far exceeded those of Saqqara. When the number of mud bricks used for the structures at Abydos and Saqqara were combined, the graphed results show the material expended for the tombs and funerary enclosures at Abydos to have exceeded those of the Saqqara tombs, with the notable exceptions of Saqqara tombs S3035 and S3036, both of which belonged to high ranking officials during Den’s reign. Overall, it would appear the kings were asserting their position and importance through the size of their mortuary structures.

Based on the surviving funerary enclosure belonging to Khasekhemwy, the structures would have been imposing. However, the modest tomb superstructures, which may have served religious purposes, may simply have existed because of the accompanying funerary enclosures, and as such, the tombs should not be looked at in isolation when analysing the mortuary complex of the kings.

Graph 4.17. Material expenditure comparison – Abydos vs. Saqqara (volume excavated)

746 The significance of this has already been discussed.
747 Engel, Archéo-Nil 18, 33, 37.
748 For clarity, the smaller Abydos tombs preceding the tomb of Aha were removed.
Graph 4.18. Material expenditure comparison – Abydos vs. Saqqara (mud bricks)
4.2.4 NAGA-ED-DER

The site of Naga-ed-Der lies on the east bank of the Nile near Abydos, opposite the modern town of Girga. Tombs from the 1st and 2nd Dynasties were found in Cemetery N1500 and N3000. These cemeteries would have served one or more towns in the region of Abydos. Remains of superstructures showed they were rectangular and built of mud brick walls, the interiors filled with gravel, rubble, sand or mud bricks. In some cases enclosure walls were found with the superstructure. The majority of the tombs were small mud brick pit tombs, the earliest and largest mastabas had niched panelled façades on at least their western (valley facing) and southern sides. The back panels of some niches were painted red.

The substructures were either roofed with timber in the conventional way, or, had vaults made of mud brick. Some of the burial chambers were accessed by a ramp or stairway, which was sealed with mud brick and occasionally, large limestone slabs. Superstructure and substructure walls were often coated with mud plaster over which a layer of white gypsum plaster was sometimes applied.

The volume of excavated material and the number of mud bricks used was calculated before the results were tabulated and graphed. The results show an undulating pattern of relatively large tombs being built during the early and middle part of the 1st Dynasty, before the size of tombs dramatically decreased. Then, towards the end 2nd Dynasty, larger tombs were built again before reducing in size at the end of the 2nd Dynasty.

In general, the tombs from Cemetery N1500 were small compared to those from Saqqara and Abydos, but larger than those at Helwan, with the exception of a few of the larger Helwan tombs. However, the tombs from Cemetery N3000 were all relatively small, with average volumes excavated to form the substructures only reaching 20m$^3$ and the largest tomb not exceeding 65m$^3$.

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749 See Volume 2, Appendix D, for tomb plans and sections. (Figure D1.1 to Figure D1.3)
750 G. A. Reisner, *The Early Dynastic Cemeteries of Naga-ed- Dêr. Part I* (Leipzig, 1908). Tombs dated to the 2nd and 3rd Dynasty were found in Cemetery N3000 and NS3500.
4.2.5 ABU RAWASH

Abu Rawash, located 9km north of Giza, is the site of a number of small pit tombs and large mud brick mastaba tombs with superstructure and subterranean chambers. Some of the larger tombs had accompanying subsidiary graves. The site of the larger tombs was first excavated by L. P. Montet who located 14 tombs dated to the 1st Dynasty and

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755 See Volume 2, Appendix D, for tomb plans and sections. (Figure D1.4 to Figure D1.5)
four dated to the 4th Dynasty. His work was continued by Klasens, who discovered an additional seven mastabas, bringing the total number of structures dated to the 1st Dynasty to 21. Over half a century after Klasen, the site is being re-examined by the French Institute of Oriental Archaeology in Cairo.

**M01**

Tomb M01 consisted of a large mud brick mastaba with palace façade panelling made up of single size niches, about 30cm wide and 20cm deep, on all four sides. The superstructure measured approximately 16.35m x 7.8m. The interior of the superstructure had four chambers, a large chamber measuring approximately 5.55m x 7.58m and three smaller chambers. The walls were originally coated with mud plaster and wooden planks as traces of the grain were visible on the mud plaster. A staircase led to the subterranean burial chamber.

Subsidiary graves flanked the western side of the superstructure. Surrounding the superstructure and subsidiary graves was an enclosure wall with a unique feature on the northwest corner. An oval structure also built of mud bricks formed a structure akin to a corner tower.

The total volume excavated to form the stairs and subterranean chamber equated to 47m². The quantity of mud bricks used, assuming the superstructure reached a height of 4m and the enclosure wall at 1.5m, equated to 162,500 units. The total face area plastered equalled 491m² for the enclosure wall, external faces of the niched mastaba and the internal walls of the chambers. The mud packed floor around the superstructure equalled 15m². The pits of the five subsidiary graves would have seen a total of 7m³ of excavated material and 3,000 mud bricks.

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756 P. Montet, “Tombeaux de la 1re et de la IVe dynasties à Abou-Roach”, *Kêmi* 7 (1938), 11–69.
759 Montet, *Kêmi* 7, Plate II.
760 Tristant, *Archéo-Nil* 18, 137.
761 The size of the mud bricks was assumed to be 23cm x 12cm x 7cm. The height of the superstructures at Abu Rawash was assumed to be the same as those at Saqqara, 4m.
M02
Tomb M02 had the same niche pattern on the north face as M01, and a slightly more elaborate niche pattern on the east wall. There was also a low bench that ran along the outside of the niched mastaba. The plans published by Montet showed details of the mastaba on the northeast corner only, and remains of an enclosure wall on the southwest corner. The interior of the mastaba had one large chamber. The mastaba measured 12.8m x 5.9m and the chamber 8.05m x 3.0m, according to the published plan dimensions. A 5.8m deep pit running the 3.0m length of the chamber led to a subterranean burial chamber.

The volume excavated to form the pit and burial chamber equalled 50m³ and a total of 140,200 mud bricks were used. The mud packed floor around the superstructure equated to 32m² and the plastered walls of the mud brick structures, 236m².

M03
Tomb M03 was a subterranean tomb with a series of chambers. No superstructure was evident in the published plans. A total of 106m³ of material was excavated to form the subterranean chambers.

M04
Due to the denuded state of the structure, insufficient data was available to calculate the material used with the exception of the volume excavated; this equated to 83m³.

M06
Tomb M06 had a niched superstructure, and the substructure was comprised of a large pit and two subterranean chambers. The volume excavated equalled 65m³. Assuming a niched mastaba similar to M01, and extrapolating the measurements from the surviving sections of walls, the total number of mud bricks would have equated to approximately 95,000 units, assuming a height of 4m for the superstructure.

762 Montet, Kêmi 7, pl. II.
763 Montet, Kêmi 7, pl. III.
764 Montet, Kêmi 7, pl. IV.
765 Montet, Kêmi 7, pl. IV.
M07

M07 was the largest of the tombs found at Abu Rawash. The mud brick mastaba had elaborate niches on all four sides, although, due to the denuded state, only the east and west walls survived. The niched walls were coated with mud plaster painted white, with traces of red paint in the upper parts of the walls and black on the bases.\(^{766}\) An enclosure wall surrounded the superstructure. The interior walls of the superstructure were plain with pilasters on all sides. In the central part, a pit was cut measuring 1.7m wide × 2.3m long and 4m deep. The bottom of the pit was sloped, leading to the subterranean burial chamber that measured 3m wide × 4.4m long and 2m high. The chamber was 5.5m below ground level. Access to the burial chamber was blocked by a stone portcullis. The enclosure wall was estimated to measure 29m × 18m, the niched superstructure 25.8m × 13.7m and the interior of the superstructure, 21m × 9m.\(^{767}\) The pilasters were 65cm wide and 23cm deep; these pilasters may have extended outwards to form a series of cross-walls forming magazines in the superstructure similar to the Saqqara tombs.\(^{768}\) These walls, of 65cm thickness, would have been capable of achieving a height of 3.9m.\(^{769}\) A line of subsidiary graves flanked the east side of the superstructure. They were covered with a double wooden floor, separated by a bed of reeds, over which a second layer of reeds was placed and finally a layer of mud bricks.\(^{770}\)

The total volume excavated equalled 130m\(^3\) and 306,800 mud bricks were used, assuming a 4m high superstructure and 1.5m high enclosure wall. Plastering equated to a total face area of 1,045m\(^2\) for the walls and 115m\(^2\) for the mud packed floor.

M08, M10, M11\(^{771}\)

Due to the limited information on these remaining tombs, the volume of excavated material was the only calculation able to be made. M08 was a small tomb with 6m\(^3\) of material excavated. M10 and M11 were larger, with 43m\(^3\) and 56m\(^3\) of material excavated respectively.

\(^{766}\) Tristant, *Archéo-Nil* 18, 142.
\(^{767}\) Montet, *Kêmi* 7, pl. V; Tristant, *Archéo-Nil* 18, Figure 14.
\(^{768}\) Tristant, *Archéo-Nil* 18, 140.
\(^{769}\) This assumes no lateral supports. Whilst this is not the 4m height assumed for the superstructure, it is possible that these walls did not reach the full height of the external walls, or the superstructure was in fact not 4m high. If the cross-walls were bonded, the maximum achievable height would have exceeded 5m.
\(^{770}\) Tristant, *Archéo-Nil* 18, 141.
\(^{771}\) Montet, *Kêmi* 7, pl. V.
<table>
<thead>
<tr>
<th>Tomb</th>
<th>Total Volume Excavated (m³)</th>
<th>Total No. of Mud Bricks</th>
<th>Total Area Plastered (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M01</td>
<td>47</td>
<td>162,500</td>
<td>506</td>
</tr>
<tr>
<td>M02</td>
<td>50</td>
<td>140,200</td>
<td>267</td>
</tr>
<tr>
<td>M03</td>
<td>106</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M04</td>
<td>83</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M06</td>
<td>65</td>
<td>95,000</td>
<td>-</td>
</tr>
<tr>
<td>M07</td>
<td>130</td>
<td>306,800</td>
<td>1,160</td>
</tr>
<tr>
<td>M08</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M10</td>
<td>43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M11</td>
<td>56</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4.8. Material expenditure summary – Abu Rawash

4.2.6 GIZA

Giza, the site of the most impressive mortuary structures in all of Egypt – the great pyramids of the 4th Dynasty – is also home to two mud brick mastaba tombs. One is dated to the reign of Djet of the 1st Dynasty and the other, Mastaba T, dated possibly to the 3rd Dynasty.

The 1st Dynasty substructure consisted of a central chamber, flanked on either end by two chambers approximately half the depth of the main chamber. The burial chamber measured 10.8m x 5.6m and was approximately 2.4m deep; the side chambers measuring 5.6m x 2.6m and 0.83m deep. The mud brick retaining walls along the excavated cut and the cross-walls were approximately 1.0m thick.

The burial chamber was lined with timber which rested on a footing beam with the space between the lining and the wall was divided by brick piers. The timber lining reduced the size of the chamber to 9.0m x 4.2m. The brick piers, which held in place the posts for the timber lining, were plastered on the sides but kept bare against the timber lining.

The superstructure consisted of palace façade panelling with the faces of brickwork coated with white plaster, as were the floors of the bays. Along the four sides of the

772 Total bricks include the superstructure and subsidiary graves.
773 See Volume 2, Appendix D, for tomb plan (Figure D1.6).
mastaba, a total of 56 subsidiary graves accompanied the tomb. On the western side, the graves were constructed as one continuous trench lined with mud brick walls. Cross-walls separated the trench into individual graves. On the remaining three sides the pit graves were individually built. The mud brick walls of the pit graves were mud plastered and roofed by wooden poles placed a few centimetres apart and then covered by brushwood. The graves varied from 2.0m to 2.6m long and were approximately 1.3m wide. The material used in constructing this tomb was calculated and summarised in the table below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Volume Excavated (m³)</th>
<th>No. of Mud Bricks</th>
<th>Plastered Face Area Superstructure (m²)</th>
<th>Plastered Face Area Substructure (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Tomb</td>
<td>410</td>
<td>718,500</td>
<td>194</td>
<td>362</td>
</tr>
<tr>
<td>Subsidiary Graves</td>
<td>500</td>
<td>155,800</td>
<td>-</td>
<td>333</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>910</strong></td>
<td><strong>874,300</strong></td>
<td><strong>194</strong></td>
<td><strong>695</strong></td>
</tr>
</tbody>
</table>

Table 4.9. Material expenditure summary – Giza

4.2.7 TARKHAN

Tarkhan, located approximately 60km south of Cairo, lies between El-Lisht and Meidum. The site was first excavated by Petrie, from 1911 to 1912, with over 2,000 tombs unearthed dating to all periods of Egyptian history, although the large majority belong to the Early Dynastic period. The cemetery at Tarkhan, like that at Helwan, contains tombs from all levels of society, with three notably large tombs: 1060, 2038 and 2050.

When Petrie excavated the site he wrote:

The size of the graves gives a general indication of the resources of the people. At Tarkhan there is a slight rise from S.D 77 to 78, and then a steady decline; at Turah the maximum is S.D 79. This is reasonable as it implies that at Tarkhan a steady decline set in under Mena, owing to the foundation of Memphis, which drew away the richer people; while Turah opposite Memphis was richest during the 1st century of the new capital…. The decline at Tarkhan was probably

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777 A total of 56 graves are numbered on the tomb plan, but only 49 graves are shown, Petrie, *Tarkhan I and Memphis V*, Plate VI.
779 See Volume 2, Appendix D, for tomb plans. (Figure D1.8 to Figure D1.9)
hastened by the rise of Memphis under Mena, while Turah, though much poorer, yet benefited by the political change.\textsuperscript{781}

**Tomb 1060**

Tomb 1060 was constructed away from the main cemetery, which was located closer to the cultivation. Built of mud brick, mud plastered and painted white, it had a superstructure which survives today to a height of just 0.7m. Mud plastered pavement lined the perimeter, upon which the enclosure wall stood. The superstructure was elaborately niched, with traces of red paint in the recesses. The ends of the superstructure were destroyed, but it is possible that there were nine niches on the long walls and four on the short walls. The recesses also had timber flooring.\textsuperscript{782} The mastaba measured 34.04m x 15.62m,\textsuperscript{783} with the internal area subdivided through a series of mud brick cross-walls, not bonded to the main walls. These walls did not form chambers as they were not built to the full height of the superstructure. The interior had been filled with sand.\textsuperscript{784}

The central chamber was dug through the gravel into bed rock to a depth of approximately 2.3m and measuring 34m x 16m. On either end of the chamber, two smaller subsidiary chambers were excavated for placing offerings, but were only 1.8m deep. Four false doors (two on the north and two on the south walls) were located in the central chamber, only 1.3cm deep. The doors were painted red in the same manner as those in the tomb of Djer and Djet. Limestone slabs measuring 46cm x 30cm x 88cm were found broken in the burial chamber, possibly used for roofing the chamber. As there were a number of large pieces of charcoal also found within the chamber, the roof may have been of wood, however, peculiarly, some of the charred wood was found in holes 8cm below the roof ledge. Petrie suggested that “... possibly the chamber may have had a wooden ceiling 3 inches thick below a heavy stone roof.”\textsuperscript{785}

\textsuperscript{783}Grajetzki, *Archéo-Nil* 18, 109.
\textsuperscript{784}Petrie, *Tarkhan I and Memphis V*, 14.
Tomb 2038

Tomb 2038 measured 32.13m x 12.95m and was surrounded by an enclosure wall of which only three sides have survived. The superstructure was built with the panel façade, nine niches on each long side and four niches on each short side. On the eastern face, traces of wood planks for flooring were found in one of the recesses. The wall thickness of the superstructure varied from 3.4m on the north to 3.9m on the west, and the interior of the superstructure was filled with sand and gravel. The size of the mud bricks were the same throughout the structure, measuring 25cm x 12cm x 7cm. The substructure was cut into the bed rock measuring 3.2m x 5.0m and lined with wood to form a chamber 2.6m x 4.2m. The pit was 5.6m deep and was reached by a sloping passage.

Tomb 2050

Tomb 2050 resembles that of Tomb 2038, with the exception of there being no sloping descent to the burial chamber, and no external vestibule to the corridor. The mastaba measured 35.38m x 15.10m, the largest at Tarkhan. The superstructure was built with the panel façade ten niches on each long side and five niches on each short side. Two brick sizes were used: small bricks for the intricate niches (17cm x 8cm x 7cm) and standard size bricks for the main superstructure (25cm x 12cm x 7cm).

The material expenditure used in constructing these tombs is summarised in the table below.

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume Excavated (m³)</th>
<th>Mud Bricks (units)</th>
<th>Plaster (m²)</th>
<th>Paint (m²)</th>
<th>Mud Packed Floor (m²)</th>
<th>Rubble Fill (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1060</td>
<td>90</td>
<td>918,000</td>
<td>1,673</td>
<td>665</td>
<td>262</td>
<td>164</td>
</tr>
<tr>
<td>2038</td>
<td>97</td>
<td>574,300</td>
<td>936</td>
<td>936</td>
<td>98</td>
<td>292</td>
</tr>
<tr>
<td>2050</td>
<td>133</td>
<td>745,700</td>
<td>861</td>
<td>860</td>
<td>150</td>
<td>430</td>
</tr>
</tbody>
</table>

Table 4.10. Material expenditure summary of large Tarkhan tombs

786 Grajetzki, Archéo-Nil 18, 109.
788 Petrie, Tarkhan II, 5.
789 Grajetzki, Archéo-Nil 18, 110.
790 Petrie, Tarkhan II, 5.
Summary of Tarkhan Results

Tarkhan tombs dated to the 1st and 2nd Dynasties were graphed in chronological order.\textsuperscript{791} Tombs 1060, 2038 and 2050 are clearly visible on Graph 4.21, which shows a huge spike in the material excavated for the substructure.

Tomb 1060, the first of the large palace façade tombs at Tarkhan, belongs to the reign between Narmer and Djet of the 1st Dynasty.\textsuperscript{792} This is a fairly long time period, which may be attributed to the tombs of that time not having been discovered yet, or, perhaps an official with a particularly long reign was eventually buried in Tomb 1060.\textsuperscript{793} Tombs 2038 and 2050 were the only other tombs of significant size.\textsuperscript{794}

After the middle of the 1st Dynasty there were no longer large mud brick palace façade tombs at Tarkhan. It would seem the place lost its importance since forty kilometres to the north, the cemeteries at Helwan and Saqqara were growing, indicating the rise of a new national centre, Memphis.\textsuperscript{795}

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\textsuperscript{791} Graph 4.21 corresponds to Petrie’s two excavation reports: \textit{Tarkhan I and Memphis V} and \textit{Tarkhan II}.
\textsuperscript{792} Grajetzki, \textit{Archéo-Nil} 18, 110.
\textsuperscript{793} Grajetzki, \textit{Archéo-Nil} 18, 110.
\textsuperscript{794} Petrie dated Tomb 1060 to Sequence Date 80, and tombs 2038 and 2050 to Sequence date 81: Petrie, \textit{Tarkhan I and Memphis V} and Petrie, \textit{Tarkhan II} (London, 1914).
\textsuperscript{795} Grajetzki, \textit{Archéo-Nil} 18, 110.
**Tarkhan versus Helwan**

Comparative data of the tombs built at Helwan with those at Tarkhan shows us that a greater number of larger tombs are to be found in Helwan. The size of the Helwan cemetery (even though both cemeteries housed a similar demographic of people), is also much bigger, as demonstrated in the graph below.\(^{796}\) This provides further proof that the new capital, Memphis, was of increasing importance.

![Graph 4.22. Material expenditure comparison – Helwan (Seasons 1942 to 1947) versus Tarkhan](image)

4.2.8 KARARA\(^{797}\)

Karâra, site of a Coptic cemetery, was first excavated by Hermann Ranke in the winter of 1912 to 1913.\(^ {798}\) Ranke found three Early Dynastic tombs beneath the Coptic graves.

**Tomb 1**

Tomb 1 had mud brick walls which were out of shape. No plans or dimensions were recorded on this tomb and therefore a material expenditure analysis was not possible.

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\(^{796}\) A total of 4,395 Helwan tombs shown on Graph 4.22 as per the published plans by Saad, compared to only 260 as published by Petrie. Saad, *Saqqara and Helwan*; Saad, *Helwan*; Petrie, *Tarkhan I and Memphis V* and Petrie, *Tarkhan II*.

\(^{797}\) See Volume 2, Appendix D, for tomb plans and sections. (Figure D1.10 to Figure D1.11)

**Tomb 2**

The excavated pit forming Tomb 2 was retained by mud brick walls. Cross-walls also separated the rectangular pit into the burial chamber and two magazines. The pit measured approximately 4.2m x 2.8m.\textsuperscript{799} The retaining walls were 40cm thick and built to a height of 1.35m. Above this height the pit had been cut further back to form ledges where the roofing beams were placed. The total excavated material equated to approximately 37m\textsuperscript{3} and a total number of 2,600 mud bricks were used.

Timber beams were found in position, measuring 25cm high and 30cm wide.\textsuperscript{800} The total number of roof beams required equated to:

- 7 beams placed over the burial chamber of 1.2 + 0.8m for overhang
- 7 planks place over the beams of the burial chamber of 2.0 + 0.8m overhang.\textsuperscript{801}

The roofing (1.0m x 0.55m) over the two magazines may have comprised smaller tree branches as the span was very small.

**Tomb 3**

Tomb 3 was a pit tomb, excavated and lined with limestone slabs. The tomb consisted of a burial chamber and four magazines subdivided by mud brick cross-walls. The pit measured approximately 4.7m x 2.3m, resulting in 38m\textsuperscript{3} of material being excavated. A total of four tonnes of limestone was used to line the tomb.

Approximately 1m below the surface, the grave was covered with unhewn timber beams, six in number. The beams were partly covered with Nile mud, before which reed mats and then mortar had been laid.\textsuperscript{802} The total area of reed matting equalled 7.5m\textsuperscript{2}. On the floor of the burial chamber, three long timber beams, also in an unhewn state, were found.\textsuperscript{803} These beams may have formed the base of a timber floor.

\textsuperscript{799} Dimensions scaled off plan in Ranke, *Karâra*, Figure 4.
\textsuperscript{800} Ranke, *Karâra*, 9.
\textsuperscript{801} The plan of Tomb 2 shows two layers of roofing planks, Ranke, *Karâra*, Figure 4.
\textsuperscript{802} Ranke, *Karâra*, 9–10.
\textsuperscript{803} A fourth beam was found placed against a wall. It is possible the original worked timber planks were reused when the tomb was plundered.
4.2.9 NAQADA

The so-called tomb of Menes, located near Naqada, most likely belongs to Queen Neithhotep, mother of King Aha. This tomb along with Saqqara Tomb S3357 is the earliest preserved niched mastaba. The mud brick mastaba tomb measured 53.4m (N-S) x 26.5m (E-W) and had palace façade niches on all four sides. The superstructure was surrounded by an enclosure wall measuring 65.1m x 34.2m. The interior perimeter of the superstructure was separated by cross-walls forming 16 compartments. These rooms had been filled with gravel and sand, equating to a volume of approximately 500m³ at 2m high. The main superstructure walls were approximately 4.3m thick and the internal cross-walls 1.0m-1.3m thick. The core of the superstructure had plain mud brick walls and formed five rooms: the burial chamber in the centre and two rooms on north and south sides. No subsidiary graves were recorded.

As the superstructure and enclosure wall were denuded, the original height of the mud brick walls was assumed to be 4m for the superstructure and 1.5m for the enclosure wall. Based on these heights, the calculated quantity of mud bricks used in the construction of the tomb was 2,227,400 units. There was no evidence of excavation for a substructure. The plastering of the walls equated to a face area of 2,370m².

4.3 Comparison of Large Mud Brick Mastaba Tombs

With the exception of the funerary enclosures built for the 1st and 2nd Dynasty kings at Abydos, the mud brick mastaba tombs of the elite, located at Saqqara, are the largest surviving mud brick structures from the Early Dynastic period. As a comparison, the combined sites were evaluated incorporating tomb structures, subsidiary graves and funerary enclosures of a select number of cemeteries.

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804 See Volume 2, Appendix D, for tomb plan and section (Figure D1.12).
805 Arnold, Ancient Egyptian Architecture, 148.
807 Whilst a 1m thick wall without the roof to restrain it could achieve a height of 6m, the original height of the superstructure was assumed to be 4m as at Saqqara.
808 This is based on the published plan of the tomb by Borchardt, ZÄS 36, Figure 21.
809 Tombs with less than 20,000 bricks used in the construction were excluded from the graph for clarity.
Graph 4.23. Volume excavated – comparison of large Early Dynastic mortuary structures

Graph 4.24a. Mud bricks used – comparison of large Early Dynastic mortuary structures (excluding Khasekhemwy)

810 The 15.2 million mud bricks used in Khasekhemwy’s mortuary structures were omitted in this graph for clarity.
The graphed results highlight the enormity of the royal mortuary structures built for the kings of the 1st and 2nd Dynasties buried at Abydos compared to the large tombs in other sites in Egypt. Furthermore, the results show the grand scale of the Saqqara tombs compared to other non-royal sites, with the exception of the tomb of Queen Neithhotep at Nagada. The importance of Helwan should also not be overlooked as some of the tombs are large in their own right, highlighting the importance of some of the people buried in this cemetery.

4.4 Conclusions
The scale of building activity that was taking place in the Early Dynasty period must have been enormous based on the material expenditure of mortuary structures at this time. If one were able to also incorporate construction activity taking place for the creation of non-mortuary structures, such as temples and housing, of which little evidence survives from this period, such constant work (a large proportion of which would have been state driven), would have kept the population very busy.

811 The inclusion of Khasekhemwy’s mud brick consumption at Abydos (excluding the 4.8 million bricks used on his Hierakonpolis funerary enclosure), surpasses every other structure built from the Early Dynastic period.
Furthermore, the workers building these tombs had to be fed, clothed, housed and their tools of trade kept in working condition. The building activities also had to be managed and meticulous records must have been kept. This meant such building activities had far reaching impacts, not only for the direct labour force, but also for the people who supported this group. Overall, the labour force and the support network needed to be well organised, something the ancient Egyptians learnt and developed effectively as their building activities beyond the Early Dynastic period became grander.

Only the largest and more prominent grave sites have been analysed and evaluated in this chapter, but it is evident that the building trade was a lucrative business in the 1st and 2nd Dynasties. Just how many industries were involved in such building activities? What was the size of the labour force? How long did some of the larger structures take to build? To answer these questions, we now turn to Chapter 5.
Chapter 5: Labour Force

The workers who built the structures that have survived to this day have long since gone, but the large structures, which once stood high above the Egyptian desert landscape, are a testament to the hard work and dedication of the people who created this once grand civilisation. Their skeletal remains, too, tell us much about their work roles and their physical health. Due to limitations in the data, however, there is little on skeletal remains from the Early Dynastic period. Nonetheless, skeletal remains from the Naqada II period cemetery at Hierakonpolis (predating the cemeteries studied in this research by a few centuries), provide some indication of the level of workers' health and the work demands placed upon them:

The large, thick, long bones indicate that the non-elite inhabitants at HK43 were robust with well-developed muscle attachments that are associated with people who work reasonably hard. … Although these people appear to have worked hard, this work was not excessively demanding on their joints. Overall, we can conclude that the population was receiving adequate nutrition that occupational stress was moderate, and that rate so infection were low.\textsuperscript{812}

5.1 Methodology

Project managing the construction of a tomb meant the builder would have been responsible for overseeing the acquisition of materials, ensuring an adequate labour force to manufacture and transport the materials to site on time, and finally, to make sure there was sufficient labour employed to construct the tomb.

In estimating the labour force, modern day manual rates were used as a starting point and factored accordingly to allow for variations in material workability and the tools used in ancient times.\textsuperscript{813} For jobs, which have changed little over time, for example bricklaying, a practical number of workers was assumed, with minimum and maximum productivity rates to provide the range of days these tasks may have taken to complete.

\textsuperscript{812} J. Rose and A. Maish, “Health and life at HK43” \textit{Nekhen News} 15 (2003), 25. Similar analysis on the skeletal remains from the pyramid builders show stresses on the vertebrae suggesting hard manual labour, but not necessarily debilitating. This research is not an anthropological study and as such further discussion refers only to the construction of the structures. Chapter 7 will, however, examine the important role construction played in Egyptian society.

Similarly, the number of porters employed to move spoil during excavation work, carry mud bricks from manufacturing brickyards to site, and transport water and raw materials for mixing mortar, plaster and paint, was also estimated based on a range of workers.

The availability of unskilled labour throughout the year fluctuated depending on agricultural demands on the population; harvest time, for example, would have occupied a larger portion of the population compared with the inundation season. It is also possible that multiple construction projects, being built simultaneously, would have put further strain on the numbers of skilled and unskilled labourers. In addition to the workers, a ‘support crew’ would have been required to sharpen tools, mix materials (such as mortar and plaster), and perhaps even feed the workers. Once again, due to the lack of data for the Early Dynastic period, a number of sources date to later periods, primarily the New Kingdom. By extrapolating data from later periods, in combination with modern day labour rates, the author was able to estimate the productivity rates of various working activities. These productivity rates were then used to determine total construction times of the tombs, as presented in the following chapter.

5.2 Ancient Egyptian Work Days
The Egyptians divided their year into three seasons: akhet, peret and shemu. The flood season, akhet, lasted from approximately July to October with the height of the flood usually in mid August. During August, farmers would row around the farms closing vents in the surrounding dykes, so that when the Nile subsided by the end of September, the farmers could open the vents and the water could run slowly off the land and leave the rich silt behind.

The next season, peret, which ran from November to February, had the farmers returning to the land to sow their seeds after ploughing or hoeing the saturated soil.

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814 Based on the number of workers required, it is more likely that workers may have returned home at midday for lunch before returning to work. This is speculative, but organised ‘feeding stations’, such as those found at the large building sites during the early half of the Old Kingdom, may not have been necessary due to the small work forces. For example, the construction of the pyramids required a workforce in the order of 10,000–20,000 people. In contrast, as will be presented in Chapter 6, the Early Dynastic tombs required no more than 100–200 people.
The final (and the busiest) season was the harvest, or *shemu*. This took place from March to June. During this time, all the villagers (including women and children) would be employed to help with the crop harvest. It was during these four months that construction activity may have slowed, as unskilled labour returned to work the fields, with only a small percentage of skilled labourers staying on site to continue work on the tombs.  

As well as the strains on the workforce from agricultural needs, the ancient Egyptian working calendar was not too dissimilar to our own, when the number of festivals and working days are considered. In the New Kingdom, the ancient Egyptian working week consisted of ten days (eight days work and two days rest). Based on this scenario, the working year would result in:

<table>
<thead>
<tr>
<th>Working week (8 days x 36 weeks)</th>
<th>288 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekends / festival days (2 days x 36 weeks)</td>
<td>72 days</td>
</tr>
<tr>
<td>Additional festival days (public holidays)</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>TOTAL days per year</strong></td>
<td><strong>365 days</strong></td>
</tr>
</tbody>
</table>

By way of comparison, the modern day working calendar consists of approximately 263 days. This means that in less than 5,000 years, construction workers have seen a reduction of 27 working days to their working year.

The working day in the New Kingdom was comprised of two by four hour shifts, with a break during the middle of the day. An 8-hour working day was also assumed for the Early Dynastic period, to estimate the work that could be undertaken per day, as no data remains on the working week during this period.

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816 M. Bierbrier, *Tomb Builders of the Pharaohs* (Cairo, 1989), 52.
817 Five other festivals existed in addition to the festivals of kingship, like the Sed-festival and coronation. These are: (1) Running of the Apis Bull, which could take place no more than once in the kings’ reign; (2) ḫ (Djet) festival, perhaps connected to the goddess of Nekhbet – the Djet festival seems to have been a recurrent event, since the second occasion of its celebration is recorded in the annals; (3) Adoration of the Celestial Horus festival; (4) Festival of Sokar; (5) dšr festival, recorded once of the Palermo stone corresponding to the early 1st Dynasty. T. A. H. Wilkinson, *Early Dynastic Egypt* (London, 2001), 300.
818 A working week for construction workers (in Australia) equals 5.5 days as Saturday is generally a half-day; 12 Rostered Days Off (RDO) and 11 public holidays, including Easter and Christmas.
819 Bierbrier, *Tomb Builders*, 53.
5.3 Tomb Planning

Prior to a single brick landing on site, or soil being turned ready for excavation, the king and those of the elite echelon would have engaged the services of a chief architect to design a suitable tomb that meet the required specifications and economic means of the individual. For those less fortunate, that is, the common man, would have appointed himself architect, engineer and project manager to undertake the work, and recruited his family and friends to help with the construction.

While no written plans have survived from the Early Dynastic period, the larger tombs must have initially been drawn on papyrus or stone, to enable the builders to work from a guide. The plans would not have been as detailed as blueprints are today, nor would they have needed to be, but considering the design of the surviving structures, they must have contained sufficient information.

From the drawing board to the construction site, the project manager was responsible for overseeing the acquisition of materials, ensuring an adequate labour force to manufacture and transport the materials to site on time, and finally, to make sure there was sufficient labour employed to construct the tomb. The following briefly discusses the labour requirements for each trade, the results of which will subsequently be used to calculate the time taken to build each structure in the proceeding chapter.

5.4 Tomb Construction

The acquisition of resources and the tools used was discussed in Chapter 3. In this chapter, the manufacturing and transportation of materials to site is reviewed. The construction of the tombs will be examined and the results summarised in the proceeding chapter, Chapter 6.

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5.4.1 MANUFACTURING MUD BRICKS
Based on the modern day mud brick making still practiced in Egypt, two men can make up to 3,000 bricks per day, with the support of one man mixing and one man transporting the raw materials to the brickmaker. Therefore, a crew of four men can make 3,000 bricks per day. This quantity of bricks would occupy an area of 160m$^2$ or cover 20m x 8m for the drying process. Therefore, ten crews (or 40 men: 20 brickmakers, 10 mixers and 10 transporters) could conceivably make 30,000 bricks per day, covering an area of 200m x 80m.822

5.4.2 BRICK TRANSPORTATION TO SITE
For royal and wealthy tombs, the transportation of mud bricks to each site would have commenced as soon as the bricks were dry enough to be moved, as resources would have been available to safeguard the materials on site.823 Less wealthy tomb owners, unable to guard against theft, most likely had bricks and other materials transported to site as required.

Depending on the size of the tomb, the transportation of bricks would have required varying numbers of porters each using a shoulder yoke to carry the bricks, as represented in the brickmaking scene in the tomb of Rekhmire.824 The carrying capacity of one man is 60 kilograms over a distance of 22km per day. Based on this fact, the

822 'The modern ethnographical parallels in Egypt and the depictions of brick-making in the tomb of Rekhmire both suggest that the crews who made the bricks also could be employed to lay the walls.' V. L. Emery and M. Morganstein, “Portable EDXRF analysis of a mud brick necropolis enclosure: Evidence of work organisation, El Hibeh, Middle Egypt”, Journal of Archaeological Science 34 (2007), 119. This suggestion of brick makers also laying the brick walls seems improbable. It is certainly possible that family members making bricks for their own domestic needs may have also acted as bricklayers to build their house or tomb, but it is seems unlikely that large state run projects would have used the same labourer for both tasks. The construction of tombs and temples would have seen the bricks being sourced from state run brickyards and bricklayers employed to construct the structures. Based on the consumption of mud bricks, the brickyards were constantly producing to keep up with demand, and the removal of workers from this activity to lay bricks would not have been very productive.

823 Fathy suggested that the brickyards should 'ideally be situated outside the area scheduled for building, so that it does not have to be moved when needed'. He goes on to say that 'it should, too, be situated between a canal to supply water and close to a supply of earth'. H. Fathy, Gourna: A Tale of Two Villages (Cairo, 1969), 91. In the Early Dynastic tombs, due to their position in the desert regions, it would have been more practical for the brick making yards to be located close to the source of the raw materials and the bricks transported to the site once dry enough.

824 N. de G. Davies, Paintings from the Tomb of Rekh-mi-re at Thebes (New York: MMA, 1943), Plate LIX. 'Though this depiction valuable for information regarding the brick-making scene, it is an imperfect source because it offers an idealised impression in which graphic space and worker numbers were subject to the limited space on the wall…', Emery and M. Morganstein, Archaeological Science 34, 115.
number of days required to transport bricks to site was able to be determined. Due to the distance from the brickyards that were located by the main source of water and mud – the Nile River – to the construction site, on average, four trips could be accomplished per day per man. With a maximum weight of 60kg of bricks per trip, each man would, on average, have carried approximately 15 bricks.

The site of Hierakonpolis where Khasekhemwy’s first enclosure was constructed has the remains of a clay mine located just east of the fort. Based on the excavator’s reports, from the size of the mine, it most likely serviced only half the brick supply for this structure.

5.4.3 EXCAVATION LABOUR RATES
The excavation or digging of the substructure of a tomb, regardless of the size of the pit, involved manual labour. The number of workers would have been determined by the size of the pit and how many men could work without encroaching on another excavator’s work area. The rate of excavation (m$^3$) per man per hour or per day was constant, with the number of days varying depending on the size of the pit being excavated and the number of workers. The rate of excavation was also governed by the material being removed. Loose soils and sand would have been far easier and faster to excavate than rock, however digging in softer soils also meant that the cut would need to be propped to prevent a collapse. The tools used would also wear more quickly in the harder materials. In addition, the material needed to be removed in unison with the excavators, otherwise the rate of excavation would have been slowed.

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825 Due to the number of bricks used on some of the larger tombs, it seems more practical that men, rather than donkeys, would have been used to transport materials to the site. Furthermore, donkeys would have been highly valued, and more likely reserved for use on agricultural fields.

826 The brickyards would have been close to a water source and near soil to minimise the double handling of materials. An average of 2.5km distance from the brickyards to the site was assumed. The distance travelled and thus the total time to transport bricks for each site are presented in the worksheets on the CD in the Appendix titled Chapter 6 Labour Force and can be manually changed. The results, however, for carrying over a distance of 2.5km are presented in the proceeding chapter.

827 Note the number of bricks transported per day is summarised in the worksheets found on the CD in the folder titled Chapter 5 & 6 Labour Force and Construction. The calculations are based on volumes rather than mud brick units to reduce the possibility of errors when converting to single brick units.

The excavation of New Kingdom tombs in the Valley of the Kings saw excavators cutting through the rock, pushing the material behind them to be broken up into manageable pieces before being carried away.\(^{829}\)

Based on modern day manual rates, one man can loosen 0.4m\(^3\)–0.8m\(^3\) per hour of hard soil with a pick and 2.3m\(^3\)–3.8m\(^3\) per hour of ordinary loam. These rates are based on the use of tools made of steel and therefore cut through the material quickly and easily. For the purposes of calculating the rate of excavation in ancient times, it was assumed that one man could excavate through gravel and rock at a rate of 1m\(^3\) per day (based on an 8-hour day).\(^{830}\) A rate of 0.8m\(^3\) per day was used for quarrying stone. The men used stone tools to excavate as metals tools were far too soft.\(^{831}\) The use of such tools meant the rate of excavation was lower than modern figures.

At the site of HK29B at Hierakonpolis, excavation teams led by Field Director R. Friedman, have been unearthing significant post construction structures. In this particular location, postholes of 90cm–100cm in diameter at the top and 80cm at the base were found cut to a depth generally of 140cm. These postholes could have accommodated wooded posts of 60cm–70cm in diameter. If local wood of acacia or sycamore had been used, an object raised 5m–6m above the ground would weight in the vicinity of 800kg–900kg. Cutting into the hard Nile silts underlying Pleistocene Terrace was in itself a laborious task and from the tool marks preserved in one of the small holes, the labourers did this using wooden spikes to dig.\(^{832}\)

5.4.4 FOUNDATIONS

It was normal practice to build brick walls up from the natural surface level with minimal foundation preparation work for Early Dynastic structures, however, a uniform substratum would also have been desirable. For brickwork, slight foundations and one

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830 The same rate was assumed whether the excavator was cutting through softer gravel and sand versus rock because cutting through softer material generally meant the walls of the excavation had to be shored to prevent any potential collapse. The time taken to do this equalled the additional time it took to excavate through rock.
831 Refer to Chapter 3 for a discussion on tools used.
832 T. Hikade, “Nothing is more permanent than a post hole”, *Nekhen News* Vol. 19 (2007), 4–5. Equipped with modern tools one of the Hierakonpolis excavation members succeeded in cutting away c. 40cm x 40cm and 30cm deep in two hours. This equates to 0.048m\(^3\) of material removed in 2 hours, or extrapolated to 0.192m\(^3\) in one 8-hour day. Based on modern manual labour rates from actual construction sites, one man can loosen 0.4-0.8m\(^3\) per hour of hard soil with a pick, suggesting excavation work on a building site is hard work.
or two courses of brickwork under the natural surface would have been sufficient.\textsuperscript{833} The first course of two bricks or more in width was sometimes laid as headers on their long edges.

5.4.5 BRICK WALL LAYOUT
The majority of brick walls from the Early Dynastic period alternated courses of headers and stretchers.\textsuperscript{834} This prevented the formation of vertical cracks. The courses of stretchers could themselves be offset by the length of half a brick each time so that the exact pattern was repeated only every fifth course.\textsuperscript{835}

Cracking of brick walls caused by uneven distribution of loads was avoided through the insertion of timber beams or sticks amongst the horizontal courses.\textsuperscript{836} The position within the wall varied from five to fourteen courses. This reinforcement was critical in thicker walls where careful bonding of courses, and sometimes even the use of mortar, was normally abandoned. The practice was often accompanied by placing a layer of reeds over the entire working surface, but this did not always correspond with the level at which the timber was inserted. A number of examples exist from the Early Dynastic period of this practice, referred to in Chapter 4.\textsuperscript{837} The amount of timber used (probably acacia and tamarisk in many instances) was shown to be quite substantial.\textsuperscript{838}

The bricklayer was responsible for ensuring that any variability due to brick sizes, uneven foundations, or poor workmanship, was corrected. Wall levels could be adjusted though the addition of extra mortar, laying bricks on their long edge or placing bricks diagonally to correct the thickness. Because vertical joints were often narrow or negligible, brick bonds were easier to maintain using bricks with approximately a 2:1 ratio (length to width). It was sometimes necessary to introduce a half brick in a stretcher course to return the courses to their intended pattern of bonding. Although

\textsuperscript{833} W. M. F. Petrie, \textit{Egyptian Architecture} (London, 1938), 9.
\textsuperscript{835} P. T. Nicholson, and I. Shaw, \textit{Ancient Egyptian Materials and Technology} (Cambridge, 2000), 88.
\textsuperscript{836} S. Clarke, “El Kab and the Great Wall”, \textit{Journal of Egyptian Archaeology} 7 (1921), 75
\textsuperscript{837} W. B. Emery, \textit{Excavations at Saqqara, Hor-Aha} (Cairo, 1939), 17; Emery, \textit{Great Tombs I}, 15.
\textsuperscript{838} Nicholson and Shaw, \textit{Materials and Technology}, 90–91.
walls were normally plastered, thereby hiding any irregularities, many well-preserved examples display a high degree of skill by the early bricklayers.\textsuperscript{839}

5.4.6 BRICKLAYING
The art of bricklaying has changed little over time. Unlike other construction activities, which have developed with the introduction of modern machinery, bricklaying has remained largely unchanged. The rate of bricklaying, therefore, can be assumed to be similar to today’s rates, with any variations due primarily to the intricacy of the brickwork in some of the tombs, for example, the elaborate niched façade on some of the larger 1\textsuperscript{st} Dynasty tombs. The number of bricks laid per day, even today, generally ranges from 800 to 1,000 units per man. In order to accommodate the time taken for planning, measuring, checking wall alignments and integrating other aspects of the structure, the rate of bricklaying used for estimating construction times was 800 bricks per day.

The bricklaying teams used in this research ranged from four bricklayers (3,200 bricks per day), up to nine bricklayers (7,200 bricks per day). Whilst more bricks could be laid per day if the number of bricklayers were increased, other factors, including the transportation of raw materials (mud and water) to make the mortar to lay the bricks, would have made the laying of more bricks impractical.\textsuperscript{840} The number of workers was also restricted based on the size of the tomb, similar to the excavation of the tomb, where too many workers would have meant they would have been in each other’s way.

5.4.7 SCAFFOLDING
Saqqara tombs S3357, S2185 and S3503 had four postholes found in the pavement in front of each of the large niches of the superstructures when first excavated.\textsuperscript{841} Emery originally suggested the holes acted to support standards but later suggested they were used for scaffolding. However, their use for scaffolding seems doubtful based on the care taken in all aspects of the construction of these tombs. That is to say, following the removal of the scaffolding, such holes would have been filled and covered with mud

\textsuperscript{839} Nicholson and Shaw, \textit{Materials and Technology}, 90.
\textsuperscript{840} This is the author’s opinion based on experience in the construction industry and in speaking with a number of bricklaying contractors.
\textsuperscript{841} W. B. Emery, \textit{Great Tombs of the First Dynasty Part II} (London, 1954), 131.
pavement. It stands to reason that Emery’s original suggestion of the holes acting to support standards seems more probable.

Walls of substantial thickness were pierced with narrow channels one or two courses high. Although it has been suggested that they aided in the drying of the bricks, it is probable that these holes are the remains of where scaffolding had once been anchored. Modern day scaffolding is secured in a similar way, with the missing bricks replaced once the scaffolding comes down. Some mud brick walls were found to have holes running perpendicular to the face (initially suggesting they were used to attach the scaffolding) but connected to longitudinal channels in the interior. These channels in the brickwork may have formed a ventilation system to assist in the drying of the brickwork.

Of working without the need for scaffolding, Somers Clarke wrote:

The old Egyptian way of building continues to this very day; the barefooted workmen stand on the wall itself, and the labourers bring the materials up to the top of the wall. Thus all the workers rise as the wall rises. Even a wall of 0.75m thickness, the men walk on the wall-top, and indeed their weight helps to solidify the structure.

Scaffolding would have been necessary, if not for the construction of the mud brick walls, then most definitely for the application of plaster and paint on the finished wall surfaces. The erection of scaffolding was calculated around modern scaffolding rates, and then factored to allow for the extra manual handling of ancient techniques, such as boards being tied together with ropes.

Unlike large modern day construction sites today, where the entire building is surrounded with scaffolding, for the construction reasons as well as the safety of the workers, it is probable the scaffolding use in ancient times would have been restricted to the area being worked on.

842 Nicholson and Shaw, Materials and Technology, 88.
843 J. Spencer, Brick Architecture in Ancient Egypt (Warminster, 1979), 116.
844 S. Clarke, “El Kab and the Great Wall” Journal of Egyptian Archaeology Vol. 7 (1921), 78.
5.4.8 PLASTERING

Labour rates for plastering walls were taken from modern day rates and then factored (as seen with other construction activities already discussed) to allow for variances in material workability from ancient to modern, as well as changes in the tools employed. In the case of plastering, whilst little has changed in the actual manual handling and application of the plaster in the past 5,000 years, modern day plaster is much easier to work with. The quality of workmanship also affected the rate of application. The base coat applied to the brick walls could be applied roughly as the subsequent coat or coats would have been finished to leave a smooth texture. Furthermore, large flat surfaces would have been able to be applied much faster than smaller, irregular surfaces, such as mud brick walls with niches.845

The time taken to plaster the mud brick surfaces was initially calculated for various applications or number of coats of plaster and based on a plain surface and an irregular surface. The final numbers used to calculate the man-hours and number of men required to plaster the various tombs was the average of these results.846 On average, one crew consisting of two plasterers and one assistant could complete 30m² per day, 847 which is consistent with modern day Egyptians who still practice similar techniques of plastering their houses.848

5.4.9 PAINTING

Labour rates employed for painting were based on modern day rates using hand brushes (as opposed to modern day mechanical means of painting). This enabled a more accurate rate. The most time consuming task, no doubt, would have been the mixing of the paint, rather than the actual application, as the builders could not simply go to the local hardware store to buy a tin of paint. Furthermore, the paint needed to be mixed and supplied constantly to the painters to ensure it was workable. A crew consisting of two painters and one assistant could paint a surface area of between 40m²–45m² per day.

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846 The rate of plastering differed, depending on the quality of workmanship. Modern day plastering labour rates classify the workmanship as ‘ordinary’ or ‘fine’ work. For plastering of these structures, ‘fine’ work was assumed due to the material in ancient times possibly being more time consuming to work with. These rates are presented in the Appendix.
847 Personal communication, Renée Friedman.
848 The assistant was responsible for mixing the raw materials to ensure a constant supply of fresh plaster throughout the day. Porters, however, delivered the raw materials to the plasterers assistants.
5.4.10 TIMBER

Determining the labour force requirements for cutting down trees, working the timber into appropriate building materials (including beams and planks), and finally constructing the structural elements of the tomb with this material involved the process outlined in this section. The species of trees that were used for construction were discussed in Chapter 3.

Tree Felling and Working of Timber

Modern construction rates formed the basis of the number of man-hours needed to complete various tasks, with the differences in ancient tools compared with modern tools factored accordingly.

The rate of felling trees was directly proportional to the diameter of the tree trunk. Working the timber into beams and planks to create roofing or lining construction materials was also dependant on the length and cross-sectional dimensions (i.e. length, width and breadth) of the piece being cut. A tree with a large diameter trunk would take longer to cut down than a small tree. The working of timber into larger planks of wood is, similarly, more time consuming. These factors were considered when estimating the time taken to source the timber for the tombs.

Installation

The time taken to install timber shrines and roof the chambers was based on calculations that excluded the time that would also have been required to cut down trees, work them into beams and planks, and transport them to site. The calculations, based on the size of the beams and planks and the quantity of timber, was first converted into cubic metres (volume of timber) and from this result it was possible to determine the days required to erect the timber shrines and install their roofs.

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850 Spreadsheets showing the tables used and calculations are presented in the Appendix in the *Labour Force* files on the CD. In summary, the estimated number of timber beams, posts and planks used for each tomb was converted into a volume unit of measure (i.e. cubic metre of timber – m³). From this unit, the rate of cutting a tree with a certain diameter trunk per m³ was applied to determine how many days it would have taken one man to cut a certain volume of timber. The number of men employed was then manipulated to balance efficiency with a workable time line to complete the task.
851 Modern day rates are calculated based on the volume of material used, which is why the number of beams and planks calculated in Chapter 4 was converted into this unit of measure (as presented in the raw data in the CD). Dagostino and Feigenbaum, *Estimating in Building Construction*, 236.
The analysis of each operation was necessary to determine the probable time frame required to complete the task. Simply assuming the activity would be done at a given rate per unit of timber, regardless of the size, length and kind of work, was not sufficient for the purposes of generating detailed, accurate estimations.\textsuperscript{852} For example, the installation of the timber shrines within the burial chambers of the royal tombs at Abydos would have been far more time consuming due to the timber frames being integrated into the brickwork.\textsuperscript{853}

5.4.11 STONE QUARRYING AND TRANSPORTATION

The acquisition of stone for construction in the Early Dynastic period was only just beginning to popularise, with its use in architectural elements of tombs still limited and in a number of tombs, not used at all.\textsuperscript{854}

The rate of excavation per man per day to cut into rock as discussed earlier was approximately 1m$^3$. This rate could be maintained if the excavator was not concerned about recovering rock in one intact piece. When quarrying, the rate of extraction would be less, which, for the purposes of this research, was assumed to be 0.8m$^3$ per day, including the extra time needed to work the faces of the cut slabs of stone.

Working in a quarry was not a desired occupation and in some instances prisoners and criminals were sent to quarries to work as punishment.\textsuperscript{855} Stonemasons were employed to dress and prepare the stone slabs and blocks as required.\textsuperscript{856}

Once extracted, the architectural stone elements had to be transported to site. As discussed in Chapter 4, some tombs used substantially sized stone slabs to seal their entrances in the form of portcullis monoliths, or, in other instances, as roofing slabs.

\textsuperscript{852} Peurifoy and Oberlender, Estimating Construction Costs, 260. The production rates used to estimate tree felling and construction labour rates is based on tabulated data, which in turn is collected from modern day construction activities thereby establishing raw numbers in order to calculate the time taken to complete these activities. The calculations are presented in the accompanying CD – Folder titled Chapter 6 Tomb Construction and the results presented in the proceeding chapter.

\textsuperscript{853} For example, tombs of Djer, Djet, Den, and Qa’a referenced in order of kings: G. Dreyer, “Abydos/Umm el-Qa’ab”, Rundbrief DAI, 2008, 18; Petrie, Royal Tombs I, 8–10, pl. LXI; G. Dreyer, et. al., “Umm el-Qa’ab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 5./6. Vorbericht”, MDAIK 49 (1993), 57; Dreyer, MDAIK 54, 142, 145, 166–167; E.–M. Engel, Das Grab des Qa’a in Umm el-Qa’ab: Architektur und Inventar Dissertation – microfiche (Göttingen, 1997), 79 – 86, Abb. 54, Abb. 55.

\textsuperscript{854} For a more detailed discussion and appropriate references on stone use see Chapter 3 Resources and Tools, and Chapter 4 Material Expenditure.

\textsuperscript{855} J. Cerny, A Community of Workmen at Thebes in the Ramesside Period (Cairo, 1973), 60.

\textsuperscript{856} Davies, Tomb of Rekh-mi-re, Plate XX.
Representations on tomb walls from New Kingdom sources show how stone was transported on barges across water and on timber sleds on land. Some samples of the timber sleds have survived to this day.  

5.4.12 TOOL MAKERS AND MAINTENANCE
Without proper tools, tomb construction would have slowed, and eventually, perhaps, even ceased. The Chief Workman or foreman on site was responsible for the daily distribution of tools, for collecting blunt tools and issuing of new ones. Likewise, the Guardians of the tombs were responsible for securing the materials used the tombs, and issuing materials to the workers as required. The most valued items would have been the copper tools, and these would have been distributed by the Guardians in the presence of the foreman and scribe. The distribution of a new tool or the exchange of a blunt implement for a sharp one would have been recorded.

5.4.13 LOCATION OF NILE AND PROXIMITY TO CONSTRUCTION SITE
Water was essential in the construction of the tombs. From its use in the manufacturing of bricks to the mixing of mortar and plaster, water needed to be constantly supplied to the workers to enable them to proceed with the construction work. Water was also required to quench the thirst of the labours employed directly and indirectly in the construction of the structures. The transportation of this commodity may have been moved over distances of 1km to 5km from the main source of the Nile, or alternatively, canals may have been constructed, enabling the water to flow closer to the desert's edge.

For the purpose of this research, an average travelling distance of 2.5km from water source to site was assumed. Any canals which were built were not considered in the calculations of the time taken to build an individual tomb structure. The reason for this is because any canal would have serviced a number of tombs within an area once it was constructed. Further, the distances from water source to site during the flood season would presumably have been less if the materials, such as the brick making yards, were within the flood plain. Although this would have been beneficial in many respects, due to the close proximity of the raw materials, the materials stored would also have needed to be moved during the inundation.

857 Clarke, and Engelbach, Ancient Egyptian Construction and Architecture, 88–89.
858 Cerny, Workmen at Thebes, 131.
859 Cerny, Workmen at Thebes, 159–160.
Based on the brick consumption of mortuary structures alone, as discussed in Chapter 4, it would seem likely that brick manufacturing was a continuous year round industry. As such, labour would have needed to be expended, whether in travelling larger distances or moving manufacturing zones during the flood season. In order to maintain some consistency in this study, the travelling distance was kept constant, thus providing comparable results between the various sites.

5.4.14 WATER REQUIREMENTS FOR BUILDING
The amount of water required to mix 1m$^3$ of mortar is approximately 200 litres.\textsuperscript{860} Assuming a mortar thickness of 1cm (and allowing for some wastage), 3,200 bricks consume 3m$^3$ of mortar and 7,200 bricks, 6m$^3$ of mortar.\textsuperscript{861} This means, 600 litres and 1,200 litres of water respectively would have been required for laying the daily number of bricks.

If the water was transported on donkeys, based on the carrying capacity of a donkey, each animal would be capable of carrying 100 litres per trip. The donkey is able to travel a distance of 24km–30km per day, or 4km per hour. As the site was 2.5km away from the water source, one donkey could do 4–5 trips per day.\textsuperscript{862}

Donkeys would have been very valuable (even New Kingdom texts from the workmen’s village at Deir el-Medina make reference to donkey’s being expensive).\textsuperscript{863} As such, it is likely they would not have been overworked. So, two donkeys carrying 400 litres of water per day, would slightly exceed the requirements for 3,200 bricks and three donkeys would be needed when 7,200 bricks were laid. Donkeys may have been far too expensive during this early period of Egyptian history, in which case, men using shoulder yokes may have transported the water to site in the same fashion as they

\textsuperscript{860} These values are based on modern day rates.

\textsuperscript{861} The number of bricks laid per day is based on four bricklayers laying a combined 3,200 per day and nine bricklayers laying 7,200 bricks daily. See Section 5.3.6 Bricklaying, in this chapter.

\textsuperscript{862} Water was especially difficult for the service of staff to bring into the workmen’s valley at Deir el-Medina. The state assigned about six men at a time to act as water carriers, and they often rented donkeys at a loss, to save themselves from carrying heavy jars of water. K. Cooney, “Labour” The Egyptian World T. Wilkinson (ed.) (New York, 2007), 171.

\textsuperscript{863} A number of Deir el-Medina ostraka have to do with donkeys – trading donkeys, renting donkeys, borrowing donkeys. They were expensive animals (25–40 Deben), rented out for long periods of up to several months, so it was useful to keep a written record of the date and terms of sale and loan. A. G. McDowell, Village Life in Ancient Egypt (New York, 1999), 85.
carried mud bricks. One man could also do 4–5 trips per day, carrying 50–60 litres per trip.\textsuperscript{864} Manual labour was cheaper and perhaps more practical than donkeys.

Another trade also requiring a constant supply of water was the plasterers. If one assumes the average thickness of mud plaster to be 2cm and the finer gypsum plaster only 1cm, the total amount of plaster required to cover an area of 10m x 10m would equate to 2m$^3$ and 1m$^3$. This does not seem great, until the actual area of the larger structures is considered.\textsuperscript{865}

Based on one crew, consisting of two plasterers and one helper completing 30m$^2$ per day, the plastering work would most likely have been governed by the rate at which the raw materials could be transported to site. Whilst a greater number of plasterers could be employed to undertake the plastering of the walls, this may not have been practical.

The raw materials required to prepare 1m$^3$ of mud plaster were mud, straw and water, and this equates to 36 loads of material that would have needed to be transported to site and 200 litres of water (200 litres of water is required per 1m$^3$ of mix).\textsuperscript{866} Similarly, 1m$^3$ of gypsum plaster would have required 36 loads per day of dry raw materials and 200 litres of water. This means that 30m$^3$, or the daily output per crew as discussed above, would have required 1,080 loads per day of dry raw materials, and 6,000 litres of water.

The raw materials, including water, needed to be transported to the site and mixed daily in order to provide a constant supply of fresh plaster to the plasterers throughout the day, possibly restricting the quantity of plaster applied per day.

\textbf{5.5 Support Workers}

The large mud brick mortuary structures generated employment for locals and spawned new industries throughout the country. The construction of these tombs did not only employ workers directly engaged with building activities, but engaged a range of external industries as workers had to be clothed and fed and their families provided with shelter. Funerary goods had to be manufactured and transported to site, all of which

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\textsuperscript{864} This assumes water was carried in lighter containers (animal skins), rather than heavy ceramic vessels. Once the water arrived on site, it could be transferred to clay jars for storage.

\textsuperscript{865} Refer to Chapter 4 for the estimated quantity of plaster consumed in each tomb.

\textsuperscript{866} The calculated 36 loads are based on the carrying capacity equaling 0.28m$^3$ per man. If one divides 1m$^3$ by 0.028, you arrive at a figure of 35.7, rounded to 36 loads.
would have been undertaken by a service industry. In addition, there were varying levels of bureaucrats, ensuring that the proper documentation and recording of activities was undertaken. As these industries did not directly affect the construction timeline of the tombs, the impact of these activities on the community at large will be discussed in Chapter 7.\textsuperscript{867}

### 5.6 Conclusion

The workforce commissioned to construct the tombs included skilled bricklayers, plasterers, painters and carpenters. Other unskilled activities, such as the transportation of materials, required a large number of people and probably provided much employment in the wider population. This may have also been true of workers excavating the substructures and subterranean tombs, with skilled workers coming at the end of the process to tidy up wall planes to ensure they were vertical and neat.

Transportation of bricks and other construction materials to site would have been undertaken throughout the building process, with the number of workers fluctuating depending on the demands imposed by the state’s other projects. For example, during the flood season when farming activities were not possible, a large number of people may have been engaged to transport materials to sites. At harvest time, however, these workers would have returned to the fields.

The time estimated in constructing the tombs does not allow for the planning process prior to building activities commencing, or whether work halted at any time due to shortages in material supplies. The number of days and years required to build the tombs was calculated from the first man excavating into the soil to the final stroke of paint being applied to the walls. Imagining the lengthy planning processes that inevitably occurred in addition to the number of construction days simply reinforces the sheer magnitude of the entire development of some of the larger tombs. The estimated

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\textsuperscript{867} Disputes by the workers resulting in work ceasing for a particular length of time cannot be discounted, as seen during the New Kingdom during the reign of Ramesses III where workers went on strike after their supplies were late. Delays in the arrival of raw materials may also have occurred. However, such unknowns will not be factored into the estimated construction time lines provided in the subsequent chapter. For further details on strikes by workers in the New Kingdom see: J. J. Janssen, “Absence from work by the necropolis workmen of Thebes”, \textit{Studien zur Altägyptischen Kultur} 8 (1980), 127–152; Bierbrier, \textit{Tomb Builders of the Pharaohs}, 41; R. David, \textit{The Pyramid Builders of Ancient Egypt. A modern investigation of Pharaoh’s workforce} (London, 1986), 73–74.
number of men and the time taken to construct a selection of Early Dynastic tombs is presented in the Chapter 6.
Chapter 6: Tomb Construction

The workforce commissioned to construct the tombs, including bricklayers, plasterers, painters and carpenters, would have been skilled tradesmen, just like construction workers today. Activities including the transportation of materials, which required a large number of people, but little or no skill, would have been distributed to the wider population.

6.1 Methodology

From a review of the time taken to carry out the various tasks in the construction program discussed in Chapter 5, and based on the materials consumed, as estimated in Chapter 4, it was possible to assess the total time it would have taken to build each tomb and present a comparison of the various sites. Variations on the number of workers and the impact on the total construction time was assessed in order to determine an economical balance, that is, the benefits of smaller work crews against the time taken to build these structures.

A full description of the construction sequence is provided for a selection of tombs from each site under review, with a summary of all the results presented on each site so as not to repeat the same construction procedure many times over. Those tombs where a full description is provided is done so due to particular architectural differences, such as the addition of stone in the construction or various construction phases.

868 While the total estimated construction time is compressed, it is important to recognise that some of the tombs were built in different stages, with some, such as the royal tombs at Abydos, undergoing alterations and additions of subsidiary chambers. Personal communication, G. Dreyer.
6.2. Tomb Construction

6.2.1 SAQQARA

1st Dynasty Tombs

**Tomb S3357**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>75 m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>785,600</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td>2,500 m² + 300 m²</td>
</tr>
<tr>
<td>Volume of Sand (false floor)</td>
<td>255 m³</td>
</tr>
</tbody>
</table>

*Mud Brick Making and Transportation*

The total number of days required to manufacture 785,600 mud bricks based on 10 crews of 20 bricklayers, ten mixers and ten transporters, making 3,000 bricks each, or 30,000 bricks per day, was estimated to total 27 working days. Once the bricks were sufficiently dry they could be transported to the construction site.

Assuming the brickyards were located a distance of 2.5km from the construction site, each porter could have done two trips per day, carrying 45kg–60kg each time. If 50 porters were employed to transport the mud bricks, a total of 259 days would have been required to carry the bricks to site. This could have been halved to 130 days, by employing 100 porters, which would seem more practical. This means a total of just under 3,000 bricks could have been transported to the site per day.

The transportation of mud bricks to the site most likely began during the planning stages, and throughout the excavation of the substructure. Transportation would have continued once the bricklayer was on site and porters would have been seen constantly delivering materials to ensure a steady supply.

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869 A description of the individual tombs and material expenditure was presented in Chapter 4. Tomb plans and elevations are reproduced from the original excavation reports in the Appendix.

870 The number of days presented here are all working days. These working days will be converted into total years taken to construct the tombs, taking holidays and festivals into account.

871 Refer to Methodology in this chapter for rates and carrying capacity of a man.
Excavation

As discussed in the methodology, the rate of excavation was governed by the number of workmen who could work in the excavation zone, and how fast the material and spoil could be removed.

For Tomb S3357, the substructure required approximately 75m$^3$ of rock to be excavated. Based on one man being physically able to excavate 1m$^3$ per day, it would have taken him 75 days to excavate the substructure. Based on the size of the pit, however, three workers could have undertaken the task of digging, removing 3m$^3$ per day, thus reducing the excavation time to only 25 days.

The material would have been removed with baskets in much the same way as tombs are re-excavated by archaeologists today. Based on the size of baskets found on ancient construction sites, the basket was able to hold approximately 0.028m$^3$ of spoil. This means 2,670 baskets would need to have been removed in total, at a rate of approximately 107 basketfuls per day. Unlike the transportation of bricks to the site, which involved carrying them over a long distance, the material being removed could have been dumped closer to the site. As such, it is possible that each porter could have conservatively made 48 trips per day or 6 trips per hour. This means three porters would have been necessary to remove 107 baskets of material, with another two to three men employed to break up the harder material and fill the baskets to be carried away.

Bricklaying

Similarly, the rate of laying the bricks relied on the rate of delivery of materials to site. As discussed above, the transportation of mud bricks would have commenced well before construction and then been stored on site. This served a dual purpose: the bricks would have continued to dry in the desert air and then been available and ready for laying as soon as the excavators completed the cutting of the substructure pit. These elite tombs would most likely have been guarded to ensure that materials stored on site did not disappear throughout the night.

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872 If the excavation of the pit took 25 days, 2670 baskets divided over this many days equals 107 baskets per days.
873 Personal communication, G. Dreyer and M. Adams, based on modern excavation sites.
The rate of bricklaying was calculated for both the lower and upper extremes: a minimum laying rate of 3,200 bricks per day and a maximum of 7,200 bricks per day. As discussed, the use of 100 porters transporting bricks meant 3,000 bricks would have arrived to site daily. This means that bricks had to be stored on site. It seems realistic to suggest that at least 10,000 bricks were stored on site at any one time, as a minimum, allowing a safety buffer for the bricklayer should there be a supply issue.

A crew of four men laying 3,200 bricks per day would have taken a total of 245 days to build up the sub- and superstructure walls and the enclosure walls. Increasing the number of bricklayers to nine, laying a combined 7,200 bricks per day, would have reduced the construction time to 109 days. This, however, assumes an uninterrupted construction phase and steady productivity rate, when, in reality, construction activities would not have been seamless, particularly, for example, when more difficult tasks like placing the roof beams interlaced with the brick walls were undertaken.

What would be a realistic number of days for completing the brickwork? To answer this question, it is important to consider the rate of delivery and mixing of mortar. To ensure a constant supply of fresh mortar, mortar would have been mixed daily. The mortar in ancient times would not have been as ‘workable’ and thus as easy to apply as modern day mortar. Of course, the process could have been sped up if the mortar was applied to the full thickness of the wall before the bricks were placed in position.874

Throughout this research the quantity of mortar used has been omitted. This is simply due to the fact that the mortar was comprised of the same material as the mud bricks, so the work undertaken in Chapter 4 for the material expenditure would be the same here, regardless of whether the material was ultimately used to make bricks or mixed into mortar. The only variance is that whilst the bricks were made close to a source of water and raw materials, the materials required to make the mortar needed to be transported to the site. The amount of mud, straw and sand was already taken into consideration with the transportation of mud bricks. As such, only the amount of water needed for mixing mortar needed to be estimated.

The amount of water required to mix $1 \text{m}^3$ of mortar is approximately 200 litres. Assuming a mortar thickness of 1cm (and allowing for some wastage), 3,200 bricks would require $3 \text{m}^3$ of mortar; and 7,200 bricks, $6 \text{m}^3$ of mortar.\textsuperscript{875} This means 600 litres and 1,200 litres, respectively, would have been required for laying the daily number of bricks. One man could do 4–5 trips per day, carrying 50–60 litres per trip.\textsuperscript{876}

As the superstructure was reaching its full height of 4m, the bricklayers would have needed to suspend their work to allow for a second group of tradesmen, roof builders, to enter the site. Because the timber over the magazines was imbedded into the brickwork, once roofed, there would have been no access to the magazines.\textsuperscript{877}

**False Floor**

It is most likely that the magazines were filled when the brick walls were still fairly low in height to make the filling process less laborious.\textsuperscript{878} An interesting observation is the quantity of fill used to create the false floors. Whilst speculative, it is possible that sand was mixed with the rubble removed from the excavated pit. After all, approximately 75$\text{m}^3$ of rubble was excavated, but a total of 255$\text{m}^3$ of material was used in filling the magazines. This means that the rubble could be stockpiled close to the construction site as proposed earlier, and the material from the pit reused. Perhaps, once the initial foundation ceremonies were conducted prior to construction commencing, the entire working area of the site became significant such that any material removed had to be reused.

Returning to the rate of construction of the tomb, the filling of the magazines involved workers refilling baskets, carrying them up and depositing the spoil between the mud brick walls. A total of 9,107 baskets of spoil would have been required, based on a volume of 255$\text{m}^3$. As the distance from the spoil heaps to the drop zone would not have been more than 100m, 200m at most, each man could carry quite a number of baskets per day. If each man could complete 6 trips per hour (allowing for filling and emptying

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\textsuperscript{875} These values are based on modern day rates.

\textsuperscript{876} This assumes water was carried in lighter containers (animal skins), rather than heavy ceramic vessels. Then, once the water arrived on site, it could be transferred to clay jars for storage.

\textsuperscript{877} This is also true when roofing the substructures, with access required to allow other tradesmen, such as plasterers, to work.

\textsuperscript{878} If the mud brick walls were too high, the porters would have wasted considerable time climbing over walls to fill up the magazines.
of baskets) over an 8-hour day, or a total of 48 trips per day, one man would have needed 190 days to complete the filling of the magazine, or ten men, only 19 days.

Plastering of Walls
With the false floors completed, plastering of the magazine walls could commence. The completion of the plastered walls would enable the ‘closing off’ of the superstructure, with the exception of the burial chamber and means of access to it for the funeral procession. Once the walls were plastered, grave goods would be deposited into the magazines, and the roofs installed before the final brickwork was completed. The only roofs, which would remain partially open, would be those above the substructure to allow access to the burial chamber for the burial.

The plastering was not only restricted to the magazine walls. The entire superstructure was plastered, as was the enclosure wall and the surrounding floor, equalling 2,800m². Based on one crew, consisting of two plasterers and one helper completing 30m² per day, the plastering work would have taken 94 days. Doubling the work crew would have reduced the plastering to only 47 days. However, this may not have been practical as the raw materials, including water, needed to be transported to the site and mixed daily in order to provide a constant supply of fresh plaster to the plasterers throughout the day.

If one assumes the thickness of mud plaster to be 2cm and the finer gypsum plaster only 1cm, the total amount of plaster required to face the tomb would have equalled 56m³ and 17m² respectively. Whilst the plastering would have been staged to correspond to the different building activities and construction phases, the labour rates would have been the same, simply undertaken at different times.

Mud Plaster
The raw materials required to prepare 56m³ of mud plaster were mud, straw and water. Allowing for wastage (70m³ of material), a total of 2,500 loads of material would have needed to be transported to site and 11,200 litres of water (200 litres per water is required per 1m³ of mix). This means, one man transporting 2 loads per day would have taken 1,250 days. Using 20 porters would have reduced this number to 63 days.
**Gypsum Plaster**

Similarly, with $20\text{m}^3$ to allow for wastage, a total of 715 baskets of raw material and 3,400 litres of water would have been necessary. This means 20 porters, carrying two baskets per day, would have taken 18 days to bring the material to site.

Therefore, the transportation of raw materials would have taken 20 porters a total of 81 days versus the plasterers only 47 days.\(^879\) In essence, the number of porters would have needed to be increased to 29 to accommodate a productivity rate of $30\text{m}^2$ per day. Alternatively, if only 20 porters were employed, the number of days needed to complete the plastering would have equalled 81 days ($63 + 18\text{ days}$).\(^880\)

The burial chamber walls were also lined with reed mats that were applied to the wet plaster to adhere to the walls. This construction time was incorporated into the plastering rate.

**Roofing**

With the plastering of the magazine walls complete, the grave goods could have been deposited and the roof of each chamber installed. This would have also enabled the brickwork above the timber roofing to be finished, and the magazines sealed off for increased security.

However, before the construction of the roof could have begun, the acquisition of timber would have been organised well in advance. It seems most likely that the bulk of the timber would have been of local origin, with the larger and longer beams, required to span the burial chamber, being of imported cedar. Local timbers were used to roof the magazines, which generally had considerably shorter spans than the burial chamber.

As presented in Chapter 4, a substantial amount of timber was consumed in the construction of these tombs. For Tomb S3357, results showed that cutting down trees

\(^879\) With a total of $73\text{m}^3$ of material ($56\text{m}^3 + 17\text{m}^3$) divided over 47 days, $1.6\text{m}^3$ of material would need to have been transported daily, requiring 29 porters to carry the raw dry materials and 8 men to carry the water.

\(^880\) The reason for two approaches being taken to calculate the number of workers and number of days is to show that whilst the tombs could have been constructed more quickly if a greater number of workers were employed, this may not have always been practical when other factors, namely the transportation of raw materials, was considered. The combination of both approaches allows one to obtain a range of construction days along with a potential workforce, which is both practical and credible.
for all the timber used took 407 days (assuming only one man was assigned the task). Increasing the workforce to ten people would have reduced the number of days to 41 for softwood trees and 50 for hardwood trees. ⁸⁸¹

Considering that 404 beams and 383 planks were required of an average length of 3.8m, the number of days it took to cut down the trees does not seem long when using a team of ten men. Assuming a consumption rate of one tree per beam and two planks per tree, a total of 596 trees would have been cut down over a period of 41 to 50 days. Taking the more conservative approach of 50 days, ten men would have cut down six trees per day, meaning the number of days calculated here is realistic.

Once cut and worked into beams and planks, the timber was transported to site. The cutting of the trees and preparation of the timber in all probability took place during other construction activities (such as bricklaying). ⁸⁸² Such planning ensured work on the tomb proceeded without the need to wait for material to arrive on site. As with most modern construction sites, there are days where all the careful planning still does not prevent some delay, such as materials not arriving on time, or the wrong materials being sent to the site.

With the timber on site, work on the roof structure could begin. This activity would have needed to have been undertaken jointly with the bricklayers who would have placed mud bricks above the beams, sealing off the magazines. Security during this time would have been high, as the magazines would have been filled with valuable grave goods.

The labour involved in putting the timber beams and planks in place was estimated to have taken two men 127 days. This means they were placing, on average, six to seven

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⁸⁸¹ The number of days used in the final tally of workdays is based on the higher hardwood timber result. The reason for this is to allow for the variations in modern day steel axes and saws versus ancient tools. However, it is important to clarify that the trees cut down – acacia, sycamore and cedar – are all considered softwoods. Softwoods, nevertheless, are not necessarily softer than hardwoods. There is an enormous variation in actual wood hardness, with the range of density in hardwoods as diverse as that of softwoods. Refer to Chapter 3 for discussion on types of timbers used.

⁸⁸² The time taken to cut timber was therefore not included in the total number of construction days.
beams or planks daily. A more practical workforce would have consisted of ten men, each working in pairs, thus completing the task in 25 days.\footnote{883}

With the roofs in place, the mud brick walls completed to their full height, and the plastering of the external walls nearing completion, the scaffolding could now have been taken down.\footnote{884}

\textit{Boat Grave}

Tomb S3357 has a boat grave situated 35m to the north of the tomb.\footnote{885} The grave was estimated to have contained 14,000 mud bricks and a surface area of 45m$^2$ plastered, assuming the structure to be 1m high. It is probable the bricks were transported to the site during the construction of the main tomb. The bricklaying would have taken five days to complete at a rate of 3,200 bricks per day and one crew of plasterers could have finished the walls in just two days. The area of sand fill in one corner of the brickwork would have taken no more than one day.

\textit{Construction Summary Tomb S3357}

The total number of days taken to construct Tomb S3357 is summarised below.

\begin{center}
\begin{tabular}{|l|l|}
\hline
\textbf{TASK} & \textbf{DAYS} \\
\hline
Excavation & 25 (3 men) ; (10 porters) \\
Brick Transport & 259 (50 porters) / 130 (100 porters) \\
Brick Laying & 245 (4 men) / 109 (9 men) \\
Scaffolding & 16 (10 men) \\
False Floor & 19 (10 men) \\
Plastering & 81 days (2 men + 1 assistant) \\
Timber Cutting & 50 (10 men) \\
Roofing & 25 (10 men) \\
\textbf{Boat Grave} & \textbf{8 days} \\
\hline
\textbf{TOTAL}\footnote{886} & \textbf{403 DAYS} \\
\hline
\end{tabular}
\end{center}

\footnote{883} The roofing construction days included the time taken to place reed mats over the timber planks. The quantity of mats used is presented in Chapter 4.
\footnote{884} The calculation of time taken to erect and dismantle the scaffolding is presented in the Appendix.
\footnote{885} W. B. Emery, \textit{Excavations at Saqqara, Hor-Aha} (Cairo, 1939), 18.
\footnote{886} Note: \textit{Italics} used on summary tables refers to tasks undertaken during other activities and not included in total number of days. This notation is the same for all tabulated construction data for subsequent Saqqara tombs.
Tomb S2185

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Excavation</td>
<td>81m³</td>
</tr>
<tr>
<td>- Mud Bricks</td>
<td>584,900</td>
</tr>
<tr>
<td>- Plaster</td>
<td>1,600m²</td>
</tr>
<tr>
<td>- Volume of Sand (false floor)</td>
<td>104m³</td>
</tr>
</tbody>
</table>

**Excavation**

A total of 81m³ of material was excavated to form the substructure. The rate of excavation was governed by the number of workmen and how fast the spoil could be removed. Based on the plan area of the pit, a total of six men could have worked within the excavation zone. This means, the excavation took 14 days to complete. A total of 6m³ of material was removed per day, equalling 214 baskets or nine porters carrying 24 baskets per day.

**Brick Transportation and Brick Laying**

A total of 584,900 bricks were estimated to have been used for Tomb S2185. The transportation of these bricks to the site would have taken 50 porters approximately 193 days and 100 porters 97 days. Again, the number of porters available probably fluctuated in response to the demands of the agricultural industry.

With sufficient bricks stockpiled on site, the bricklayers could begin working as soon as the excavation of the substructure was complete. Assuming 3,200 bricks were laid per day, a total of 183 days would have been required to complete the brickworks. Increasing the laying rate to 7,200 bricks would reduce the construction time to only 82 days. 887

The amount of mortar required, as discussed for Tomb S3357, to lay 3,200 bricks equals approximately 3m³ and 6m³ for 7,200 bricks, allowing for some wastage. This means, 600 litres and 1,200 litres, respectively would have been required for laying the daily number of bricks. Using men to transport the water on shoulder yokes in the same manner as the bricks were carried to site, carrying 50 litres of water and doing two trips per day, a total of between six to twelve men would have been required.

887 The mortar requirements would be the same as those discussed for Tomb S3357.
These results show that it is possible that between 3,200 to 7,200 bricks could be laid per day. In practice, the bricklaying would not have been uninterrupted because, for example, of things like the alignment of walls needing to be checked as work progressed, or work slowing because of delays in the supply of materials or labour issues. More intricate work, too, could have caused the productivity rate to vary or even stop altogether, as would have occurred when scaffolding was erected as the walls grew higher.\textsuperscript{888}

\textit{Scaffolding}
At the full height of 4m, the superstructure would require the erection of scaffolding to continue with the brickworks and finally plaster the walls. Based on a work crew of ten men working in pairs, the placement of scaffolding around the structure would require 20 days to install and subsequently dismantle.\textsuperscript{889} This activity no doubt took place at the same time as the bricklaying and plastering and did not add to the total construction time.

\textit{False Floor}
The volume of material used to create the false floors was 104m\textsuperscript{3}. As with Tomb S3357, the volume of material needed was greater than the volume excavated. This means the total amount of the material excavated was probably replaced to build up the false floors. The volume amounted to 3,716 baskets of material, which one man could transport over a period of 155 days or ten porters in just under 16 days.

\textit{Plastering}
The enclosure wall, superstructure and internal magazines had all been plastered, equalling 1,600m\textsuperscript{2}. Assuming one crew (two plasterers and one assistant) completing 30m\textsuperscript{2} per day, the plastering would have taken 50 days. With the plastering complete, the roofing of the magazines could commence.\textsuperscript{890}

\textsuperscript{888} Whilst the thickness of the walls meant that the bricklayers could work on the actual walls, the scaffolding would still have been necessary for other activities such as plastering and painting.
\textsuperscript{889} No doubt the scaffolding was not built around the entire superstructure but moved with the workers to minimise the use of resources. Modern day construction has the scaffolding wrapped around the entire building until all façade work is completed.
\textsuperscript{890} From a construction timeline, the substructure would have been roofed well before this, as the timber beams were embedded into the brick walls. However, for the purpose of describing each trade and construction process clearly, each task is grouped and considered independently to produce the final total number of days required to construct the tomb.
Roofing

The roof layout for the magazines was considered to be similar to the previous tomb. As such, it was estimated that Tomb S2185 required 833 beams with an average length of 3.9m. This is a huge number, based on a beam diameter of 8cm.\textsuperscript{891} The number of trees required to produce this many beams could be cut down by ten men over a period of 29 days.\textsuperscript{892} This meant that 29 trees were cut daily or 6 trees for each man working in pairs. As they were only cutting 8cm diameter tree trunks, this is plausible.

The timber, once transported to the site, was ready to be installed. The labour rate to install the 833 beams, based on only 2 men working, equalled 37 days. This means that they had to place 23 beams per day. It may have been desirable to enlist more men to cover the magazines in a shorter time period. Furthermore, due to the length of the beams being almost 4m in length, it is probable that the carpenters installing the beams were assisted by perhaps one or two extra workers. Increasing the number of carpenters to ten men, to be consistent with the earlier tomb discussed, would have reduced the installation time to seven days. This means that 119 beams were placed in position daily or 24 beams for every two men (three beams per hour), which sounds practical.

Stone

A new element was introduced into this tomb; the use of limestone monolithic slabs to roof and possibly line the subterranean rooms.\textsuperscript{893} The total volume of limestone used to line and roof the chambers was approximately 43.3m\textsuperscript{3} (or 91 tonnes). The limestone slabs were quarried and then transported to site.

The rate of excavation per man per day to cut into rock as discussed earlier was approximately 1m\textsuperscript{3}. This rate could be maintained if the excavator was not concerned about recovering the rock in one intact piece. When quarrying, the rate of extraction would be less, resulting in a lower rate of excavation, which, for the purposes of this research, was assumed to be 0.8m\textsuperscript{3} per day, allowing for the extra time needed to work the faces of the cut slabs of stone. Therefore, one man alone would take 54 days to

\textsuperscript{891} Refer to Chapter 4 for material expenditure analysis.
\textsuperscript{892} Rates are based on hardwood timber using modern day cutting rates. Refer to appendix for breakdown of how each number was determined.
\textsuperscript{893} ‘...the sunken (chambers) were lined with stone, except those at the north and south ends. The central row was roofed with stone, above which had been laid wooden flooring of the upper set of chambers’, J. E. Quibell, Excavations at Saqqara (1912–1914), Archaic Mastabas. (Cairo, 1923), 5.
extract 91 tonnes of stone. A team of two men could complete the task in 27 days. This activity would take place during construction work on the tomb and would therefore not impact on the total number of days required to build the tomb.

The placement of the stone slabs, once transported to the site, would involve a far greater number of men, as the last thing the builder managing the progress of construction would have wanted is for one of the slabs to crack or split. Based on the average size of the stone slabs being 2.2m (shortest span of roof) x 1.0m x 25cm thick, each slab, on average, weighed 1.2 tonnes (0.55m$^3$). Assuming that a crew of 12 men were able to manoeuvre two slabs into position daily, the stone placement would have taken just under 40 days to complete.$^{894}$ The problem with this scenario is that the amount of stone seems unusually high. The roof of the chambers alone contained 12m$^3$ of 24 tonnes of limestone (the balance accounted for in the stone lining). If the stone lining was not as extensive as assumed in the calculations, the stone roofing alone could have been completed in 10 days.

*Construction Summary Tomb S2185*

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>14 (6 men); (9 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>193 (50 porters) / 97 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>183 (4 men) / 82 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>20 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>16 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>15 days (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>29 (10 men)</td>
</tr>
<tr>
<td>Roofing</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>27 (2 men)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>10 (12 men) – excluding stone lining (40 days including)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>245 DAYS</strong></td>
</tr>
</tbody>
</table>

$^{894}$ These figures assume a total of 79 slabs to line and roof the structure.
**Tomb S3471**

<table>
<thead>
<tr>
<th>Task</th>
<th>Volume of Sand (false floor)</th>
<th>Excavation</th>
<th>Mud Bricks</th>
<th>Plaster</th>
<th>Volume of Sand (false floor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>206m³</td>
<td>772,000</td>
<td>2,770m²</td>
<td>109m³</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S3471**

<table>
<thead>
<tr>
<th>Task</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>30 (7 men) ; (11 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>255 (50 porters) / 127 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>242 (4 men) / 107 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>21 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>17 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>87 (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>47 (10 men)</td>
</tr>
<tr>
<td>Roofing</td>
<td>18 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>394 DAYS</strong></td>
</tr>
</tbody>
</table>

**Tomb S3504**

<table>
<thead>
<tr>
<th>Task</th>
<th>Tomb</th>
<th>Subsidiary Graves (62)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>506m³</td>
<td>286m³</td>
</tr>
<tr>
<td>- Excavition</td>
<td>1,360,200</td>
<td>94,500</td>
</tr>
<tr>
<td>- Mud Bricks</td>
<td>3,420m² + 290m²</td>
<td>621m²</td>
</tr>
<tr>
<td>- Plaster (walls + mud packed floor)</td>
<td>506m³ (assumed)</td>
<td>–</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S3504**

<table>
<thead>
<tr>
<th>Task</th>
<th>DAYS – Tomb S3504</th>
<th>DAYS – Subsidiary Graves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavition</td>
<td>35 (15 men) ; (22 porters)</td>
<td>29 (10 men) ; (15 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>449 (50 porters) / 225 (100 porters)</td>
<td>34 (50 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>425 (4 men) / 189 (9 men)</td>
<td>30 (4 men) / 14 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>28 (10 men)</td>
<td>–</td>
</tr>
<tr>
<td>False Floor</td>
<td>35 (35 men)</td>
<td>–</td>
</tr>
<tr>
<td>Plastering</td>
<td>124 (2 men + 1 assistant), (13 porters)</td>
<td>21 (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>39 (2 men + 1 assistant)</td>
<td>–</td>
</tr>
<tr>
<td>Bull-Head’s Bench</td>
<td>10 (10 men)</td>
<td>–</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>68 (10 men)</td>
<td>66 (10 men)</td>
</tr>
<tr>
<td>Roofing</td>
<td>48 (10 men) + 2 Days</td>
<td>13 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>718 DAYS</strong></td>
<td><strong>93 DAYS</strong></td>
</tr>
</tbody>
</table>

---

895 *Bull-head’s Bench* - A low bench running along the base of the superstructure was decorated with life sized bull-heads modelled in clay with real horns held in place with wooden pegs. Originally there would have been 300 heads (Emery, *Great Tombs II*, 8). It is likely that these heads were mass-produced and then placed in position when the plastering of the tomb and painting was being undertaken, as evidenced by the fact that some of the heads contain splashes of paint. The placement of the bull-heads could be completed by a group of ten men placing three heads in position each per day, in just ten days. The manufacturing of the clay heads was assumed to have been done off-site and commissioned during other construction activities, therefore not adding to the total construction time. The placement of the heads around the structure, however, was added to the construction program.

896 The extra two days allows for the placement of timber planks around the pilasters and fixing of gold leaf decoration.
Tomb S3503

**Tomb**

- Excavation | 186m³ | 613,300
- Mud Bricks |
- Plaster (walls + mud packed floor) | 1,470m² + 415m² |
- Volume of Sand (false floor) | 217m³ |

**Subsidiary Graves and Boat Grave**

<table>
<thead>
<tr>
<th>Subsidiary Graves (20)</th>
<th>Boat Grave</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Excavation</td>
<td>75m²</td>
</tr>
<tr>
<td>- Mud Bricks</td>
<td>6,700</td>
</tr>
<tr>
<td>- Plaster</td>
<td>122m²</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S3503**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>31 (6 men) ; (9 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>202 (50 porters) / 101 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>192 (4 men) / 86 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>20 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>32 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>63 (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>35 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>45 (10 men)</td>
</tr>
<tr>
<td>Roofing</td>
<td>35 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>388 DAYS</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Subsidiary Graves</th>
<th>DAYS – Boat Grave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>4 (6 men) ; (9 porters)</td>
<td></td>
</tr>
<tr>
<td>Brick Transport</td>
<td>5 (30 porters)</td>
<td>9 (50 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>2 (4 men)</td>
<td>5 (4 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>4 (2 men + 1 assistant)</td>
<td>2 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>24 (10 men)</td>
<td>–</td>
</tr>
<tr>
<td>Roofing</td>
<td>8 (10 men)</td>
<td>–</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>18 DAYS</strong></td>
<td><strong>7 DAYS</strong></td>
</tr>
</tbody>
</table>

897 - The tomb would have originally contained 22 subsidiary graves of which only 20 were found. Emery, *Great Tombs II*, 129.
**Tomb S3507**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>40 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>153 (50 porters) / 77 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>146 (4 men) / 65 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>20 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>42 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>43 days (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>33 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Bull-Head’s Bench</td>
<td>8 (10 men)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>6 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>6 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>68 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>23 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>341 DAYS</strong></td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S3507**

- Excavation: $80 \text{m}^3$
- Mud Bricks: $464,600$
- Plaster (walls + mud packed floor): $1,040 \text{m}^2 + 350 \text{m}^2$
- Volume of Sand (false floor): $565 \text{m}^3$
### Tomb S3506

<table>
<thead>
<tr>
<th></th>
<th>Tomb</th>
<th>Subsidiary Graves (10)</th>
<th>Boat Grave</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Excavation</td>
<td>725m³</td>
<td>50m³</td>
<td>83m³</td>
</tr>
<tr>
<td>- Mud Bricks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Small Bricks (17x7x7cm)</td>
<td>80,400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Normal Bricks (23x13x7cm)</td>
<td>1,076,000</td>
<td>3,500</td>
<td>7,000</td>
</tr>
<tr>
<td>- Plaster</td>
<td>2,250m²</td>
<td>40m²</td>
<td>–</td>
</tr>
<tr>
<td>- Volume of Sand&lt;sup&gt;898&lt;/sup&gt;</td>
<td>844m³</td>
<td>–</td>
<td>75m³</td>
</tr>
</tbody>
</table>

### Construction Summary Tomb S3506

**TASK** | **DAYS – Main Tomb**
---|---
Excavation | 61 (12 men) ; (18 porters)
Brick Transport<sup>899</sup> | 132 (50 porters) / 66 (100 porters)
Brick Laying | 362 (4 men) / 161 (9 men)
Scaffolding | 14 (10 men)
False Floor | 63 (20 men) / 26 (50 porters)
Plastering | 75 (2 men + 1 assistant), (13 porters)
Painting | 24 (2 men + 1 assistant)
Stone Quarrying | 2 (1 man)
Stone Placement | 1–2 (6 men)
Timber Cutting | 24 (10 men)
Timber Roofing | 13 (10 men)
**TOTAL** | **600 DAYS**

**TASK** | **DAYS – Subsidiary Graves (10)** | **DAYS – Boat Grave**
---|---|---
Excavation | 13 (4 men) ; (6 porters) | 21 (4 men) ; (6 porters)
Brick Transport | 3 (50 porters) | 4 (50 porters)
Brick Laying | 2 (4 men) | 3 (4 men)
Sand Fill | – | 6 (20 porters)
Mud Packed Superstructure | 10 (2 men + 1 assistant) | –
Timber Cutting | 37 (10 men) | –
Roofing | 4 (10 men) | –
**TOTAL** | **29 DAYS** | **30 DAYS**

The total construction time for Tomb S3506 came to 659 days or 2½ years, of which the main component was the construction of the mud brick walls of the main tomb.

<sup>898</sup> Assuming the fill reached a height of 2m for the tomb, the total volume of material equated to 844m³. It seems unlikely that the interior of the structure would have been filled to its full 4m height as it would have been a waste of energy and labour resources. It is important to note, however, that the superstructure wall thicknesses would have allowed for the internal pressures exerted by the fill, even at 4m.

<sup>899</sup> The number of porters may have fluctuated depending on the time of year, and the demands for porters in other areas.
**Tomb S3035**

Tomb S3035, the tomb of Hemaka, was of a scale yet to be seen in the Early Dynastic period – a reflection of his status as royal chancellor, the position at the head of the treasury.900

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td>835m³</td>
</tr>
<tr>
<td><strong>Mud Bricks</strong></td>
<td></td>
</tr>
<tr>
<td>- Small Bricks (17cm x 7cm x 7cm)</td>
<td>400,000</td>
</tr>
<tr>
<td>- Normal Bricks (23cm x 13cm x 7cm)</td>
<td>2,959,500</td>
</tr>
<tr>
<td><strong>Plaster</strong></td>
<td>1,440m²</td>
</tr>
<tr>
<td><strong>Volume of Sand (false floor)</strong></td>
<td>824m³</td>
</tr>
</tbody>
</table>

*Excavation*

The total material excavated to create the stairs and substructure equated to 835m³. The plan area of the substructure allowed for only eight men to work at the one time. This means, the entire substructure could have been cut over a period of 105 days and the material removed using 12 porters carrying 24 baskets each over an eight-hour working day.

*Brick Transportation and Brick Laying*

A total of 2,959,500 normal size (23cm x 13cm x 5cm) and 400,000 small size (17cm x 5cm x 5cm) mud bricks were used in the construction of Tomb S3035. The task of transporting over 3.3 million bricks to site would have been a huge undertaking, let alone the manufacturing of this many bricks.

The transportation of this quantity of bricks to site would have required a large number of people. Assuming that the daily carrying capacity of one man was two loads, 50 porters would have taken 977 days to complete this task, or if the number of porters was increased to 100 men, 489 days, or almost two years. So, it seems likely that at least 100 men were employed to transport the bricks to site.

The task of laying all these bricks would have also taken considerable time. A workforce of just four bricklayers laying a combined 3,200 bricks per day would take

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1,050 days. Increasing the number to nine bricklayers, placing 7,200 bricks daily, would have reduced the workdays required to 467 days.

Some might argue, for such a large tomb, that the number of bricklayers should simply be increased to improve productivity. However, by increasing the number of bricks laid per day, you also increase the quantity of raw materials needed daily to produce fresh mortar.\(^{901}\) Therefore, despite the large quantity of bricks required, it would have been impractical to lay more than 7,200 bricks per day.\(^{902}\)

*False Floor*
The floor level of some magazines had been filled with clean sand to a height of 2m with matting placed above.\(^{903}\) Assuming all the magazines had a false floor, the time taken to place 824m\(^2\) of sand, most likely reused material removed from the excavated substructure, equated to 123 days using ten men. Assuming twice as many men were employed, the filling of the magazines would have taken only 62 days.

*Plastering*
The whole exterior of the superstructure had been finished with mud plaster and then a whitewash (sulphate of lime) applied. The walls had been painted red, possibly to resemble timber.\(^{904}\) The substructure had also been faced with a thick gypsum plaster, so that the total face area equated to 1,440m\(^2\). Assuming a work crew of two plasterers and one assistant, the plastering would have taken 46 days to complete.

*Painting*
Assuming the total exterior face of the superstructure had been painted, a face area equal to 1,220m\(^2\), the task of painting would have taken two men a total of 29 days.

*Roofing*
In the tomb of Hemaka it is fortunate that roofing remains over the magazines have been preserved. All the magazines had been roofed with roughly hewn wooden planks

\(^{901}\) The supply of bricks would have also needed to be increased to support a larger bricklaying work crew. After all, 150 porters were only capable of transporting 7,100 bricks per day. So, in essence, it was a fine line between the numbers of bricks laid per day versus the quantity of materials (including the mortar mixes) which could be transported daily from a practical perspective.

\(^{902}\) Refer to Tomb S3357 for mortar requirements for laying this quantity of mud bricks.


7cm thick that were supported by rough wooden beams, 15cm in diameter.\textsuperscript{905} It was estimated that Tomb S3035 consumed 552 beams of average length 2.5m and 661 planks (14cm x 7cm) of average length 5.3m.\textsuperscript{906} Based on these numbers, and assuming one tree was cut per beam and two planks were taken from each tree, a total of 882 trees would need to have been cut down. In order to cut this quantity of trees, a team of ten men would have required 128 days or seven trees per day, which seems practical. The time taken to install the roofs once the timbers had been transported to site, assuming 20 beams could be placed per day with a team of ten men, equalled 61 days.

\textit{Stone}

The inclusion of a stairway into the design of the tomb meant the entry passage needed to be blocked off, in this case with a portcullis stone. Tomb S3035 had three blocking stones along the stairway equating to a total volume of 6m\textsuperscript{3}, approximately 12.3 tonnes of limestone. One man could quarry and dress the stone in 16 days. The transportation of the material would have been done during other construction activities and therefore not impacted on the construction program. The positioning of the three portcullis stones would have taken at least one day each.

\textit{Construction Summary Tomb S3035}

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>105 (8 men) ; (12 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>977 (50 porters) / 489 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>1,050 (4 men) / 467 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>32 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>62 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>46 (2 men + 1 assistant), (13 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>29 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>16 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>3 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>128 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>61 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,356 DAYS</strong></td>
</tr>
</tbody>
</table>

The total number of days required to construct the tomb of Hemaka was estimated to have taken 1,356 days, almost 5 years.\textsuperscript{907} This could have been significantly reduced if

\textsuperscript{905} Emery, \textit{Hemaka}, 4.

\textsuperscript{906} Refer to Chapter 2 for full details on roof.

\textsuperscript{907} This total is based on a worst case scenario of 3,200 bricks being laid per day. The reason for the lower productivity rate and maximum number of working days was to allow for other factors that may have interrupted the construction of the tomb.
the brickwork was completed faster. Laying a consistent 7,200 bricks per day would have reduced the days to 773 days or just over 3 years.

**Tomb S3036**

<table>
<thead>
<tr>
<th>Task</th>
<th>Volume of Sand (false floor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>560m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>1,764,200</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td>2,500m² + 240m²</td>
</tr>
<tr>
<td>Volume of Sand (false floor)</td>
<td>835m³</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S3036**

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>141 (4 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>362 (50 porters) / 181 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>552 (4 men) / 245 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>24 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>62 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>92 (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>9 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>2 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>114 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>65 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>914 DAYS</strong></td>
</tr>
</tbody>
</table>

**Tomb X**

<table>
<thead>
<tr>
<th>Task</th>
<th>Volume of Sand (false floor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>180m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>858,000</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td>440m²</td>
</tr>
<tr>
<td>Volume of Sand (false floor)</td>
<td>45m³</td>
</tr>
</tbody>
</table>

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908 Excavating in the gravel would have been easier than cutting through rock, but the gravel walls would have needed shoring. For the purposes of estimating the labour days taken to excavate the pit, the excavation rate was kept at a consistent 1m³ per man per day. Any time savings generated by cutting through the gravel would have been taken up in constructing walls to secure the unstable cut.

909 The bonded cross-walls mean that unlike earlier tombs where the bricks of intersecting walls did not interlock, these walls were linked by the brick laying pattern. Refer to Emery’s plans for brick pattern. Emery, *Great Tombs* I, Plate 14. Emery wrote that this may have been due to the bricks used in Ankh-ka’s tomb being uniform in size, whilst Hemaka’s Tomb S3035 utilised small bricks for the niches and normal size bricks everywhere else. Emery, *Great Tombs* I, 73. Whilst possible, it raises the question of why earlier tombs, such as S3357, S3471, S3503 and S3507, also had deep niches when they too only used a single sized brick.

910 Plastered surfaces included: both faces of the enclosure wall, the corridor between the enclosure and superstructure walls, the exterior of the superstructure, all the magazines walls above the false floor level, the substructure and the stairway.
### Construction Summary Tomb X

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>90 (4 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>283 (50 porters) / 142 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>268 (4 men) / 119 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>8 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>7 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>15 (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>3 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1–2 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>6 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>388 DAYS</strong></td>
</tr>
</tbody>
</table>

#### Tomb S3338

- Excavation 324m³
- Mud Bricks (brick size of 24cm x 11cm x 7cm) 479,400
- Plaster No evidence
- Volume of Sand (false floor) 262m³

### Construction Summary Tomb S3338

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>164 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>158 (50 porters) / 79 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>150 (3,200 bricks) / 67 (7,200 bricks)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>12 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>39 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>No evidence of plastering</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>11 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>11 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>6–7 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>378 DAYS</strong></td>
</tr>
</tbody>
</table>

#### Tomb S3111

- Excavation 160m³
- Mud Bricks (brick size of 24cm x 11cm x 7cm) 911 188,200
- Plaster 770m²
- Volume of Sand (false floor) 154m³

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911 It is possible that a smaller tomb correlates to fewer resources being available to the owner, meaning the labour force able to work on the tomb was also smaller. As such, the number of bricklayers may have been confined to no more than four, laying 3,200 bricks per day.
Construction Summary Tomb S3111

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>32 (2 men) ; (8 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>62 (50 porters) / 31 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>59 (3,200 bricks) / 26 (7,200 bricks)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>14 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>23 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>26 (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>7–8 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>3 (4 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>17 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>10 (10 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>153 DAYS^{912}</td>
</tr>
</tbody>
</table>

Tomb S3038

- Excavation
- Mud Bricks (168,700; 59,000; 376,300) 291 m$^3$
- Plaster (573 m$^2$; –; 1,155 m$^2$) 604,000
- Volume of Sand (three building phases) 1,728 m$^2$; 142 m$^3$; 45 m$^3$; 262 m$^3$

Tomb S3038 underwent three distinct building phases. Due to the uniform size, texture and colour of the mud bricks used throughout the three periods, however, it is probable that the works were undertaken within a close period of time.^{913} For the purposes of calculating the construction time, each phase was considered independently.

**Period A**

**Excavation**

The total volume excavated in Period A equated to 291 m$^3$. Based on the plan area of the main pit, a total of eight men could have excavated the first 1.4m depth (measuring 6.2m x 17m), and only four men within the deeper pit (4.75m x 7.8m x 1.75m deep). The larger area would have taken eight men 28 days to excavate, and the burial pit could have been excavated in 17 days by four men. Twelve porters could have removed 8 m$^3$ of material per day, and six porters, 4 m$^3$ per day.

^{912} It is possible that due to the size of the tomb, the labour available may have been restricted. As such, the number of porters, for example, who carried the bricks to site, may have been no more that 50, resulting in the potential increase of construction days from 153 days up to 220 days, allowing for the extra days required to transport the bricks to site.

^{913} Emery, *Great Tombs* I, 82.
Brick Transportation and Brick Laying

The superstructure during the first building phase was a rectangular block of brickwork with vertical sides, which covered the burial pit, and the subsidiary rooms, against which, on the north, south and west sides, sand and rubble had been placed to act as the foundation for a series of mud brick steps. The maximum height of this structure did not exceed 2.3m as the original top was found intact on the north and south sides.914

The total amount of bricks used during Period A amounted to approximately 168,700 units. The transportation of this quantity would have taken 50 porters 52 days. Four bricklayers could complete the brickworks in 53 days at a rate of 3,200 bricks laid daily. At a height of 2.3m, scaffolding would not have been necessary.

Rubble Fill

The volume of rubble amounted to 142m³. The material used as rubble may have been the same material excavated from the substructure. A total of ten men could have placed the material over a period of 21 days, working in conjunction with the bricklaying crew.

Plastering

The total face area estimated to have been plastered during the first building phase was 573m³. The time taken to plaster the surfaces was estimated to have taken one crew a total of 20 days.

Roofing

The material used to roof the substructure was estimated to be comprised of 26 beams of 18cm diameter and 5.6m length over which were laid 32 planks (30cm x 15cm x 8.6m long). This amount of timber would have necessitated the cutting of 42 trees, taking ten men approximately 11 days. The placement of the roof over the tomb would have taken an equal number of men, approximately nine days.

914 Emery, Great Tombs I, 83.
<table>
<thead>
<tr>
<th>TASK</th>
<th>PERIOD A – DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>45 (4–8 men) ; (6–12 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>52 (50 porters) / 26 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>53 (4 men) / 24 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>21 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>20 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>11 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>9 (10 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>174 DAYS</td>
</tr>
</tbody>
</table>

**Period B**

Period B underwent only two changes: the construction of brick terraces around the stepped superstructure and the raising of the existing terrace between the stairways and the southeast corner.\(^916\) No additional excavation work was undertaken. No information was presented on whether the alternations and additions that took place during the second building phase had been plastered. Therefore, it was assumed that no plastering was undertaken during Period B.

<table>
<thead>
<tr>
<th>TASK</th>
<th>PERIOD B – DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick Transport</td>
<td>18 (50 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>19 (4 men) / 9 (9 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>44 DAYS</td>
</tr>
</tbody>
</table>

**Period C**

The third and final building phase involved the addition of mud brick walls to complete the superstructure with the palace façade exterior. This meant additional plastering work would need to be undertaken, and scaffolding would need to be erected. No additional excavation work was undertaken.

\(^915\) An additional 26 days to transport bricks was added to the total number of construction days.  
\(^916\) Emery, *Great Tombs* I, 87.  
\(^917\) 18 days for carting bricks was added to the total number of construction days.
<table>
<thead>
<tr>
<th>TASK</th>
<th>PERIOD C – DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>Nil</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>110 (50 porters) / 55 (100 porters)(^{918})</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>118 (4 men) / 53 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>14 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>39 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>39 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>5 days (2 men + 1 assistant),</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>11 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>9 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>265 DAYS</strong></td>
</tr>
</tbody>
</table>

Total Construction Time for Tomb S3038

The three building phases of Tomb S3038 amounted to a total construction time of 483 days. This assumes that there was no break in between each building phase.

The different construction phases equated to the following:

<table>
<thead>
<tr>
<th>CONSTRUCTION PERIOD</th>
<th>CONSTRUCTION DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period A</td>
<td>174 days</td>
</tr>
<tr>
<td>Period B</td>
<td>44 days</td>
</tr>
<tr>
<td>Period C</td>
<td>265 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>483 DAYS</strong></td>
</tr>
</tbody>
</table>

\(^{918}\) 55 days for carting bricks was added to the total number of construction days.

\(^{919}\) The whole exterior of the superstructure was covered with gypsum plaster, as were the stairs and the substructure. Emery, *Great Tombs* I, 90–91.

\(^{920}\) The plastered walls of the burial chamber were subsequently painted with a dado of yellow. Emery, *Great Tombs* I, 91.
### Tomb S3505

<table>
<thead>
<tr>
<th>Task</th>
<th>DAYS</th>
<th>Volume of Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>92 (5 men) ; (8 porters)</td>
<td>460m³</td>
</tr>
<tr>
<td>Mud Bricks (total for all phases)</td>
<td>2,014,700</td>
<td>2,600m² + 530m²</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td>2,600m² + 530m²</td>
<td>1,040m³</td>
</tr>
</tbody>
</table>

#### Construction Summary Tomb S3505

<table>
<thead>
<tr>
<th>Task</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>92 (5 men) ; (8 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>665 (50 porters) / 333 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>672 (4 men) / 280 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>20 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>75 (20 men) / 31 (50 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>105 (2 plasterers + 1 assistant) / 53 (4 plasterers + 2)</td>
</tr>
<tr>
<td>Painting</td>
<td>38 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (6 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>13 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>9 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>992 DAYS</strong></td>
</tr>
</tbody>
</table>

### Tomb S3500

<table>
<thead>
<tr>
<th>Task</th>
<th>Tomb</th>
<th>Subsidiary Graves (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>365m³</td>
<td>4.4m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>601,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td>1,010m²</td>
<td>10m²</td>
</tr>
<tr>
<td>Volume of Sand</td>
<td>273m³</td>
<td>–</td>
</tr>
</tbody>
</table>

#### Construction Summary Tomb S3500

<table>
<thead>
<tr>
<th>Task</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>92 (4 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>198 (50 porters) / 99 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>188 (4 men) / 84 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>8 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>21 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>34 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>10 (5 men)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>7 (4 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>3 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>3 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>345 DAYS + 12 days (subsidiary graves)</strong></td>
</tr>
</tbody>
</table>

921 The total time taken to build the four subsidiary graves was added to the summary table as the additional days were minimal compared to the construction of the main structure.
Tomb S3121

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>32 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>27 (50 porters) / 14 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>26 (4 men) / 15 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>4 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>13 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Painting</td>
<td>16 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>10 (5 men)</td>
</tr>
<tr>
<td>Stone Placement(^923)</td>
<td>7 (4 men)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>1 (2 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>1 (2 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>99 DAYS</strong></td>
</tr>
</tbody>
</table>

The height was assumed to not have exceeded 2m, so scaffolding would not have been required.

\(^923\) The passageway had been roofed with large limestone blocks with an average size of 0.6m x 1.0m and 2m in length (Emery, *Great Tombs* I, 117). The total volume of stone equated to 8.4m\(^3\), or just over 17 tonnes. Quarrying this amount of stone would have taken one man a total of 11 days, cutting at a rate of 0.8m\(^3\) per day. A total of seven slabs had been placed over the passage, weighing, on average, 2.6 tonnes each. These slabs would have been transported to site during other construction activities. The placement of the slabs, however, would have added to the overall construction program. Based on ten men being required to move 1 tonne, at least 30 men would be needed to manoeuvre each slab into place. Assuming each slab took one day to secure into position, the stone roofing could have been completed in seven days.
Tomb S3120

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>18 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>36 (50 porters) / 18 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>26 (4 men) / 12 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>4 (5 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>10 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Painting</td>
<td>16 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>11 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>103 DAYS</strong></td>
</tr>
</tbody>
</table>

Construction Summary Tomb S3120

*2nd Dynasty Royal Tombs at Saqqara*

Hetepsekhemwy

Hetepsekhemwy, first ruler of the 2nd Dynasty, chose to be buried at Saqqara instead of Abydos, where his predecessors had been laid to rest. Remains of a superstructure no longer survive, however, an extensive series of subterranean galleries and chambers enabled an approximate construction time to be determined for this portion of the tomb. An average height of 2m was assumed for the subterranean gallery tomb, with the volume excavated based on scaling the plan of the tomb.

Excavation

The tomb was comprised of an estimated floor plan area of 1,810m², which, at 2m high, resulted in 3,200m³ being excavated. From the plan area of the tomb and the size of the

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924 As with Tomb S3121, the height was assumed not to have exceeded 2m, so scaffolding was not used.
925 An additional 184 days were added to the total construction time to allow for the transportation of bricks to site as it seems unlikely that more than 50 porters would have been assigned to this tomb. This assumes the transportation of bricks commenced at the same time as excavation of the tomb. So, 36 days to transport bricks minus 18 days to excavate = 18 days.
926 The construction of this subterranean tomb was undertaken over different stages. However, for the purpose of this research, the total estimated construction time is presented. C. Lacher, “Das Grab des Hetepsechemui/Raneb in Saqqara”, *MENES, Studien zur Kultur und Sprache der ägyptischen Frühzeit und des Alten Reiches* 5 (2008), 440.
927 An average height of 2m was estimated based on data available on other subterranean tombs. See Quibell, *Archaic Mastabas*. 

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corridors, it is possible that five to ten excavators may have been employed to cut out
the tomb. The range would have depended on how practical it was to use only five
evacators supported by five men to break-up the rock into smaller pieces, ready to be
removed by 12 porters. A total of ten men excavating would have required the support
of a similar number of men to break-up the rock, and 16 porters. It is likely that cutting
the subterranean tomb with such large numbers of workers would have rendered the
conditions underground intolerable; the removal of 10m$^3$ of material daily meant 360
baskets of material needed to be removed each day or 45 baskets per hour.

By employing five excavators, the tomb would have taken an estimated 724 days to cut;
a team of ten could have completed the same task in half that time. Ultimately, the use
of five excavators, however, appears to be far more realistic and logistically practical.

**Brick Transportation and Brick Laying**

Based on the reconstruction of the superstructure by Lacher,\textsuperscript{928} the number of bricks
estimated to have been consumed by Hetepsekhemwys’s tomb equated to 793,650. The
time taken to transport the bricks to the site would have amounted to 243 days using 50
porters, and 121 days using 100 porters. The bricklayers would have taken 248 days to
construct the mud brick walls, at a rate of 3,200 bricks per day, and 110 days laying
7,200 bricks per day.

**Plastering**

Assuming the exterior of the superstructure had been plastered, resulting in a total wall
area of 1,360m$^2$, one crew could have completed these works in 34 days.

**Construction Summary Hetepsekhemwy**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>724 (5 men) ; (12 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>243 (50 porters) / 121 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>248 (4 men) / 110 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>9 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>46 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,018 DAYS</strong></td>
</tr>
</tbody>
</table>

\textsuperscript{928} Lacher, *MENES* 5, 430–431.
The tomb of Hetepsekhemwy was estimated to have taken a total of 3.5 years to complete, largely due to the time required to excavate the substantial subterranean galleries and rooms.

**Ninetjer**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation (1,800m³)</td>
<td>407 (5 men) ; (12 porters)</td>
</tr>
<tr>
<td>Brick Transport &amp; Laying</td>
<td>248 (4 men); 243 (50 porters)</td>
</tr>
<tr>
<td>Plastering</td>
<td>46 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>701 DAYS</strong></td>
</tr>
</tbody>
</table>

2nd Dynasty Saqqara Private Tombs

**Tomb S3024**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>131 (2–4 men) ; (3–6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>56 (50 porters) / 28 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>59 (4 men) / 26 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>2 (4 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>22 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>6 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Painting</td>
<td>16 (2 men + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (9 men)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>15 (4 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>249 DAYS</strong></td>
</tr>
</tbody>
</table>

---


930 No superstructure was found for the tomb of Ninetjer. Lacher, Tomb of King Ninetjer, 217. For completeness, however, a superstructure of similar size to that of Hetepsekhemwy was assumed, despite the latter have a more extensive subterranean gallery.

931 Scaffolding would not have been required on the exterior of the superstructure based on the assumed height of 2m. However, some method of support may have been necessary if the brick walls lining the stairway extended the full height of the cut, which could have been undertaken in two days. The placement of the scaffolding in this area could have taken place during other construction activities.
Tomb S2302

- Excavation: 197m³
- Mud Bricks: 642,900
- Plaster: 1,150m²
- Rubble Fill: 1,270m³

Tomb S2302 was made up of a mud brick superstructure filled with ‘black mud filling’ beneath which lay the subterranean gallery tomb.\textsuperscript{932}

**Excavation**

The total volume excavated to create the subterranean gallery equated to approximately 197m³. The excavation of this tomb could have been undertaken progressively, each room excavated as the corridor was being cut, thereby limiting the excavators to perhaps no more than one or two per room due to the size and cramped conditions. Alternatively, the full length of the corridor may have been excavated and each room, on both the left and right sides of the corridor, subsequently excavated together. This means 14 excavators (seven rooms each side) could have been working at any one time. Whilst this would have certainly accelerated the construction program, it would also have been impractical due to the number of support workers required and the volume of dust they would have generated in such a small area. The corridor would have quickly become stifling hot with little or no air and visibility would also have been poor. With this in mind, a team of two men excavating was presumed for the purpose of calculating the number of workdays it would have taken to construct the tomb.

As the workers were cutting in rock, a rate of 0.8m³ per day per man was deduced for the subterranean tombs, resulting in a total of 123 excavation days being required.\textsuperscript{933} Three porters could have carried the material out of the tomb, and it is possible that an equal number of men would have been employed to break down the large pieces of rock cut by the excavators to make transportation more manageable.

\textsuperscript{932} Quibell, *Archaic Mastabas*, 29.

\textsuperscript{933} The productivity rate was reduced from 1.0m³ to 0.8m³ due to the conditions for excavating underground would have made the job a more laborious task than working in an open cutting.
Brick Transportation and Brick Laying

A total of 642,900 mud bricks were calculated to have been required to build the superstructure at a height of 4m.\textsuperscript{934} The transportation of this many bricks would have taken 50 porters 189 days and 100 men a total of 95 days. Based on the bricklaying rate ranging from 3,200 per day up to 7,200, the total construction days necessary to complete the brick works would have been between 90 and 201 days.

Rubble Fill

Assuming the rubble only came up to a height of 1m above ground, a total of 1,270m\textsuperscript{3} of material would have been needed to fill the interior of the superstructure.\textsuperscript{935} Employing 20 porters would have increased the workdays to 95 days.\textsuperscript{936}

Roofing and Sealing the Tomb

The introduction of subterranean gallery tombs meant timber roofs were no longer required. Entry into the tomb was through the stairway blocked with one or more portcullis stones. For the purposes of calculating the construction time for the subterranean tombs, portcullis stones were estimated to have taken one day to quarry and one day to put into position per slab.

Construction Summary Tomb S2302

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>123 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>189 (50 porters) / 95 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>201 (4 men) / 90 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>15 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>95 (20 men) / 38 (50 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>39 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>459 DAYS</strong></td>
</tr>
</tbody>
</table>

\textsuperscript{934} Whilst tombs S3121, S3120 and S3024 were assumed to have had 2m high superstructures, the height of the 2\textsuperscript{nd} Dynasty subterranean gallery tombs was assumed, once again, to be 4m. This is because the footprint of the superstructures is so substantial.
\textsuperscript{935} Note: The thickness of the superstructure mud brick walls was approximately 5.5m meaning that structurally, they were capable of withstanding the pressure from rubble placed within the interior to the full height of 4m. A height of 1m was assumed, as a greater height would have increased the volume of material to be deposited beyond practical levels.
\textsuperscript{936} This number of porters was assumed for the 1\textsuperscript{st} Dynasty tombs also.
### Tomb S2171

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Excavation</td>
<td>64 m³</td>
</tr>
<tr>
<td>- Mud Bricks</td>
<td>420,100</td>
</tr>
<tr>
<td>- Plaster</td>
<td>450 m²</td>
</tr>
<tr>
<td>- Rubble Fill</td>
<td>560 m³</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb S2171**

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>40 (2 men); (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>123 (50 porters) / 62 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>132 (4 men) / 59 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>10 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>20 (20 men) / 17 (50 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>15 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>230 DAYS</strong></td>
</tr>
</tbody>
</table>

937 Based on Reisner’s calculated floor plan area of the subterranean structure equalling 40.67 m², and assuming an average height of 1.6m, the total volume excavated equalled 64m³. The height of 1.6m was chosen based on Tomb S2302, which is a larger subterranean tomb and was documented to be 1.4m to 1.8m high. G. A. Reisner, *The Development of the Egyptian Tomb Down to the Accession of Cheops* (Oxford, 1936), 138–139.

938 Due to the width of the corridors and size of the rooms, the excavation rate was controlled by the number of workers who could work within the confined space. It is possible that one worker, and no more than two, excavated the underground tomb. It is unlikely, however, that the full length of the corridor was cut by two men and the rooms on either side by extra workers. The reason for this, as discussed with Tomb S2302, was that too many workers in such a small area would have made working conditions intolerable and unsafe, even by ancient standards. The workers also had oil lamps for lighting the dark underground chambers, further reducing air quality. Therefore, supposing that only two workers were employed at any one time, the subterranean tomb would have taken a total of 40 days to cut out.

939 The difference between the days required to transport the bricks to site using 100 men (62), and the time taken to excavate the tomb (40), equals 22 days, which was added to the total construction time.
Tomb S2498

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>29 (2 men) ; 6 porters</td>
<td>45m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td></td>
<td>385,100</td>
</tr>
<tr>
<td>Plaster</td>
<td></td>
<td>470m³</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td></td>
<td>285m³</td>
</tr>
</tbody>
</table>

Construction Summary Tomb S2498

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>29 (2 men) ; 6 porters</td>
<td>45m³</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>113 (50 porters) / 56 (100 porters)</td>
<td>89m³</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>121 (4 men) / 54 (9 men)</td>
<td>759,300</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>8 (10 men)</td>
<td>786m³</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>22 (20 men) / 9 (50 men)</td>
<td>540m³</td>
</tr>
<tr>
<td>Plastering</td>
<td>16 (2 plasterers + 1 assistant)</td>
<td></td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
<td></td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>216 DAYS</strong></td>
<td></td>
</tr>
</tbody>
</table>

Tomb S2307

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>56 (2 men) ; 6 porters</td>
<td>89m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td></td>
<td>759,300</td>
</tr>
<tr>
<td>Plaster</td>
<td></td>
<td>786m³</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td></td>
<td>540m³</td>
</tr>
</tbody>
</table>

Construction Summary Tomb S2307

<table>
<thead>
<tr>
<th>Task</th>
<th>Days</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>56 (2 men) ; 6 porters</td>
<td>89m³</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>222 (50 porters) / 111 (100 porters)</td>
<td>759,300</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>238 (4 men) / 106 (9 men)</td>
<td>786m³</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>10 (10 men)</td>
<td></td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>41 (20 men) / 16 (50 men)</td>
<td></td>
</tr>
<tr>
<td>Plastering</td>
<td>27 (2 plasterers + 1 assistant)</td>
<td></td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
<td></td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>363 DAYS</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

940 Reisner, *Development of the Egyptian Tomb*, 139–140.
941 Based on the plan of the superstructure as published by Quibell, the superstructure, at a height of 4m, would have consumed 385,100 mud bricks. Quibell, *Archaic Mastabas*, pl. 2.
942 An additional 27 days were added to the total construction. This is based on 100 porters transporting brick taking 56 days minus 29 days excavation = 27 days.
943 Reisner, *Development of the Egyptian Tomb*, 140.
944 The quantity of bricks was estimated based on Quibell’s plan of the superstructure and scaling the thickness of the mud brick walls. Quibell, *Archaic Mastabas*, pl. 1.
945 Based on the scale of the superstructure, it is probable that a greater number of porters may have been assigned to transport mud bricks to site. As such, no additional days were added to allow for the transportation of bricks to site since this would have taken place during other activities.
Tomb S2322

- Excavation\(^{946}\) 43\(\text{m}^3\)
- Mud Bricks\(^{947}\) 220,000
- Plaster\(^{948}\) 298\(\text{m}^2\)
- Rubble Fill 120\(\text{m}^3\)

Construction Summary Tomb S2322

The summarised results below have been calculated for a 4m high mud brick superstructure and 2m high superstructure.

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS (Based on 4m high superstructure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>27 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>65 (50 porters) / 33 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>69 (4 men) / 31 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>6 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>41 (20 men) / 16 (50 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>10 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>148 DAYS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS (Based on 2m high superstructure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>27 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>34 (50 porters) / 17 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>37 (4 men) / 16 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>41 (20 men) / 16 (50 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>6 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>106 DAYS</td>
</tr>
</tbody>
</table>

\(^{946}\) Reisner, *Development of the Egyptian Tomb*, 141.

\(^{947}\) It is possible that the smaller superstructures by this stage were only built to a height of 2m, resulting in the number of bricks used equalling 115,400. Refer to the Construction Summary Table for the time taken to build this tomb, assuming heights of 2m and 4m.

\(^{948}\) A 2m high superstructure would have only had 172\(\text{m}^2\) plastered.
### Tomb S2337

- Excavation 949
- Mud Bricks
- Plaster
- Rubble Fill

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>59 (2 men) ; (6 porters)</td>
<td>94m³</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>138 (50 porters) / 70 (100 porters)</td>
<td></td>
</tr>
<tr>
<td>Brick Laying</td>
<td>148 (4 men) / 66 (9 men)</td>
<td></td>
</tr>
<tr>
<td>Scaffolding</td>
<td>12 (10 men)</td>
<td></td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>57 (20 men) / 23 (50 men)</td>
<td></td>
</tr>
<tr>
<td>Plastering</td>
<td>18 (2 plasterers + 1 assistant)</td>
<td></td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
<td></td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2835 DAYS</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Tomb S2406

- Excavation 950
- Mud Bricks
- Plaster
- Rubble Fill

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>55 (2 men) ; (6 porters)</td>
<td>88m³</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>97 (50 porters) / 46 (100 porters)</td>
<td></td>
</tr>
<tr>
<td>Brick Laying</td>
<td>103 (4 men) / 46 (9 men)</td>
<td></td>
</tr>
<tr>
<td>Scaffolding</td>
<td>8 (10 men)</td>
<td></td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>19 (20 men) / 23 (50 men)</td>
<td></td>
</tr>
<tr>
<td>Plastering</td>
<td>13 (2 plasterers + 1 assistant)</td>
<td></td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>1 (1 man)</td>
<td></td>
</tr>
<tr>
<td>Stone Placement</td>
<td>1 (4 men)</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>200 DAYS</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

949 Reisner, *Development of the Egyptian Tomb*, 141–142.
950 Reisner, *Development of the Egyptian Tomb*, 143.
951 An additional nine days (55 days minus 46 days), were added to the construction time as discussed for the earlier tombs. Refer to Tomb S2171.
Summary of Results - Saqqara

In summary, it can be seen from the chart below, that the number of days taken to construct the tombs at Saqqara reduced over time. This is due to the diminishing size and changes in styles of tombs, the later tombs being subterranean.

One could speculate that the diminishing size of the elite private tombs during the 2nd Dynasty coincided with the kings of this period moving away from their ancestral burial ground at Abydos and choosing to be buried at Saqqara. The wealthy tomb owners, then, would have needed to be content with building more modest tombs next to their kings.

---

Graph 6.1: Saqqara – total construction days

---

952 The choice by the 2nd Dynasty kings to be buried at Saqqara, as discussed earlier, could be two-fold: (1) to be closer to the centre of power and capital Memphis, and (2) due to the geology of Saqqara being conducive for the new style of subterranean tomb.
6.2.2 HELWAN

Tomb 1473.H.2

The total volume excavated for Tomb 1473.H.2 amounted to 310m$^3$. The substructure, entered via a stairway, was comprised of two magazines and the burial chamber. Based on the size of the three rooms, however, it would seem unlikely that more than two men could have worked at the same time due to the close proximity of each room. Assuming an excavation crew of two men then, the substructure would have taken 155 days to cut with the assistance of at least three porters.

Brick Transportation and Brick Laying

A total of 177,500 mud bricks were calculated to have been used to build the superstructure. The transportation of this quantity of bricks to the site would have taken 50 porters a total of 75 days and 100 porters 37 days. The task of laying this quantity of bricks would have taken four bricklayers (3,200 bricks per day) a total of 57 days and nine bricklayers (7,200 bricks per day) only 25 days. The superstructure of the tomb was estimated not to have exceeded 2m in height, and would therefore not require scaffolding.\(^{953}\)

Plastering

The total face area plastered was calculated to be 530m$^2$. One crew consisting of two plasterers and one assistant completing 30m$^2$ per day could have plastered the walls of the tomb in 18 days.

Roofing

Based on the roofing design and the assumed beam dimensions, the resultant timber requirements, as discussed in Chapters 2 and 4, were 27 beams of 30cm diameter x 3m long with 15 planks x 3.2m long and 10 planks x 5.5m long (30cm x 12cm). If one tree was cut to produce each beam, and two planks could be sourced from one tree, a total of 40 trees would have needed to be cut down. A team of ten men working in pairs could have completed this task in 12 days. The roof placement once the timber had arrived to the site would have taken the same number of workers (ten men) a total of four days to install.

\(^{953}\) The height of the superstructure of all Helwan tombs was calculated at 2m.
Summary Tomb 1473.H.2

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>155 days</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>75 (50 porters) / 37 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>57 (4 men) / 25 (9 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>18 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>12 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>4 (10 men)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>234 DAYS</td>
</tr>
</tbody>
</table>

The results for the remaining Helwan tombs are summarised below.\(^{954}\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td></td>
<td></td>
<td></td>
<td>65 days(^{956})</td>
<td>47 days(^{957})</td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>35 days</td>
<td>33 days</td>
<td>39 days(^{955})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters</td>
<td>4 days</td>
<td>20 days</td>
<td>16 days</td>
<td>73 days</td>
<td>224 days</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>90 days</td>
</tr>
<tr>
<td>Bricklaying</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>2 days</td>
<td>12 days</td>
<td>8 days</td>
<td>35 days</td>
<td>-</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>1 day</td>
<td>6 days</td>
<td>4 days</td>
<td>17 days</td>
<td>54 days</td>
</tr>
<tr>
<td>Plastering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>Nil(^{958})</td>
<td>3 days</td>
<td>3 days</td>
<td>6 days</td>
<td>22 days</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td></td>
<td></td>
<td></td>
<td>17 days</td>
<td>-</td>
</tr>
<tr>
<td>(2 men)(^{959})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Stone Placement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15 days</td>
<td>-</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>6 days</td>
<td>6 days</td>
<td>2 days</td>
<td>-</td>
<td>11 days</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2–4 men)</td>
<td>7 days</td>
<td>4 days</td>
<td>2 days</td>
<td>-</td>
<td>12 days</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 porters)</td>
<td>7 days</td>
<td>5 days</td>
<td>3 days</td>
<td>7 days</td>
<td>9 days</td>
</tr>
<tr>
<td>TOTAL</td>
<td>51 days</td>
<td>51 days</td>
<td>51 days</td>
<td>110 days</td>
<td>144 days</td>
</tr>
</tbody>
</table>

\(^{954}\) Refer to Chapter 4 for quantity of materials used for each tomb. The total number reflects the maximum number of days taken to build the structures. Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.

\(^{955}\) Based on the plan area of the substructure, only one excavator could be engaged to cut the pit.

\(^{956}\) The plan area of pit allowed for three excavators to cut the substructure.

\(^{957}\) The plan area of pit allowed for three excavators to cut the substructure.

\(^{958}\) No plastering or painting of the tomb walls was recorded. As the tomb was incomplete, the walls may have been left bare. Z. Y. Saad, *Royal Excavations at Helwan (1945-1947)* SASAE 14 (Cairo, 1951), 7–8.

\(^{959}\) One man quarrying at 0.8m\(^3\) per day and one man to work the faces of the quarried stone.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td>46 days</td>
<td>64 days $^{960}$</td>
<td>74 days</td>
<td>183 days</td>
<td>42 days $^{961}$</td>
</tr>
<tr>
<td>2 men (3 porters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 porters</td>
<td>61 days</td>
<td>190 days</td>
<td>90 days</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>20 porters</td>
<td>30 days</td>
<td>95 days</td>
<td>45 days</td>
<td>200 days</td>
<td>114 days</td>
</tr>
<tr>
<td>50 porters</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>100 days</td>
<td>46 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000/day</td>
<td>16 days</td>
<td>46 days</td>
<td>22 days</td>
<td>–</td>
<td>55 days $^{962}$</td>
</tr>
<tr>
<td>2,000/day</td>
<td>8 days</td>
<td>23 days</td>
<td>11 days</td>
<td>120 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>6 days</td>
<td>9 days</td>
<td>6 days</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 men) $^{963}$</td>
<td>–</td>
<td>5 days</td>
<td>3 days</td>
<td>15 days</td>
<td>16 days</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>4 days</td>
<td>2 days</td>
<td>10 days</td>
<td>13 days</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>3 days</td>
<td>10 days</td>
<td>10 days</td>
<td>5 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2–4 men)</td>
<td>6 days</td>
<td>14 days</td>
<td>8 days</td>
<td>10 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 porters)</td>
<td>5 days</td>
<td>10 days</td>
<td>8 days</td>
<td>7 days</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>71 days</td>
<td>124 days</td>
<td>109 days</td>
<td>330 days</td>
<td>112 days</td>
</tr>
</tbody>
</table>

$^{960}$ Based on the plan area of the substructure, only one excavator could be engaged to cut the pit.

$^{961}$ Based on the plan area of the substructure, only one excavator could be engaged to cut the pit.

$^{962}$ Due to the small pit, only one bricklayer could have worked within the confined space.

$^{963}$ One man quarrying at 0.8m$^3$ per day and one man to work the faces of the quarried stone.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>121 days</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>180 days</td>
</tr>
<tr>
<td>- 3 men (5 porters)</td>
<td>–</td>
<td>77 days</td>
<td>40 days</td>
<td>45 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters</td>
<td>27 days</td>
<td>303 days</td>
<td>24 days</td>
<td>269 days</td>
<td>–</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>–</td>
<td>121 days</td>
<td>–</td>
<td>108 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>13 days</td>
<td>–</td>
<td>12 days</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>7 days</td>
<td>73 days</td>
<td>6 days</td>
<td>65 days</td>
<td>–</td>
</tr>
<tr>
<td>- 3,000/day</td>
<td>–</td>
<td>49 days</td>
<td>–</td>
<td>43 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>3 days</td>
<td>8 days</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 men)</td>
<td>2 days</td>
<td>54 days</td>
<td>19 days</td>
<td>2 days</td>
<td>43 days</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1 day</td>
<td>1 day</td>
<td>22 days</td>
<td>6 days</td>
<td>1 day</td>
<td>34 days</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>11 days</td>
<td>5 days</td>
<td>6 days</td>
<td>9 days</td>
<td>41 days</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2–4 men)</td>
<td>15 days</td>
<td>13 days</td>
<td>17 days</td>
<td>10 days</td>
<td>36 days</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 porters)</td>
<td>10 days</td>
<td>7 days</td>
<td>10 days</td>
<td>6 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>157 days</td>
<td>200 days</td>
<td>79 days</td>
<td>127 days</td>
<td>250 days</td>
</tr>
</tbody>
</table>

964 Based on the plan area of the substructure, nine excavators could have been engaged to cut the pit requiring a minimum of 14 porters per day.

965 One man quarrying at 0.8m³ per day and one man to work the faces of the quarried stone.

966 The tomb, when first excavated, was found to have been walled up on the lower portions of the west and east sides with pieces of limestone muddled together. It was suggested that the tomb may have being lined with limestone, which was then plundered by builders in later periods. Saad, Helwan, 18.

967 The placement of timber is based on an increased workforce of ten men.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1 man (3 porters)</td>
<td>56 days</td>
<td>–</td>
<td>53 days</td>
<td>55 days</td>
<td>45 days</td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>–</td>
<td>58 days</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters</td>
<td>161 days</td>
<td>94 days</td>
<td>50 days</td>
<td>255 days</td>
<td>17 days</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>65 days</td>
<td>38 days</td>
<td>20 days</td>
<td>102 days</td>
<td>–</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>- 1,000/day</td>
<td>84 days</td>
<td>45 days</td>
<td>24 days</td>
<td>122 days</td>
<td>9 days</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>42 days</td>
<td>23 days</td>
<td>12 days</td>
<td>61 days</td>
<td>–</td>
</tr>
<tr>
<td>- 3,000/day</td>
<td>28 days</td>
<td>15 days</td>
<td>–</td>
<td>41 days</td>
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</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>18 days</td>
<td>6 days</td>
<td>10 days</td>
<td>6 days</td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>2 days</td>
<td>4 days</td>
<td>2 days</td>
<td>15 days</td>
<td>7 days</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2–4 men)</td>
<td>4 days</td>
<td>8 days</td>
<td>5 days</td>
<td>15 days</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 porters)</td>
<td>3 days</td>
<td>11 days</td>
<td>5 days</td>
<td>8 days</td>
<td>4 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>123 days</td>
<td>128 days</td>
<td>97 days</td>
<td>145 days</td>
<td>64 days</td>
</tr>
</tbody>
</table>

968 The plan area of the substructure allowed for five excavators to cut the pit.
<table>
<thead>
<tr>
<th></th>
<th>480.H.3</th>
<th>499.H.2</th>
<th>553.H.2</th>
<th>505.H.4</th>
<th>OP2/1</th>
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<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1 man (3 porters)</td>
<td>13 days</td>
<td>-</td>
<td>32 days</td>
<td>91 days</td>
<td>27 days</td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>-</td>
<td>33 days</td>
<td>-</td>
<td>45 days</td>
<td>-</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 10 porters</td>
<td>-</td>
<td>50 days</td>
<td>29 days</td>
<td>-</td>
<td>122 days</td>
</tr>
<tr>
<td>- 20 porters</td>
<td>-</td>
<td>25 days</td>
<td>15 days</td>
<td>-</td>
<td>61 days</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>-</td>
<td>10 days</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>-</td>
<td>12 days</td>
<td>7 days</td>
<td>-</td>
<td>29 days</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>-</td>
<td>6 days</td>
<td>-</td>
<td>-</td>
<td>15 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>-</td>
<td>3 days</td>
<td>2 days</td>
<td>10 days</td>
<td>6 days</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(10 men)</td>
<td>3 days</td>
<td>4 days</td>
<td>4 days</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(2–4 men)</td>
<td>2 days</td>
<td>4 days</td>
<td>3 days</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(10 porters)</td>
<td>1 day</td>
<td>5 days</td>
<td>2 days</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>16 days</td>
<td>57 days</td>
<td>46 days</td>
<td>101 days</td>
<td>64 days</td>
</tr>
</tbody>
</table>

Despite the large subterranean tomb, due to the width of its passages, it seems unlikely that more than one excavator, perhaps two, were engaged to cut the underground chambers. This meant the excavation of this tomb would have taken between 45 to 91 days, the latter being most probable due to the confined space being compounded with the addition of men carrying the material.
<table>
<thead>
<tr>
<th>Helwan</th>
<th>810.H.3</th>
<th>25.H.5</th>
<th>OP4/1</th>
<th>OP4/2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1 man (3 porters)</td>
<td>55 days</td>
<td>73 days</td>
<td>-</td>
<td>11 days</td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>-</td>
<td>-</td>
<td>56 days</td>
<td>-</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td>216 days</td>
<td>-</td>
</tr>
<tr>
<td>- 10 porters</td>
<td>-</td>
<td>-</td>
<td>108 days</td>
<td>-</td>
</tr>
<tr>
<td>- 20 porters</td>
<td>-</td>
<td>-</td>
<td>43 days</td>
<td>-</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td>52 days</td>
<td>-</td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>-</td>
<td>-</td>
<td>26 days</td>
<td>-</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td>9 days</td>
<td>-</td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>55 days</td>
<td>73 days</td>
<td>117 days</td>
<td>11 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Helwan</th>
<th>OP4/15</th>
<th>OP4/19</th>
<th>OP4/35</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>15 days</td>
<td>13 days</td>
<td>11 days</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 10 porters</td>
<td>23 days</td>
<td>77 days</td>
<td>75 days</td>
</tr>
<tr>
<td>- 20 porters</td>
<td>-</td>
<td>39 days</td>
<td>38 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>8 days</td>
<td>26 days</td>
<td>26 days</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>4 days</td>
<td>13 days</td>
<td>13 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>3 days</td>
<td>4 days</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Rubble Fill</strong></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26 days</td>
<td>43 days</td>
<td>42 days</td>
</tr>
</tbody>
</table>
Summary of Results – Helwan

The following graph presents the total construction days tabulated.

Graph 6.2: Helwan – total construction days

It is possible that the rate of bricklaying for the Helwan tombs was controlled by the quantity of bricks delivered per day. As the cemetery was tightly packed with graves, it seems unlikely construction materials would have been stored on site, since there would have been a high probability of theft unless someone was appointed to guard the materials. As such, the rate of construction may have been based on the brick transportation figures and not the bricklaying rate, therefore increasing construction times depending on the number of porters and bricklayers available each day.
6.2.3 ABYDOS

1st Dynasty Royal Tombs

Tomb B0/1/2

<table>
<thead>
<tr>
<th>TOMB</th>
<th>B1</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>34.4m³</td>
<td>18.6m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>5,800</td>
<td>4,350</td>
</tr>
<tr>
<td>Plaster</td>
<td>34.1m²</td>
<td>24.4m²</td>
</tr>
</tbody>
</table>

Construction Summary B1/2

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>35 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>8 (10 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>7 (2 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>3 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Roofing</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>47 DAYS</strong></td>
</tr>
</tbody>
</table>

Assuming B0 was constructed during the same period of time as B1/2, with the addition of extra workers, we can deduce that the total construction time for B0/1/2 could have taken approximately 47 days.

Tomb B7/9

<table>
<thead>
<tr>
<th>TOMB</th>
<th>B7</th>
<th>B9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>37m³</td>
<td>33m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>5,700</td>
<td>3,600</td>
</tr>
<tr>
<td>Plaster</td>
<td>35m²</td>
<td>34m²</td>
</tr>
</tbody>
</table>

Construction Summary Tomb B7/9

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>39 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>12 (10 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>6 (2 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>4 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Roofing</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>51 DAYS</strong></td>
</tr>
</tbody>
</table>
Tomb B17/18

<table>
<thead>
<tr>
<th>TOMB</th>
<th>B17</th>
<th>B18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>35m³</td>
<td>53m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>6,780</td>
<td>8,950</td>
</tr>
<tr>
<td>Plaster</td>
<td>21m²</td>
<td>50m²</td>
</tr>
</tbody>
</table>

Construction Summary Tomb B17/18

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>53 (2 men) ; (6 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>9 (10 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>10 (2 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>5 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Roofing</td>
<td>2 days</td>
</tr>
<tr>
<td>TOTAL</td>
<td>70 DAYS</td>
</tr>
</tbody>
</table>

Aha – B10/15/19, 13/14, B16

<table>
<thead>
<tr>
<th>TOMB</th>
<th>B10/15/19</th>
<th>13/14, B16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>1,075m³</td>
<td>886m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>318,500</td>
<td>190,200</td>
</tr>
<tr>
<td>Plaster</td>
<td>270m²</td>
<td>780m²</td>
</tr>
</tbody>
</table>

Excavation

Based on the plan area of each pit pertaining to B10/15/19, a total of 18 men could have been engaged cutting 18m³ daily. This means the total time taken to excavate B10/15/19 equated to 67 days, requiring the additional support of 27 porters.

The 37 chambers designated 13/14 and B16 were smaller in plan and only one man would have been able to work within the confines of each. This resulted in the total excavation time of 24 days, if each of the 35 graves were cut simultaneously, employing a total 37 workers daily. The removal of 37m³ of material per day meant a total of 55 porters were required, but this may not have been practical. Therefore, assuming that only half this number was employed to cut 13/14 and B16, 48 days, and only 19 excavators and 30 porters would have been required.

As such it is possible that B10/15/19 were excavated first, taking 67 days and 18 excavators per day, followed by 13/14 and B16 over a period of 48 days with 19
excavators, and approximately 30 porters. Assuming this to be true, the total number of days required to excavate these chambers would have amounted to 115 days.

It is important to note that the sandy stratum at Abydos would have been easier to excavate than the tough rock encountered at Saqqara and Helwan. However, loose material has its own problems, specifically, that it needs to be retained to prevent the collapse of the cutting. As such, the excavation rate of 1m³ per man per day (the same rate as used to excavate the Saqqara and Helwan tombs) was maintained, and this allowed for the extra time that would have been required to build temporary supports when cutting the graves at Abydos.

**Brick Transportation and Bricklaying**

The transportation of over half a million bricks for Aha’s tomb meant a sizable crew of porters was necessary. A team of 50 porters would have taken a total of 168 days to transport this number of bricks to site. The brickworks would have taken four bricklayers laying 3,200 bricks per day approximately 159 days to complete. Increasing the number of bricks laid per day to 7,200 would have decreased the working days to only 71.

**Scaffolding**

At an average depth of 3.6m, chambers B10/B15/B19 would have needed scaffolding, although the bricklayers may have stood on the walls as the walls grew in height. However, scaffolding would have been necessary, if not for the construction of the mud brick walls, then most definitely for the application of plaster and paint on the finished wall surfaces. If scaffolding had been used, the total time taken to erect and subsequently dismantle the scaffolding utilising five men would have amounted to six days. The subsidiary chambers 13/14 and B16 did not require scaffolding.

**Plastering**

By the time of Aha’s tomb, the plasters would have been well on their way to fine tuning their skills, and as such the daily plastering rate for the purposes of calculating the time taken to plaster the walls was increased from 10m² to 30m² per crew (two

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970 Refer to Chapter 5, Section 5.4.7 for further discussion on scaffolding and evidence of scaffolding.
plasterers and one assistant).\textsuperscript{971} This means the chambers would have taken some 35 days to plaster.

\textit{Timber Shrine and Roofing}

There were postholes on floor of the long walls of the three chambers, B10/B15/B19, that were used to support the timber shrine.\textsuperscript{972} The postholes measured 40cm–50cm in diameter and 90cm–95cm deep; the remains of wooden posts ca. 25cm diameter, were found \textit{in-situ} in B10 and B19. Smaller postholes of 25cm and 40cm–45cm diameter were also found.\textsuperscript{973} In addition, holes for the roofing beams were found 3.8m above floor level. The roof of B15 formed a dense sequence of about 20 cross beams, 15cm–20cm diameter spaced at 15cm–35cm diameter, placed along the longitudinal wall.\textsuperscript{974}

A team of ten men, completing three chambers per day would have taken a total of 13 days to roof the subsidiary chambers and construct the tumulus mound above. An additional two days would have been required to roof the three larger chambers B10/15/19.

\textit{Construction Summary - Aha}

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>115 (18–19 men) ; (30 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>168 (50 porters) / 84 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>159 (4 bricklayers) / 71 (9 bricklayers)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>6 (5 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>35 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Roofing + Mounds</td>
<td>15 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>324 DAYS</strong></td>
</tr>
</tbody>
</table>

\textsuperscript{971} This is the same productivity rate as assumed for the Saqqara tombs.
\textsuperscript{972} Petrie, \textit{Royal Tombs} II, 7; Kaiser and Dreyer, \textit{MDAIK} 38, 218.
\textsuperscript{973} For full details on positioning of postholes see Kaiser and Dreyer, \textit{MDAIK} 38, 218.
\textsuperscript{974} Kaiser and Dreyer, \textit{MDAIK} 38, 216, 218, Abb 2.
Excavation

Based on the plan area of the main tomb, a total of 20 men could have excavated the pit, taking 40 days to complete the task. A total of 30 porters carrying 24 baskets each could have removed 20m$^3$ of spoil per day.  

The excavation of the 330 subsidiary chambers required the removal of 2,400m$^3$ of material. Assuming a workforce of 20 men was organised to work on these chambers once the main tomb was cut, a total of 120 days would have been required. Due to the large area covered by the subsidiary chambers, however, a workforce twice this size could have been employed with 60 to 90 porters supporting the excavators, reducing the number of working days to 60. It is still possible (even probable) that this work was undertaken whilst the main tomb was under construction and therefore 120 days may have been acceptable to ensure the extra labourers and porters were utilised on the main tomb to transport bricks to the site instead.

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977 Includes bricks used for tumulus mound. See Chapter 4, fig. 4.1. When calculating the quantity of materials consumed, it was assumed that the mound covered the burial chamber but did not extend beyond the thick mud brick retaining walls of the substructure, as evidenced from the tumulus remains found in Djet’s tomb. G. Dreyer, Rundbrief DAI, 2008, 17–19.

978 Note: Based on Engel’s calculations for the tomb of Qa’a, there were 30 porters employed to every ten workers. Engel, Archéo-Nil 18, 31–41. This means each porter was only carrying two loads per hour. It was estimated that each porter could carry three loads of 50kg each per hour, as the material could be stockpiled close to the area being excavated. Modern excavation sites have shown that labourers can carry up to six baskets of spoil per hour. It is possible that the lower carrying rate was due to the porters also being required to break up the material into smaller pieces to transport. However, this is an unlikely scenario at this site because the material was very sandy, not rocky. As the number of porters did not directly affect the total construction time, the rate of three loads per hour per man is presented in the summary table for each structure. If six loads were carried, then the number of porters required could be halved.
Brick Transportation and Bricklaying

A total of 279,600 mud bricks were used to construct the walls around the substructure and tumulus mound of the main tomb and 502,000 for the 330 subsidiary chambers. The transportation to site of the bricks for the main tomb would have taken 50 porters 92 days. Similarly, the bricks for the subsidiary chambers would have taken 50 men, 166 days to carry to the site from the brickyards.

The bricklaying for the main structure and the subsidiary chambers, then, took 87 days and 157 days respectively, based on a laying rate of 3,200 bricks per day. Increasing the laying rate to 7,200 bricks daily however, would have reduced the construction time to 39 days and 70 days.

Plastering

A total face area of 694m² was plastered in Djer’s substructure. Based on two crew’s and a productivity rate of 30m² per day, a total of 12 days would have been needed.

The subsidiary chambers had a total of 4,405m² of walls plastered, or 13m² of wall face area per chamber. Assuming three crews (six plasterers and three assistants) were employed, a total of 45 days would have been required to complete this task.

Timber Shrine and Timber Roofing

The quantity of timber used in building the timber shrine amounted to approximately 14 post columns, ca. 13cm x 23cm and 2.5m long. 979 Five beams measuring ca. 30cm x 30cm x 9m placed longitudinally and four transverse beams measuring 30cm x 30cm, built into the mud brick walls acted as roof supports. 980 The beams along the perimeter would have totalled ca. 38m along the external frame of the shrine (adjacent to brick walls) and ca. 30m along the internal frame of the shrine. 981

979 The beam dimensions have been converted and rounded up for clarity from 12.7cm x 22.5cm.
980 This is based on the timber shrine being of similar design to the reconstruction of Den’s shrine. The reason for choosing four transverse beams is due to the four brick cell walls on the north wall. It is possible that only two beams were placed as used on Den’s shrine. G. Dreyer, et. al., “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 9./10. Vorbericht”, MDAIK 54 (1998), Abb. 32.
981 Due to the lack of archaeological evidence, the lining of the timber shrines is speculative. Whether the shrines were covered, however, with wood, matting or fabric, or a combination of these, is inconclusive for most of these tombs. Personal communication based on the tomb of Qa’a, E-M. Engel.
A total of 40 beams of 12cm–24cm diameter, spaced at 15cm–20cm centres, were estimated for the roof.\(^{982}\) The chambers formed by the walls supporting the wooden shrine were shown to have been roofed separately by smaller beams of 15cm diameter and placed 25cm below the main roof. This detail was not noted when Petrie first excavated the tomb. Dreyer noted: “In preparation for the roof constructions, the upper part of the walls of the king’s chamber were built with three steps on the inside: the lowest one serving as the support for the roofing of the small chambers, the second for the upper roof beams and the third one as a frame for the uppermost matting and bricklayers”.\(^{983}\) Roofing requirements for the 330 chambers, with an average size of 1.7m x 1.3m, would have equated to approximately 4,010 beams of 15cm diameter placed side by side, and 2.0m long, allowing for sufficient overhang.\(^{984}\)

The cutting of the timber for the tomb of Djer, was estimated to have taken ten men a total of 16 days. The subsidiary chambers would have required substantially more labour, due to the sheer number of beams required, even if local timber and off-cuts were used. A total of 20 men, over a period of 122 days would have cut the necessary timber.

Once the timber was delivered to the site, the carpenters would have begun their work. Working in unison with the bricklayers for the erection of the timber shrine, as beams were embedded into the brick walls, a team of ten carpenters could have had the shrine and roof installed in 28 days (assuming no delays in the brickwork).\(^{985}\)

The roofing of the subsidiary chambers would have been a far more laborious task as there were 330 chambers to cover. A team of ten men would have taken 54 days to roof the chambers. Despite the large quantity of timber required to be installed, the task was

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\(^{982}\) There were a few surviving beam holes on the south wall of the tomb. Dreyer, *Rundbrief DAI*, 2006, 13.


\(^{984}\) Local timbers, such as acacia or sycamore tree branches, were used to meet the large volumes required in the subsidiary chambers, and imported cedar was reserved for the main tomb. Engel, *Archéo-Nil* 18, 32. The average size of the subsidiary chambers is provided only as a guide to estimate the general requirements for the roofing of these pit chambers. It is understood by the author that the subsidiary chambers did vary in size as is clearly evident in the plan of the tomb.

\(^{985}\) This does not allow for the time required to line the shrine with timber planks, as no evidence suggesting it was lined with timber remains. For estimated timber requirements, if the shrine was, in fact, lined, refer to Chapter 4.
fairly straightforward compared with the construction of the shrine within the main tomb chamber.\textsuperscript{986}

\textbf{Rubble Fill}

The mound for the main tomb was built up of sand and rubble filling, which, based on a height of 2m, equalled 330m\textsuperscript{3} of material. It would have taken 20 porters approximately 24 days to fill.\textsuperscript{987} Assuming the subsidiary chambers were built up to height of only 0.5m, a total of 350m\textsuperscript{3} of rubble would have been required. The time taken to place the material, employing the same number of porters as the main tomb, would have equalled 27 days.

\textit{Construction Summary Tomb of Djer}

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (330)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>115 (20 men) ; (30–45 porters)</td>
<td>120 (20 men) ; (30–45 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>92 (50 porters) / 46 (100 porters)</td>
<td>166 (50 porters) / 83 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>87 (4 men) / 39 (9 men)</td>
<td>157 (4 men) / 70 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>6 (5 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>11 (2 plasterers + 1 assistant)</td>
<td>45 (6 plasterers + 3 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>16 (10 men)</td>
<td>61 (10 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>28 (10 men)</td>
<td>54 (10 men)</td>
</tr>
<tr>
<td>Rubble fill</td>
<td>24 (20 porters)</td>
<td>27 (20 porters)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>268 DAYS</td>
<td>403 DAYS</td>
</tr>
</tbody>
</table>

The total construction time for the substructure of the main tomb and subsidiary chambers was dependent firstly on how the work was carried out, and secondly, on what activities were done simultaneously and consecutively for the two components of the tomb. The following summary provides two possible scenarios for the total construction times.

\textsuperscript{986} The estimated number of beams placed over the subsidiary graves of 2,000 allows for spacing between each beam or tree branch of 10-15cm, (as seen over the chambers of Aha and Khasekhemwy’s chambers). Kaiser and Dreyer, \textit{MDAIK} 38, 216, 218, Abb 2; G. Dreyer, et al. “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 13./14./15. Vorbericht", \textit{MDAIK} 59 (2003), 108–111, Abb. 17.

\textsuperscript{987} Based on each man carrying 24 baskets per day. Reducing the loads to 16 per day per man, (two per hour) would have increased the working days to 37.
If the main tomb and the subsidiary chambers were built simultaneously, the total construction time would have amounted to 403 days. If, however, the tomb and subsidiary chambers were built consecutively, the construction time would have been approximately 671 days. No doubt, the construction sequence may have been a combination of both, depending on the labour made available, the timely arrival of materials to site, and other mitigating factors.

Option 1 – Simultaneous construction

| Main – 268 Days | Subsidiary Graves – 403 Days | TOTAL CONSTRUCTION = 403 DAYS |

Option 2 – Consecutive construction

| Main – 268 Days | Subsidiary Graves – 403 Days | 671 DAYS |

Djet

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (223)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>450m³</td>
<td>970m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>121,200</td>
<td>227,300</td>
</tr>
<tr>
<td>Plaster</td>
<td>703m²</td>
<td>2,056m²</td>
</tr>
<tr>
<td>Tumulus Rubble</td>
<td>187m²</td>
<td>285m²</td>
</tr>
</tbody>
</table>

Excavation

The total volume excavated for Djet’s tomb was 450m³. Based on the area of the pit, a workforce of 15 men could have been engaged to complete the excavation in 31 days. The pit was 3.3m deep and would have required shoring.

The total volume excavated for the 223 subsidiary chambers equated to 970m³. Assuming 15 men were employed, the excavation of this many chambers would have taken 65 days. The subsidiary chambers were initially excavated as one massive trench,

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subsequently subdivided by mud brick walls. A larger excavation crew could have been assigned if 65 days was considered unacceptably long.

**Brick Transportation and Bricklaying**

The main tomb contained 121,200 mud bricks, the subsidiary chambers 227,300. Transportation of bricks to the site was estimated to have taken 50 porters 40 days and 75 days respectively. The brick walls could have been completed over 38 days for the main tomb and 71 days for the subsidiary chambers using a crew of four bricklayers, with a daily output of 3,200 bricks.

**Plastering**

The main tomb had a total area of 703m² plastered. This included not only the walls, but also the floor, which had been whitewashed.\(^{989}\) Based on the work of one crew, the main tomb could have been plastered in 16 days, and the subsidiary chambers in 47 days.\(^{990}\)

**Timber Shrine and Timber Roofing**

A total of 30 beams of 27cm diameter and 9.8m long, spaced at 27cm centres, were estimated for the roof of the main chamber. As with the subsidiary chambers from Djer’s tomb, those accompanying Djet’s tomb were most likely roofed with local timbers. Roofing requirements for the 223 burials approximated 1,190 beams of 15cm diameter placed 10-15cm apart, and 2.0m long, allowing for sufficient overhang.

The quantity of timber used to build the timber shrine was based on a similar design to that of Den’s tomb. The quantity of timber used in building the frame of the timber shrine was estimated to be approximately 22 post columns, ca. 13cm x 23cm and 2.3m long.\(^{991}\) Six beams measuring ca. 30cm x 30cm x 12m placed longitudinally and two transverse beams also 30cm x 30cm, built into the mud brick walls would have acted as supports for the roof of the shrine.\(^{992}\) The beams along the perimeter would have

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\(^{990}\) One crew equalled two plasterers and one assistant.

\(^{991}\) The beam dimensions are based on those used on the tomb of Djer as Petrie recorded the thickness of the planks and not beams, which were 3.5 inches thick (10cm). Petrie, *Royal Tombs I*, 8–9.

\(^{992}\) Based on the timber shrine being of similar design to the reconstruction of Den’s shrine. Dreyer, *MDAIK* 54 (1998), Abb. 32.
totalled ca. 30m along the external frame of the shrine (adjacent to brick walls) and ca. 22m along the internal frame of the shrine.\textsuperscript{993}

Felling of trees and cutting the timber into proper sizes would have taken ten men a total of 18 days.\textsuperscript{994} This same number of workers could have installed the timber shrine and roof over a period of 29 days.

The task of roofing the 223 subsidiary chambers would have taken considerably longer. A group of 20 men would have cut the timber over 36 days and ten men could have roofed these chambers in 32 days, amounting to seven chambers per day.

\textit{Rubble Fill}

The mounds were built up with rubble and sand, presumably from the excavation of the substructure, and encased with two layers of mud bricks. The main structure would have taken 20 porters a total of 13 days carrying 48 baskets each per day. The mounds above the subsidiary chambers would have taken 22 days to construct with 11 chambers being completed daily.

\textit{Construction Summary Tomb of Djet}

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (223)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>31 (15 men) ; (23 – 34 porters)</td>
<td>65 (15 men) ; (23 – 34 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>40 (50 porters) / 20 (100 porters)</td>
<td>75 (50 porters) / 38 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>38 (4 men) / 17 (9 men)</td>
<td>71 (4 men) / 32 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>5 (5 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>16 (2 plasterers + 1 assistant)</td>
<td>47 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>18 (10 men)</td>
<td>36 (20 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>29 (10 men)</td>
<td>32 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>13 (20 porters)</td>
<td>22 (20 porters)</td>
</tr>
<tr>
<td>\textbf{TOTAL}</td>
<td>127 DAYS</td>
<td>237 DAYS</td>
</tr>
</tbody>
</table>

\textsuperscript{993} Dreyer, \textit{MDAIK} 54, Abb. 31, Abb. 32.

\textsuperscript{994} Refer to Chapter 4 for breakdown of timber dimensions used.
The total construction program may have varied depending on whether the main tomb and subsidiary chambers were built at the same time. The tomb complex of Djet would have taken between 237 and 364 days to construct.

**Merneith**

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (49)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume Excavated</strong></td>
<td>500m³</td>
<td>326m³</td>
</tr>
<tr>
<td><strong>Mud Bricks</strong></td>
<td>281,800</td>
<td>122,500</td>
</tr>
<tr>
<td><strong>Plaster</strong></td>
<td>513m²</td>
<td>496m²</td>
</tr>
<tr>
<td><strong>Tumulus Rubble</strong></td>
<td>118m²</td>
<td>60m²</td>
</tr>
</tbody>
</table>

**Construction Summary Tomb of Merneith**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>31 (20 men reduced to 6 men)</td>
<td>17 (20 men) ; (30 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>93 (50 porters) / 47 (100 porters)</td>
<td>40 (50 porters) / 20 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>88 (4 men) / 39 (9 men)</td>
<td>38 (4 men) / 17 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>.5 (6 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>12 (2 plasterers + 1 assistant)</td>
<td>13 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>26 (10 men)</td>
<td>18 (20 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>24 (10 men)</td>
<td>9 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>9 (20 porters)</td>
<td>6 (20 porters)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>164 DAYS</td>
<td>83 DAYS</td>
</tr>
</tbody>
</table>

The construction program for both the tomb and subsidiary chambers may have been undertaken simultaneously or consecutively, or a mixture of both. If built simultaneously, the total time would have amounted to 164 days. The construction time would have increased to 247 days, if built consecutively.

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Den

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (153)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>3,008 m³</td>
<td>1,190 m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>492,500</td>
<td>200,000</td>
</tr>
<tr>
<td>Plaster</td>
<td>1,464 m²</td>
<td>2,371 m²</td>
</tr>
<tr>
<td>Tumulus Mound</td>
<td>350 m²</td>
<td>320 m²</td>
</tr>
</tbody>
</table>

Excavation

The tomb of Den was the first at Abydos to incorporate a stairway into the burial chamber, making access for workers excavating the tomb much easier. Based on the plan area of the tomb, a workforce of 35 men could have excavated the whole tomb at one time. However, this may not have been practical. The removal of 35 m³ per day required an additional 52 porters to support the excavators to remove the spoil. The walls of the cut also needed shoring to prevent the collapse of loose material, making working conditions dusty, crowded and less than ideal. As such, using a maximum workforce of 20 men, supported by 30 porters, the excavation of the pit was estimated to have taken 151 days.

The 153 subsidiary chambers bordering the tomb had 1,190 m³ excavated. The plan area occupied by these chambers was extensive, so a greater workforce could have been mobilised. Nevertheless, if 20 men were employed the chambers would have been cut in 60 days.

Brick Transportation and Bricklaying

The mud bricks used to build the substructure of the tomb and subsidiary chambers consisted of just over half a million units. Transporting this quantity of bricks would have taken 50 porters 163 days for the 492,500 bricks used on the main tomb, and a further 66 days for the subsidiary chambers.

The building of the mud brick walls was equally time-consuming. Using a laying rate of 3,200 bricks per day, the main tomb would have taken 154 days to build, and the chambers 62 days. More than doubling the laying rate to 7,200 bricks would have reduced the workdays to 68 days and 28 days.

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997 The number of porters was based on each man carrying 48 baskets per day.
Scaffolding
The burial chamber of Den’s tomb was cut to a depth of 7m, making the use of scaffolding essential. A total of ten men could have placed and then dismantled the scaffolding in only two days, based on the plan area of the pit. The subsidiary chambers, which were assumed to average 2m in height, would not have required scaffolding.

Plastering
The plastering of the walls was estimated to have taken one crew a total of 37 days for the substructure of the main tomb and 58 days for the 153 subsidiary chambers.

Stone
Den chose to have a granite floor installed in his burial chamber in addition to lining the walls with timber. The stone acquired for the granite floor was most likely from stone boulders, which did not require quarrying; the boulders could have been worked into slabs. Granite is a hard stone and working it into slabs would have been time consuming, but not too laborious for the ancient Egyptians who had been working with all types of stone to make stone vessels since Predynastic times.

The slabs were approximately 281cm x 163cm and 12.7cm thick. The total quantity of stone amounted to 11.3m$^3$ or approximately 25 tonnes. Assuming a cutting rate of 0.5m$^3$ per man per day, allowing for the harder granite material compared to limestone, the slabs would have taken one man a total of 23 days to cut. If the slabs weighed 1.2 tonnes each, a minimum of ten men would have been required to handle such heavy pieces of stone. The pavement could have been laid in 12 days, assuming 10m$^2$ of paving was laid daily, including the placement of limestone slabs below the granite acting as a foundation.

The introduction of the stairway entrance to the tomb meant the addition of one or more portcullis stones. The acquisition and transportation of the limestone slabs used for the blocking stone would have been undertaken alongside other activities (such as bricklaying and plastering) and the placement, finally lowering the stone into place, would have taken one day.

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998 Petrie reported the slabs to be 111 inches x 64 inches x 5 inches thick (other blocks measured 53 inches x 28 inches; 98 inches x 28 inches; and 52 inches x 27 inches and 6 inches thick). W. M. F. Petrie, *Royal Tombs of the Earliest Dynasties, Part II* (London, 1901), 10.
Timber Shrine and Timber Roofing

The timber shrine consisted of external columns, 30cm x 30cm, secured into the brickwork, which was connected to the outer frame for mounting the reed mat covering.999

The post columns, 28 in total, measuring 30cm x 30cm were estimated to be 4m in height. The beams along the perimeter would have totalled ca. 47m along the external frame of the shrine (adjacent to brick walls) and ca. 38m along the internal frame of the shrine.1000

The roofing over the main chamber was estimated to have consumed 30 beams of 30cm diameter spaced 24cm–30cm apart, and approximately 11m long. The staircase leading to the king’s burial chamber was similar to the main chamber in that it was roofed with timber beams (10cm in diameter), reed mats, and bricks. The entrance of the niche was covered 4.72m above the floor level with beams that were 15cm in diameter.1001

Of the 153 subsidiary chambers accompanying the tomb, assuming local timbers were used to roof these chambers,1002 a total of 595 beams of 20cm diameter placed side by side would have been required.

Cutting down the required trees to obtain the necessary timber for the main tomb would have taken ten men a total of 29 days. The building of the wooden structure within the burial chamber and subsequent roofing would have taken a total of 31 days. Assuming the 153 subsidiary chambers were roofed with tree branches and off-cuts, a total of 18 days would have been required, based on 595 beams. The roofing of the chambers could have been completed in 31 days if four chambers were covered daily.

Rubble Fill

The superstructure mound was not of solid mud brick but filled with sand and rubble. Employing 20 porters to carry 24 baskets daily, this task would have taken 37 days to

999 Dreyer, MDAIK 54, 142–145, Abb. 32.
1000 Dreyer, MDAIK 54, Abb. 31.
1001 Dreyer, MDAIK 54, 146.
1002 The assumed quantity is based on an overall length of 237m for the combined graves.
complete. Similarly, the porters covering the subsidiary chambers would have taken 24 days.

Construction Time Tomb of Den

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (153)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>151 (20 men) ; (30 porters)</td>
<td>60 (20 men) ; (30 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>163 (50 porters) / 81 (100 porters)</td>
<td>66 (50 porters) / 33 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>154 (4 men) / 68 (9 men)</td>
<td>62 (4 men) / 28 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>13 (10 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>37 (2 plasterers + 1 assistant)</td>
<td>58 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Stone Cutting</td>
<td>23 (1 man)</td>
<td>Nil</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>12 (10 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>29 (10 men)</td>
<td>18 (20 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>31 (10 men)</td>
<td>31 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>37 (20 men)</td>
<td>24 (20 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>422 DAYS</strong></td>
<td><strong>235 DAYS</strong></td>
</tr>
</tbody>
</table>

These calculations show us that Den’s tomb could have taken between 422 days and 657 days to build, equating to almost 4 years.

Anedjib

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>320m³</td>
<td>270m³</td>
</tr>
<tr>
<td>Mud Bricksootnote{1003}</td>
<td>121,800</td>
<td>54,050</td>
</tr>
<tr>
<td>Plaster</td>
<td>297m²</td>
<td>663m²</td>
</tr>
<tr>
<td>Tumulus Mound</td>
<td>147m²</td>
<td>47m²</td>
</tr>
</tbody>
</table>

Excavation

Only ten men could have worked within the confines of the pit being excavated, based on the plan area of the tomb, meaning the pit would have taken 32 days to excavate. The volume excavated for the 65 subsidiary chambers amounted to 270m³. Due to the large plan area of these chambers, a greater number of workers could have been engaged to cut these pits. However, if only ten men were employed, these chambers would have taken 28 days to cut.

Brick Transportation and Bricklaying

The tomb of Anedjib was far smaller than that of his predecessor with a total of 121,800 mud bricks used in the tomb and 54,050 within the subsidiary chambers. Transportation of bricks to the site would have taken 50 porters 40 days and 18 days respectively. Bricklaying would then have taken 38 days for the tomb and 17 days for the chambers.\textsuperscript{1004}

Plastering

The passageway and the walls of the two rooms of the main tomb were plastered, totalling an area of 297m\textsuperscript{2}. If the walls of the subsidiary chambers had also been plastered, they would have equalled 663m\textsuperscript{2}. Assuming that only one plasterer was employed, plastering 15m\textsuperscript{2} per day, the tomb could have been completed in seven days. Covering a greater area, the plastering of the subsidiary chambers may have required two plasterers, enabling the job to be completed in 19 days.

Timber Shrine and Timber Roofing

The timber roof was presumably supported by the timber shrine, which in turn was supported by posts. The timber flooring of the main tomb required approximately 20 planks of wood, 50cm wide x 5cm thick and 4.5m long.\textsuperscript{1005} Petrie reported that the planks had been cut off-site, evidenced by the fact that in some areas they were too long for the intended room.\textsuperscript{1006} A total of 18 roofing beams (22cm diameter placed 55cm apart and 5m long) were estimated to have been required to roof the two chambers.\textsuperscript{1007}

Felling the number of trees needed to produce the necessary amount of beams and planks would have taken ten men 6 days. The construction of the timber shrine and roof by the carpenters would have taken ten men a total of four days. However, due to the small area within the pit, it is unlikely more than 2–4 men were able to work, increasing the number of construction days to at least six.

\textsuperscript{1004} Based on a daily productivity rate of 3,200 bricks.
\textsuperscript{1005} Petrie gives a plank width of 50cm. Petrie, \textit{Royal Tombs} I, 12.
\textsuperscript{1006} Petrie, \textit{Royal Tombs} I, 12.
\textsuperscript{1007} The beam dimensions are those used for the calculations undertaken in Chapter 1, and are based on data from the excavation reports. Because some of the tombs had no recorded data on beam dimensions due to the denuded state of the tomb, averages from tombs where data was available was used.
The 65 subsidiary chambers had an estimated 188 beams when spaced 20cm apart.\textsuperscript{1008} Ten men could cut the timber required over a period of 12 days. The roofing of the chambers could be completed in ten days.

*Construction Time Tomb of Anedjib*

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>32 (10 men) ; (15 porters)\textsuperscript{1009}</td>
<td>28 (10 men) ; (15 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>40 (50 porters) / 20 (100 porters)</td>
<td>18 (50 porters) / 9 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>38 (4 men) / 17 (9 men)</td>
<td>17 (4 men) / 8 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (5 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>7 (1 plasterers + 1 assistant)</td>
<td>19 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>6 (10 men)</td>
<td>12 (10 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>4 (10 men)</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>21 (20 men)</td>
<td>4 (20 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>102 DAYS</strong></td>
<td><strong>75 DAYS</strong></td>
</tr>
</tbody>
</table>

Due to the small size of the tomb, compared to those built by Anedjib’s predecessors, it is possible that the tomb and the accompanying chambers where built one after the other in order to use a smaller number of workers. Alternatively, they could have been built at the same time. Regardless of the sequencing, the construction of Anedjib’s substructure and subsidiary chambers would not have exceed one year. The building of Anedjib’s tomb could have taken from 102 days up to 177 days.

*Semerkhet*

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (69)\textsuperscript{1010}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>750m(^3)</td>
<td>260m(^3)</td>
</tr>
<tr>
<td>Mud Bricks\textsuperscript{1011}</td>
<td>287,100</td>
<td>72,500</td>
</tr>
<tr>
<td>Plaster</td>
<td>403m(^2)</td>
<td>527m(^2)</td>
</tr>
<tr>
<td>Tumulus Mound</td>
<td>228m(^2)</td>
<td>50m(^2)</td>
</tr>
</tbody>
</table>

Unlike the earlier tombs at Abydos, Semerkhet chose to incorporate the subsidiary chambers within the main tomb structure. The results discussed below will report the

\textsuperscript{1008} If only 188 beams were used, cutting 20 trees daily, the timber could have been sourced in ten days.

\textsuperscript{1009} Based on each porter removing 24 baskets of spoil per day.

\textsuperscript{1010} Sixty-seven subsidiary graves and two magazines are assigned to the tomb of Semerkhet. Engel, *Archéo-Nil* 18, 39.

combined labour force utilised to build the tomb, with the break down between the two components of the tomb presented in the summary table, enabling comparisons of labour and construction times between the other tombs.

Excavation

The substructure of Semerkhet’s tomb consisted of a large floor plan area (26m x 18m) cut to a depth of 1.2m which served as the subsidiary chambers, before reducing in size (16.4m x 7.6m x 2.3m deep) for the burial pit. The difference in size allowed a total of 35 workers to cut the first portion of the pit and only 21 men the second. If 35 men had been employed to excavate the top 1.2m depth of the tomb, forming the subsidiary chambers, 52 porters would have been required to remove the spoil. Adopting a more conservative approach, using no more than 20 excavators (the number who would have been able to fit in the deeper portion of the tomb), the total tomb could have been excavated in 51 days, with the assistance of 30 porters.

Timber Shrine and Timber Roofing

The roofing of the main chamber was estimated to consist of 65 planks of 25.4cm x 20cm and 8m length roofed the burial chamber, placed above the supporting beams.

The subsidiary chambers were estimated to have had 315 beams of 20cm diameter spaced at 20cm centres.

The timber used in building the frame of the timber shrine, based on a similar construction to the reconstruction of Den’s shrine, amounted to one large beam measuring ca. 30cm x 30cm and 16m length placed longitudinally and six transverse beams also 30cm x 30cm and 6m long, embedded into the brickwork to support the shrine. It is possible such beams served to support the roof of the main chamber.

Based on these requirements, a team of ten woodcutters could have cut the required amount of wood for the main tomb in 22 days. A total of ten men could have cut down the timber to roof for the subsidiary chambers in 38 days. The carpenters could have

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1012 This is based on 24 baskets removed daily per porter. Reducing the loads to only 16 baskets per day increases the number of porters that would have been required to 79.

1013 The main tomb would have taken 38 days and the subsidiary graves connected to the tomb a total of 13 days.

1014 The planks may have been thinner, but the calculations undertaken to determine the roof capacity were based on these dimensions.

1015 Dreyer, MDAIK 54, Abb. 32.
installed the timber shrine and roofing of the main tomb in 18 days, and 17 days for the subsidiary chambers.

**Rubble Fill**

The placement of rubble to form the 2m high superstructure was estimated to have taken 20 porters a total of 16 days, and the 50cm high mounds over the smaller chambers, four days.

**Construction Time Tomb of Semerkhet**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers (69)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>38 (20 men) ; (30 – 45 porters)</td>
<td>13 (20 men) ; (30 – 45 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>95 (50 porters) / 47 (100 porters)</td>
<td>24 (50 porters) / 12 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>90 (4 men) / 40 (9 men)</td>
<td>23 (4 men) / 10 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (5 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>7 (2 plasterers + 1 assistant)</td>
<td>15 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>22 (10 men)</td>
<td>38 (10 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>18 (10 men)</td>
<td>17 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>16 (20 porters)</td>
<td>4 (20 porters)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>169 DAYS</strong></td>
<td><strong>72 DAYS</strong></td>
</tr>
</tbody>
</table>

The incorporation of subsidiary chambers within the main tomb structure means the construction of both elements had to have been undertaken simultaneously. As such, the total construction time for the substructure would have taken at least 241 days.

**Qa’a**

Qa’a also had subsidiary chambers incorporated into the main substructure. This meant the construction of the chambers and the main substructure needed to be undertaken at the same time.1017

1016 The following material estimates are based on scaling off the tomb plans and sections as published by Dreyer and his team. They differ slightly from the results published by Engel in her PhD dissertation on the tomb of Qa’a, as will be discussed later. E.-M. Engel, *Das Grab des Qa’a in Umm el-Qa’ab: Architektur und Inventar* Dissertation – microfiche (Göttingen, 1997), 96–103.

1017 The two components are presented individually in the summary tables. This will enable direct comparisons to be made when the results for the individual tombs are discussed.
<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>640m³</td>
<td>844m³</td>
</tr>
<tr>
<td>Mud Bricks&lt;sup&gt;1018&lt;/sup&gt;</td>
<td>341,000</td>
<td>137,500</td>
</tr>
<tr>
<td>Plaster</td>
<td>303m²</td>
<td>648m²</td>
</tr>
<tr>
<td>Tumulus Mound</td>
<td>200m²</td>
<td>28m²</td>
</tr>
</tbody>
</table>

*Excavation*

The main tomb had 640m³ of material excavated to create the substructure and 844m³ to create the subsidiary chambers. With a large plan area, a total of 30 men could have excavated down to the subsidiary chambers floor level. However, only 12 men could have been employed once the burial chamber was reached due to the reduced floor plan area. If only 12 men were employed to excavate the entire tomb structure, the substructure would have taken approximately 125 days, with the assistance of up to 27 porters.

*Timber Shrine and Timber Roofing*

The timber shrine consisted of large timber beams placed horizontally to form the frame along the base, and vertical posts that served to support the roof and act as scaffolding for the lining. The timber shrine was built simultaneously with the mud brick walls as the beams forming the frames are embedded in the brickwork.<sup>1019</sup>

The roof of the burial chamber consisted of 20 beams approximately 30cm in diameter and 6.5m long. Imprints show that the beams were spaced 0m–0.3m apart.<sup>1020</sup> It is possible that 22 timber planks would have been needed above these, measuring 25cm x 6cm thick, 11m long, and positioned side by side.<sup>1021</sup>

Based on the amount of timber consumed, a total of ten men would have needed approximately 16 days. The subsidiary chambers required up to 213 beams of 20cm diameter, and this would have required an additional 12 days to cut. The carpenters, once the timber was dispatched to the site, would have taken a total of 33 days to line and roof the entire structure.

<sup>1019</sup> Engel, *Das Grab des Qa‘a*, 6, 79 – 87, Abb. 54, Abb. 55.
<sup>1020</sup> See Engel, *Das Grab des Qa‘a*, 9, for spacing of beams according to imprints found.
<sup>1021</sup> Engel, *Das Grab des Qa‘a*, 85, Abb. 57.
Construction Time Tomb of Qa’a

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Main Tomb</th>
<th>DAYS – Subsidiary Chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>54 (15 men) ; (18 porters)</td>
<td>71 (15 men) ; (18 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>113 (50 porters) / 56 (100 porters)</td>
<td>45 (50 porters) / 23 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>197 (4 men) / 47 (9 men)</td>
<td>43 (4 men) / 19 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (5 men)</td>
<td>Nil</td>
</tr>
<tr>
<td>Plastering</td>
<td>5 (2 plasterers + 1 assistant)</td>
<td>20 (6 plasterers + 3 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>16 (10 men)</td>
<td>12 (10 men)</td>
</tr>
<tr>
<td>Timber Shrine and Roofing</td>
<td>13 (10 men)</td>
<td>13 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>23 (20 porters)</td>
<td>Calculated as part of main tomb</td>
</tr>
<tr>
<td>TOTAL</td>
<td>292 DAYS</td>
<td>147 DAYS</td>
</tr>
</tbody>
</table>

Engel estimated the total time to construct the tomb of Qa’a to be approximately two years.\textsuperscript{1023} There were variances in the number of workers employed and the time taken to complete various tasks, but the overall construction time was very similar. For example, in Phase 1, Engel calculated that a total of ten excavators were supported by 30 porters taking a total of 100 days to dig out the substructure. The mud bricks were transported to site during this time and two bricklaying crews (where one crew consisted of one bricklayer and up to five support labourers) built the mud brick walls over a period of 300 days. Phase 2 of the construction of Qa’a tomb saw an extra 120 days added to the total construction time, equating to a grand total of 520 days. The author estimated a total of 439 days. As bricklaying was the most time consuming activity, if the number of bricklayers assumed by the author was halved, the results here, would have produced a similar construction time to Engel's.\textsuperscript{1024} It seems unlikely, however, that such a small number of bricklayers would be employed, given that this was by far the most time consuming task.

\textit{2\textsuperscript{nd} Dynasty Tombs}

**Peribsen**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Excavation</td>
<td>660m(^3)</td>
</tr>
<tr>
<td>- Mud Bricks\textsuperscript{1025}</td>
<td>171,000</td>
</tr>
<tr>
<td>- Plaster</td>
<td>590m(^2)</td>
</tr>
</tbody>
</table>

\textsuperscript{1022} The range of porters is based on each man carrying 24 baskets per day.
\textsuperscript{1023} Engel, \textit{Archéo-Nil} 18, 33.
\textsuperscript{1024} Engel, \textit{Das Grab des Qa’a}, 96–98.
**Excavation**

The total volume excavated to create the substructure of Peribsen’s tomb equalled 660m³. Based on the plan area of the tomb, it was estimated 25 men could have worked to cut the pit. However, to minimise the level of congestion in the pit, especially with the addition of porters moving in and out of the excavation zone, no more than 20 excavators would have been used. Twenty excavators would have been able to excavate Peribsen’s tomb in 33 days.

**Timber Roofing**

The substructure was roofed with timber. The burial chamber contained 26 beams (30cm diameter x 4.8m long) and the two surrounding passages contained 265 beams (20cm x 2.4m long placed at 20cm spacing).\(^{1026}\) The cutting of this amount of timber would have taken ten men a total of 22 days. Roofing the entire structure took an equal number of men approximately 13 days.

**Construction Time Tomb of Peribsen**

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Substructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>33 (20 men) ; (30 porters)(^{1027})</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>56 (50 porters) / 28 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>53 (4 men) / 24 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>6 (5 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>20 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>22 (10 men)</td>
</tr>
<tr>
<td>Timber Placement</td>
<td>13 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>10 (20 porters)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>129 DAYS</strong></td>
</tr>
</tbody>
</table>

**Khasekhemwy**\(^{1028}\)

<table>
<thead>
<tr>
<th>TASK</th>
<th>VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>4,540m³ / 24,900m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>528,600</td>
</tr>
<tr>
<td>Plaster</td>
<td>2,460m²</td>
</tr>
</tbody>
</table>

\(^{1026}\) In Chapter 4, a total of 525 beams were presumed to have been used, placed side by side. As this is not efficient, it is likely they were spaced out resulting in half this number, or 265 as mentioned.

\(^{1027}\) The number of porters based on each carrying 24 baskets of spoil per day. This number would increase to 45 men if they only carried 16 baskets per day.

\(^{1028}\) Dreyer’s revised plan of this tomb documents various building stages and new details of the stone built burial chamber. Dreyer, *MDAIK* 59, 67–138.
Excavation

The burial chamber and subsidiary chambers of Khasekhemwy’s tomb is 3.6m from floor level to the top of the mud brick walls. However, from floor level to desert ground level, the total depth is 13m. The excavation of the total depth meant 24,900m$^3$ of sand needed to be removed.

The sandy soil meant that the walls would have required substantial shoring during excavation to prevent the collapse of the exposed cut. Based on the plan area of the tomb, a total of 126 men could have excavated such a large pit. However, this means 126m$^3$ of material needed to be removed daily, which also would have required at least 188 porters. Such a large number would seem impractical, as the pit would have soon become overcrowded with excavators and porters. The engagement of 60 excavators supported by 90 porters would have made working conditions more tolerable. Based on the removal of 24,900m$^3$, 60 workers would have been able to excavate the pit in 468 days.

Brick Transportation and Brick Laying

A total of 528,600 mud bricks were used in the construction of Khasekhemwy’s substructure. The transportation of this many bricks to the site would have taken 50 men 175 days, or 87 days if the number of porters were doubled. Depending on the number of bricklayers employed, the construction of the brick walls may have taken up to 165 days to complete (based on a daily output of 3,200 bricks), or 73 days (based on 7,200 bricks laid per day).

Stone Chamber

Khasekhemwy’s burial chamber was lined and paved with limestone blocks and may originally have been roofed with small stone slabs resting on the timber shrine within. The surface of the stone chamber was thinly coated with a smooth, fine-grained plaster. The total volume of stone was calculated to be 15.6m$^3$. At a cutting rate of 0.8m$^3$ per man per day, one man alone could have quarried the necessary stone pieces in

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1029 Dreyer, MDAIK 59, Abb. 17.
1030 Based on the removal of 24 baskets per man per day.
1031 It is possible that Khasekhemwy’s builders made use of a depression in the landscape thereby negating the need to remove so much material. However, based on Dreyer’s reconstructed tomb elevation, the void above the tomb would appear to have been ‘re-filled’ with sand before the superstructure was built at desert level. Dreyer, MDAIK 59, 67–138: III Abb 17.
1032 Dreyer, MDAIK 59, 108.
just 20 days, with an extra man employed to dress the faces of the stone. The cutting and transportation would have been undertaken during other construction activities. The construction of the stone chamber, however, would have taken a work force of four to eight men approximately 16 days to complete.\textsuperscript{1033}

\textit{Timber Shrine and Roofing}

The 58 chambers were roofed with tree branches as shown by the remains of post holes 10cm and 20cm spaced at a distance of 25cm. The difference in diameter reflects the tapering of the tree branches.\textsuperscript{1034} A total of ten men took a total of 62 days to source the timber for these chambers. The placement of the timber shrine within the burial chamber, assuming only two men worked within the confined space, would have resulted in a construction time of nine days. The placement of the 912 roofing beams over the remaining chambers would have taken ten men a total of 21 days. The entire substructure could have been roofed in 30 days.

\textit{Painting}

Discolorations on the northern and eastern walls indicate the timber shrine was painted red.\textsuperscript{1035} The total face area painted was approximately 22m\textsuperscript{2}, taking one crew of two painters no more than one day to paint.

\textit{Construction Time Substructure of Khasekhemwy}

\begin{tabular}{|l|l|}
\hline
\textbf{TASK} & \textbf{DAYS – Substructure} \\
\hline
Excavation & 468 (60 men) ; (90 porters)\textsuperscript{1036} \\
Brick Transport & 175 (50 porters) / 87 (100 porters) \\
Brick Laying & 165 (4 men) / 73 (9 men) \\
Scaffolding & 13 (5 men) \\
Plastering & 72 (2 plasterers + 1 assistant) \\
Painting & 1 (2 painters + 1 assistant) \\
Stone Quarrying & 20 (2 men) \\
Stone Placement & 16 (4–8 men) \\
Timber Cutting & 62 (10 men) \\
Timber Placement & 30 (10 men) \\
\hline
\textbf{TOTAL} & \textbf{752 DAYS} \\
\hline
\end{tabular}

\textsuperscript{1033} This is based on a conservative estimate of the placement of 1m\textsuperscript{3} per day. The variance in workers is due to no more than four men being able to work within the confines of the burial chamber, but may have been supported by a similar number of men to move the blocks into position.

\textsuperscript{1034} Dreyer, \textit{MDAIK} 59, 112.

\textsuperscript{1035} Dreyer, \textit{MDAIK} 59, 138.

\textsuperscript{1036} Based on the removal of 24,900m\textsuperscript{3} of sand. The removal of only 4,540m\textsuperscript{3} would have taken the same number of men only 76 days.
**Tumulus Mound of Khasekhemwy**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Main Superstructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mud Bricks</td>
<td>98,000</td>
</tr>
<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>- Stone lining</td>
<td>157m³</td>
</tr>
<tr>
<td>- Plaster</td>
<td>177m²</td>
</tr>
<tr>
<td>- Volume of sand/ rubble</td>
<td>24,906m³</td>
</tr>
</tbody>
</table>

**Brick Transportation and Bricklaying**

Based on Dreyer’s reconstruction of Khasekhemwy’s tomb, the tumulus mound may have been lined with stone rather than mud bricks.  

If mud bricks had been used, 50 porters could have transported over 30 days. The bricklayers could then have lined the mound in 33 days.

**Stone lining**

If the tumulus mound had instead been lined with stone slabs (total quantity equalling 157m³), a team of ten men could have quarried and dressed the slabs in approximately 40 days. Based on two men able to lay 1m³ per day, a team of ten men would have taken 32 days to line the mound. Thus, these results show that the days required to line the tumulus mound, whether with stone or mud bricks, are comparable.

**Rubble Fill**

At a depth of 13m from desert level to floor level, the amount of material that needed to be replaced before the superstructure could be built at desert level amounted to 18,000m³. If 100 men were employed to replace the material above the substructure, a total of 268 days would have been required.

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1038 Productivity rate of 3,200 bricks per day (four bricklayers).
1039 The volume was calculated based on an original depth of 13m minus the construction of the substructure to 3.6m, resulting in the volume of material to be replaced being a depth of 9.4m (i.e. 13m − 3.6m = 9.4m).
Construction Time of Tumulus Mound

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Tumulus Mound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick Transport</td>
<td>30 (50 porters) ; 15 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>31 (3,200 bricks) / 14 (7,200)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>40 (10 men)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>32 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>268 (200 porters)</td>
</tr>
<tr>
<td>Plastering</td>
<td>6 (2 plasterers + 1 assistant)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>337 DAYS</td>
</tr>
</tbody>
</table>

Total Construction Time

The total construction time for the tomb of Khasekhemwy equated to 1,089 days based on a practical number of workers being employed. More than half this time would have been occupied with the removal and subsequent filling of the 13m depression.

1st Dynasty Funerary Enclosures

The analysis of the royal tombs suggest that minimal effort was expended on the superstructures, compared with the grand mud brick structures of Saqqara’s 1st Dynasty high officials. The reason for this can be attributed to the construction of the separate funerary enclosures that complemented the royal tombs.

Aha

Aha had three funerary enclosures built, accompanied by subsidiary chambers. The total bricks consumed by all three equalled 1,358,900 units. The construction of the funerary enclosures would have commenced after a number of mud bricks had been stockpiled on site. Building the funerary enclosures began with the construction of the mud brick walls, unlike the tombs where excavation work preceded this activity. As such, the rate of construction was governed by how quickly bricks could be delivered to the site. Once the brickwork was completed, plastering of the exterior walls could have begun. The total face area plastered for each of the three enclosures and accompanying subsidiary chambers was: 1,225m², 212m², 208m² and 29m².

---

1040 It is probable, however, that the number of workers was doubled, thereby reducing the time taken to 134 days.

1041 This includes the bricks used for the subsidiary graves. The three enclosures alone consumed 1,323,300 bricks and the subsidiary graves 35,600 bricks. A height of 5m was chosen due to the possible conservatism employed by the builders of Khasekhemwy’s structure; having 5m thick walls but built to a height of 11m. Likewise, the mud brick walls of his predecessors funerary enclosures were, on average, half this thickness, and this would suggest they were built to half the height of 5m.
The task of roofing the 13 subsidiary chambers was estimated to have taken a group of 10 men, five days to cut the timber, and two men completing three chambers per day a total of four days to install the roofs.

<table>
<thead>
<tr>
<th></th>
<th>Enclosure 1</th>
<th>Enclosure 2</th>
<th>Enclosure 3</th>
<th>Subsidiary Chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 100 porters</td>
<td>122 days</td>
<td>48 days</td>
<td>44 days</td>
<td>6 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day (4 men)</td>
<td>236 days</td>
<td>94 days</td>
<td>84 days</td>
<td>11 days</td>
</tr>
<tr>
<td>- 7,200/day (9 men)</td>
<td>105 days</td>
<td>42 days</td>
<td>37 days</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 plasterers, 1 assistant)</td>
<td>41 days</td>
<td>8 days</td>
<td>7 days</td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Scaffolding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>11 days</td>
<td>4 days</td>
<td>4 days</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>5 (10 men)</td>
</tr>
<tr>
<td><strong>Timber Placement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>4 (2 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>277 days</td>
<td>102 days</td>
<td>91 days</td>
<td>16 days</td>
</tr>
</tbody>
</table>

Aha’s funerary enclosure complex was estimated to have taken 486 days to build.

**Djer**

Djer had a single funerary enclosure built, surrounded by 269 subsidiary chambers. The total mud bricks used equalled 2,144,300 for the enclosure, and 268,700 for the chambers. The plastered mud brick walls equated to 3,380m² for the main enclosure and 893m² for the subsidiary chambers.

One crew of two plasterers and one assistant, as discussed with the earlier tombs, can plaster 30m² per day. As such, it was estimated that four crews would have been engaged to plaster the walls of Djer’s funerary enclosure and the subsidiary chambers, completing this task in 38 days. However, considering the amount of raw materials required to plaster 120m³ per day, a total of 72 porters would have been required to carry the supplies and to mix the products to produce fresh plaster throughout the day.

---

1042 No extra days were added to accommodate the transportation of bricks to site as porters, once finished with the tomb, may have been redirected to transport bricks for the funerary enclosure.

1043 Note: the use of *italics* refers to tasks undertaken during other activities and not included in total number of days.

1044 A total of 269 subsidiary graves have been found so far and there is the possibility that more subsidiary graves once surrounded the funerary enclosure.
From this perspective then, it seems probable that there were only two plastering crews at most. Although it would be possible to engage this many porters to bring the materials to site – they had, after all, transported mud bricks and the raw materials for the mortar – it appears more likely that only two plastering crews (four plasterers and two assistants) would have been employed to work on the entire complex. The task of roofing the 269 subsidiary chambers would have taken considerably longer. A group of 20 men would have cut the timber over 101 days and ten men could have roofed these chambers in 36 days, amounting to seven chambers per day.

The time taken to construct the complex, therefore, is summarised below.

<table>
<thead>
<tr>
<th></th>
<th>Djer</th>
<th>Enclosure</th>
<th>Subsidiary Chambers (269)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td></td>
<td>702 days</td>
<td>89 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td></td>
<td>351 days</td>
<td>44 days</td>
</tr>
<tr>
<td>Bricklaying</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day (4 men)</td>
<td></td>
<td>670 days</td>
<td>37 days</td>
</tr>
<tr>
<td>- 7,200/day (9 men)</td>
<td></td>
<td>298 days</td>
<td>15 days</td>
</tr>
<tr>
<td>Plastering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 plasterers, 2 assistants)</td>
<td></td>
<td>58 days</td>
<td>14 days</td>
</tr>
<tr>
<td>Scaffolding (10 men)</td>
<td></td>
<td>32 days</td>
<td>Nil</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td></td>
<td></td>
<td>101 (10 men)</td>
</tr>
<tr>
<td>Timber Placement</td>
<td></td>
<td></td>
<td>36 (10 men)</td>
</tr>
<tr>
<td>TOTAL CONSTRUCTION TIME</td>
<td>728 days</td>
<td>87 days</td>
<td></td>
</tr>
</tbody>
</table>

Djet

Djet’s funerary enclosure, like his predecessor, was surrounded by subsidiary graves, 154 found thus far. Smaller in size, the total mud bricks used equalled 1,979,700 for the funerary enclosure and 110,200 for the subsidiary chambers. The plastered mud brick walls equated to 3,124m² for the main enclosure and 612m² for the subsidiary chambers.

The task of roofing the 154 subsidiary chambers would have taken a group of 20 men a total of 58 days to cut the timber and ten men could have roofed these chambers in 21 days.
<table>
<thead>
<tr>
<th></th>
<th>Djet Enclosure</th>
<th>Subsidiary Chambers (154)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td>648 days</td>
<td>36 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td>324 days</td>
<td>18 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day (4 men)</td>
<td>619 days</td>
<td>34 days</td>
</tr>
<tr>
<td>- 7,200/day (9 men)</td>
<td>275 days</td>
<td>15 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 plasterers, 2 assistants)</td>
<td>40 days</td>
<td>13 day</td>
</tr>
<tr>
<td><strong>Scaffolding</strong></td>
<td>29 days</td>
<td>Nil</td>
</tr>
<tr>
<td>(10 men)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>58 (10 men)</td>
</tr>
<tr>
<td><strong>Timber Placement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION TIME</strong></td>
<td>659 days</td>
<td>68 days</td>
</tr>
</tbody>
</table>

**Merneith**

The funerary enclosure ascribed to Merneith, consisted of 1,152,900 bricks for the main structure and 63,900 bricks for the subsidiary chambers. The plastered mud brick walls equated to 2,160m² for the main enclosure and 305m² for the subsidiary chambers.

<table>
<thead>
<tr>
<th></th>
<th>Merneith Enclosure</th>
<th>Subsidiary Chambers (75)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td>378 days</td>
<td>21 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td>189 days</td>
<td>11 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day (4 men)</td>
<td>360 days</td>
<td>20 days</td>
</tr>
<tr>
<td>- 7,200/day (9 men)</td>
<td>160 days</td>
<td>9 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 plasterers, 2 assistants)</td>
<td>37 days</td>
<td>5 day</td>
</tr>
<tr>
<td><strong>Scaffolding</strong></td>
<td>19 days</td>
<td>Nil</td>
</tr>
<tr>
<td>(10 men)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td>30 (10 men)</td>
</tr>
<tr>
<td><strong>Timber Placement</strong></td>
<td></td>
<td>12 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION TIME</strong></td>
<td>397 days</td>
<td>37 days</td>
</tr>
</tbody>
</table>

**Unidentified 1**

The funerary enclosure classified as Unidentified 1 consumed a total of 1,220,000 mud bricks and the plastered walls equalled 2,400m² of wall face area.
### Western Mastaba

The so-called Western Mastaba and accompanying boat grave is also yet to be assigned to a king. The total mud bricks used equalled 1,933,600 for the funerary enclosure (of which 2,394 m² of wall area had been plastered), including the boat grave.\(^{1045}\)

<table>
<thead>
<tr>
<th>Western Mastaba</th>
<th>Enclosure</th>
<th>Boat Grave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td>633 days</td>
<td>115 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td>317 days</td>
<td>56 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day (4 men)</td>
<td>495 days</td>
<td>109 days</td>
</tr>
<tr>
<td>- 7,200/day (9 men)</td>
<td>220 days</td>
<td>49 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 plasterers, 2 assistants)</td>
<td>38 days</td>
<td>2 day</td>
</tr>
<tr>
<td><strong>Scaffolding</strong> (10 men)</td>
<td>16 days</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION TIME</strong></td>
<td>5339 days</td>
<td>111 days</td>
</tr>
</tbody>
</table>

The Western Mastaba complex was estimated to have taken a total of 644 days to construct.

---

\(^{1045}\) The Funerary Enclosure consumed approximately 1,583,000 mud bricks, and the boat graves an estimated 350,600.
2nd Dynasty Funerary Enclosures

Peribsen

The funerary enclosure ascribed to Peribsen contained a total of 1,033,500 mud bricks and the plastered walls equated to a face area of 3,366m².

<table>
<thead>
<tr>
<th></th>
<th>Peribsen</th>
<th>Enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>- 50 porters</td>
<td>339 days</td>
</tr>
<tr>
<td></td>
<td>- 100 porters</td>
<td>169 days</td>
</tr>
<tr>
<td>Bricklaying</td>
<td>- 3,200/day (4 men)</td>
<td>323 days</td>
</tr>
<tr>
<td></td>
<td>- 7,200/day (9 men)</td>
<td>144 days</td>
</tr>
<tr>
<td>Plastering</td>
<td>(4 plasterers, 2 assistants)</td>
<td>57 days</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>(10 men)</td>
<td>35 days</td>
</tr>
<tr>
<td>TOTAL CONSTRUCTION TIME</td>
<td></td>
<td>380 days</td>
</tr>
</tbody>
</table>

Khasekhemwy

Khasekhemwy liked to build large, impressive structures, as demonstrated by the size of the tomb he built at Abydos. His funerary enclosure was no different. The sheer scale surpassed anything seen thus far in the Early Dynastic period, standing at 11m tall, it contained a staggering 10.2 million bricks.\(^{1047}\) At this height, the total number of days

\(^{1046}\) The thickness of the plaster was assumed to be 3cm. However, if the plaster was 8cm thick, as in the case of Khasekhemwy’s funerary enclosure, it is doubtful that a plastering rate of 30m² per day could have been achieved. Assuming that only 20m² per day per crew was possible, the plastering time would have increased to 85 days.

\(^{1047}\) One reason Khasekhemwy’s structure remained relatively unscathed, unlike early funerary enclosures, which, in most cases, only survive to a few bricks high, may be due to its height of 11m tall. David O’Conner wrote: 'Early Dynastic remains here (Djer’s enclosure) were severely eroded and very much cut up by later tomb shafts and pits, …. built directly upon the surface were the remains of several mud-brick funerary chapels or shrines, dated by the associated ceramic to the Middle Kingdom. The stratum appears too dense to be a product of wind-deposition; so, following a suggestion of M. Adams, we can reasonably interpret it as a product of a deliberate levelling operation, the filling in of an irregular topography so as to provide a level surface upon which the chapels and shrines could be built.' See O’Connor, *JARCE XXVI* (1989), 67. It was assumed the early structures were only built to a height of 5m by the author, however, this is speculative. The reason for the assumed height of 5m, as discussed earlier, was based on the fact that Khasekhemwy’s structure had 5m thick walls and was built to a height of 11m, while the structures of his predecessors had walls, on average, half this thickness. It is logical, then, to suppose that they would have also been built to half the height of Khasekhemwy’s structure. So, based on the assumed height of 5m for the funerary enclosures of Khasekhemwy’s predecessors, it is possible that later builders were confident in demolishing and reusing the materials of a structure only 5m tall, levelling the structure and leaving only a footprint behind, whilst an 11m high structure would have been far more challenging and thus
required to install and subsequently dismantle the necessary scaffolding would have been significant. The plastered walls equated to a face area of 9,860m². A tomb of this magnitude would have required a substantial labour force, as summarised in the table below.\textsuperscript{1048}

The time taken to construct the complex is summarised below. Khasekhemwy’s funerary enclosure was estimated to have taken a total of 1,660 days to complete, which is almost 6 years.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|}
\hline
\textbf{Transportation} & \textbf{Enclosure} \\
\hline
- 100 porters & 1,664 days \\
- 200 porters & 832 days \\
- 500 porters & 333 days \\
\hline
\textbf{Bricklaying} & \\
\hline
- 3,200/day (4 men) & 3,178 days \\
- 7,200/day (9 men) & 1,413 days \\
- 9,000/day (12 men) & 1,059 days \\
- 12,000/day (15 men) & 848 days \\
\hline
\textbf{Plastering} &  \\
\hline
- 4 plasterers, 2 assistants & 247 days \\
- 8 plasterers, 4 assistants & 124 days \\
\hline
\textbf{Scaffolding} (10 men) & 88 days \\
\hline
\textbf{TOTAL CONSTRUCTION TIME} & 1,660 days \\
\hline
\end{tabular}
\end{table}

survived the recycling process employed by future builders. However, the author does not agree with the theory that such structures were demolished, ritualistically or otherwise, as it goes against Egyptians desire for things to last eternity.\textsuperscript{1048} Khasekhemwy had previously built a large mud brick enclosure at Hierakonpolis that measured 64.4m x 74.7m and had a large gateway at the southern end of the east wall. The structure survives to a height of approximately 9m, although it has been suggested that it most likely lost 1m in height due to weathering. Friedman, R. F. “New observations on the fort at Hierakonpolis” in Hawass, Z. H. and J. Richards (eds.), The Archaeology and Art of Ancient Egypt. Essays in Honor of David B. O’Connor. ASAE 36. Cairo: 309–336. This structure, at 10m high, would have consumed approximately 4.8 million bricks as calculated by the author (or 12,373m³). The excavators estimated a total of 4 million bricks (using average brick size 25cm x 13cm x 8.5cm). See R. Jaeschke, “Fort-i fications”, Nekhen News Volume 17 (2005), 23–25; N. Hampson and R. Friedman, “Mapping the fort and more”, Nekhen News Volume 12 (2000), 20–21.

Khasekhemwy’s funerary enclosure had 8cm thick plaster. As such the daily plastering rate of 30m² was reduced to 20m² per day per crew.\textsuperscript{1049}
The time taken to construct the subsidiary chambers was considerably more than the time taken to construct the tomb structure of some earlier kings, including Aha, Djer and Djet. In fact, the construction of Djer’s subsidiary graves was estimated to have taken twice as long as his actual tomb. The subsidiary chambers surrounding a select number of elite tombs at Saqqara, however, were fewer in number and therefore did not surpass the construction days of the main tomb structure.

The Western Mastaba funerary enclosure was accompanied by boat graves.
Looking at the combined tombs and funerary enclosures, Khasekhemwy’s mortuary complex overshadowed his predecessors (Graph 6.5). Khasekhemwy’s funerary enclosure alone, containing over 10.2 million bricks, took the most time and effort. Djer’s mortuary complex followed, although the complex took almost half the time of that ascribed to Khasekhemwy. Furthermore, Djer’s tomb complex took almost an equal number of days to that of Den's, although Den’s tomb was larger. Djer’s tomb complex took a large number of days to build, not because the king had a remarkably large tomb, but because of the number of subsidiary chambers accompanying his tomb. This is something his successors chose to reduce in number, so that by the time Den built his tomb, more resources were put into building the tomb, rather than the subsidiary chambers. It is unfortunate that a funerary enclosure is yet to be located for Den, as well as Anedjib, Semerkhet and Qa’a, as a more complete comparison and assessment could be carried out.\footnote{Funerary Enclosures labelled Unidentified 1 and Western Mastaba, have been dated to the 1\textsuperscript{st} Dynasty but are yet to be ascribed to specific kings. Some scholars, as discussed earlier, have Unidentified 1 associated with Semerkhet.}
6.2.4 NAGA-ED-DER

The calculations presented in the following table are based on the assumption that the tombs had superstructures built up to a height of 2m.\textsuperscript{1053}

<table>
<thead>
<tr>
<th>Naga-ed-Der\textsuperscript{1054}</th>
<th>1506</th>
<th>1581</th>
<th>1571</th>
<th>1514</th>
<th>1515</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>13 days</td>
<td>55 days</td>
<td>58 days</td>
<td>59 days</td>
<td>72 days</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters\textsuperscript{1055}</td>
<td>129 days</td>
<td>125 days</td>
<td>60 days</td>
<td>135 days</td>
<td>51 days</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>52 days</td>
<td>50 days</td>
<td>24 days</td>
<td>54 days</td>
<td>21 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>94 days</td>
<td>91 days</td>
<td>44 days</td>
<td>94 days</td>
<td>37 days</td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>47 days</td>
<td>46 days</td>
<td>22 days</td>
<td>47 days</td>
<td>18 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>14 days</td>
<td>24 days</td>
<td>6 days</td>
<td>18 days</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Painting</strong>\textsuperscript{1056}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>-\textsuperscript{1057}</td>
<td>-</td>
<td>1 day</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 days</td>
<td>4 days</td>
<td>-</td>
<td>5 days</td>
<td>-</td>
</tr>
<tr>
<td><strong>Roofing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 days</td>
<td>5 days</td>
<td>Corbelled roof</td>
<td>6 days</td>
<td>Corbelled roof</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>159 days</td>
<td>209 days</td>
<td>124 days</td>
<td>219 days</td>
<td>128 days</td>
</tr>
</tbody>
</table>

\textsuperscript{1053} A height of 2m was assumed by the author for the superstructure of medium and small size tombs for cemeteries where the general population was buried.

\textsuperscript{1054} Note: The use of \textit{italics} refers to tasks undertaken during other activities and not included in total number of days.

\textsuperscript{1055} Due to the status of these tombs, it seems unlikely that the bricks were transported to site and stored prior to use as assumed for the elite cemetery at Saqqara and the royal tombs at Abydos. The owners of these tombs may not have had the resources to employ security to safe guard materials stored on site. Therefore, the transportation of bricks to site had to coincide with the bricklayers. For this reason, the lower rate of 1,000 bricks per day, which required the use of 20 porters to supply enough bricks to site daily, is the most likely scenario.

\textsuperscript{1056} The back panels of some of the niches were found to be painted red. P. V. Podzorski, “The Early Dynastic mastabas of Naga ed-Deir”, \textit{Archéo-Nil} 18 (2008), 89–102.

\textsuperscript{1057} There was no mention of the tomb being painted in the excavation report.
<table>
<thead>
<tr>
<th></th>
<th>1513</th>
<th>1586</th>
<th>1584</th>
<th>1572</th>
<th>1605</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>57</td>
<td>62</td>
<td>33</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters</td>
<td>57</td>
<td>56</td>
<td>42</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1,000/day</td>
<td>42</td>
<td>43</td>
<td>31</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Painting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Corbelled Roofing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Timber over doorway</strong>&lt;sup&gt;1058&lt;/sup&gt;</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>120</td>
<td>123</td>
<td>79</td>
<td>77</td>
<td>87</td>
</tr>
</tbody>
</table>

The tombs presented above were selected as they were of a larger size and provide an indication of how long the bigger tombs at Naga-ed-Der took to build.

<sup>1058</sup> Wood saplings had been placed over the doorway to the corbelled roof tombs, acting as a lintel.
6.2.5 ABU RAWASH

<table>
<thead>
<tr>
<th>Tomb</th>
<th>Volume Excavated (m³)</th>
<th>Bricks Used</th>
<th>Plastered Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M01</td>
<td>47</td>
<td>162,500</td>
<td>506</td>
</tr>
<tr>
<td>M02</td>
<td>50</td>
<td>140,200</td>
<td>267</td>
</tr>
<tr>
<td>M06</td>
<td>65</td>
<td>95,000</td>
<td>–</td>
</tr>
<tr>
<td>M07</td>
<td>130</td>
<td>306,800</td>
<td>1,160</td>
</tr>
</tbody>
</table>

The construction times for tombs M01, M02 and M06 are summarised in the table below. Tomb M07 was reviewed separately – its size warranting a larger work force than those estimated for M01, M02 and M06.

<table>
<thead>
<tr>
<th>Abu Rawash</th>
<th>M01</th>
<th>M02</th>
<th>M06</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1 man (2 porters)</td>
<td>39 Days$^{1060}$</td>
<td>63 days$^{1061}$</td>
<td>82 days$^{1062}$</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 20 porters</td>
<td>242 days</td>
<td>205 days</td>
<td>140 days</td>
</tr>
<tr>
<td>- 50 porters</td>
<td>100 days</td>
<td>82 days</td>
<td>56 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2,000/day</td>
<td>82 days</td>
<td>71 days</td>
<td>48 days</td>
</tr>
<tr>
<td>- 3,000/day</td>
<td>55 days</td>
<td>47 days</td>
<td>32 days</td>
</tr>
<tr>
<td><strong>Scaffolding (10 men)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2 days</td>
<td>2 days</td>
<td>3 days</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td>24 days$^{1064}$</td>
<td>9 days</td>
<td>No records of plastering</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong>$^{1065}$</td>
<td>147 days</td>
<td>146 days</td>
<td>132 days</td>
</tr>
</tbody>
</table>

$^{1059}$ Only tombs M01, M02, M06 and M07 were analysed as there is currently insufficient information available on the remaining 1st Dynasty tombs to prepare a full construction program.

$^{1060}$ The rate of excavation was 1m³ per day. The main tomb took 32 days to cut, and the subsidiary graves took seven days.

$^{1061}$ Tomb M02 had a pit cut 5.4m deep, leading down to the subterranean chamber. The rate of excavation would have been more arduous for those removing the spoil as the pit grew deeper. As such, the rate of excavation was reduced to 0.8m³ to compensate for the increased level of difficulty.

$^{1062}$ The rate of excavation was 0.8m³ per day.

$^{1063}$ Transportation of bricks to the site probably commenced at the same time excavation of the tomb began.

$^{1064}$ The main tomb took 17 days to plaster; subsidiary graves took seven days to plaster.

$^{1065}$ Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.
<table>
<thead>
<tr>
<th>Abu Rawash</th>
<th>M07</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
</tr>
<tr>
<td>- 2 men (3 porters)</td>
<td>82 Days</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td>179 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td>90 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
</tr>
<tr>
<td>- 3,000/day</td>
<td>103 days</td>
</tr>
<tr>
<td>- 7,200/day</td>
<td>43 days</td>
</tr>
<tr>
<td><strong>Scaffolding</strong> (10 men)</td>
<td>7 days</td>
</tr>
<tr>
<td><strong>Plastering</strong> (1 plasterer, 1 assistant)</td>
<td>39 days</td>
</tr>
<tr>
<td><strong>Painting</strong>&lt;sup&gt;1066&lt;/sup&gt;</td>
<td>26 days</td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong> (portcullis stone)</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Timber Roofing</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>253 days</td>
</tr>
</tbody>
</table>

<sup>1066</sup> The niched walls were coated with mud plaster and painted white, with traces of red paint in the upper part of the walls and black on the base. Y. Tristant, “Deux grands tombeaux du cimetière M d’Abou Rawach (I<sup>e</sup> dynastie)”, *Archéo-Nil* 18 (2008), 142; Y. Tristant, “Les tombes des premières dynasties à Abou Rouch”, *Bulletin de L’Institut Français D’Archéologie Orientale* 108 (2008), 325–370.
6.2.6 GIZA TOMB

<table>
<thead>
<tr>
<th>TOMB</th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (56)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Excavated</td>
<td>410m³</td>
<td>500m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>718,500</td>
<td>155,800</td>
</tr>
<tr>
<td>Plaster</td>
<td>556m²</td>
<td>333m²</td>
</tr>
</tbody>
</table>

The time taken to construct the Giza tomb and the accompanying subsidiary chambers is summarised in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Main Tomb</th>
<th>Subsidiary Chambers (56)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 5 men (8 porters)</td>
<td>83 days</td>
<td>101 days</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 porters</td>
<td>421 days</td>
<td>92 days</td>
</tr>
<tr>
<td>- 100 porters</td>
<td>210 days</td>
<td>46 days</td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 3,200/day</td>
<td>225 days</td>
<td>59 days</td>
</tr>
<tr>
<td>- 7,200/day</td>
<td>100 days</td>
<td>22 days</td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 plasterers, 1 assistant)</td>
<td>19 days</td>
<td>5 day</td>
</tr>
<tr>
<td><strong>Scaffolding</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10 men)</td>
<td>8 days</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lining (10 men)</td>
<td>30 days</td>
<td>7 days\textsuperscript{1069}</td>
</tr>
<tr>
<td>- Roofing (10 men)</td>
<td>14 days</td>
<td></td>
</tr>
<tr>
<td><strong>Lining and Roofing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lining (4 men)</td>
<td>19 days</td>
<td></td>
</tr>
<tr>
<td>- Roofing (4 men)</td>
<td>16 days</td>
<td>14 days</td>
</tr>
<tr>
<td><strong>TOTAL\textsuperscript{1070}</strong></td>
<td>362 days</td>
<td>179 days</td>
</tr>
</tbody>
</table>


\textsuperscript{1068} Fifty-six graves are numbered but only 49 graves are shown on the plan. Petrie, *Tarkhan I and Memphis V*, Plate 6.

\textsuperscript{1069} All the subsidiary graves had been roofed by wooden poles spaced several centimetres apart and covered by brushwood. W. M. F. Petrie, *Gizeh and Rifeh* (London, 1907), 3.

\textsuperscript{1070} Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.
6.2.7 TARKHAN

**Tomb 1060**

<table>
<thead>
<tr>
<th>Description</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>90m³</td>
</tr>
<tr>
<td>Mud Bricks</td>
<td>1,673m² + 262m²</td>
</tr>
<tr>
<td>Plaster (walls + mud packed floor)</td>
<td></td>
</tr>
<tr>
<td>Volume of Sand (false floor)</td>
<td>164m³</td>
</tr>
</tbody>
</table>

**Excavation**

Excavation of the substructure would not have had more than two workers engaged at any one time due to the confined floor plan area. The total time, therefore, estimated to have taken to excavate the substructure of Tomb 1060 equated to 45 days. Approximately three porters could have removed the spoil daily by carrying 24 baskets each.

**Brick Transportation and Brick Laying**

Tomb 1060 contained just under one million mud bricks – the estimated number used if the superstructure had been built to a height of 4m, and the surrounding enclosure wall 1.5m. The transportation of this quantity of bricks to the site would have taken 50 porters a total of 475 days and 100 men 278 days. The bricklayers would have commenced construction of the mud brick walls soon after the completion of the excavation works. A total of four bricklayers would have needed 287 days. Increasing the daily brick rate from 3,200 to 7,200, the mud brick walls could have been completed in 128 days.

**False Floor**

Assuming the false floors reached a height of 1m, a total of 164m³ of material would have been required.\(^{1071}\) A work crew of ten men carrying 24 baskets per day would have needed 25 days to deposit the material to build up the false floors.

**Plastering**

The mud brick walls of the interior and exterior of the superstructure, the substructure walls and the enclosure wall had all been plastered. The floor between the enclosure

---

\(^{1071}\) As the surviving height of the superstructure is only 0.7m it is impossible to determine the actual height of the false floor as the walls were plastered from the ground up.
wall and the superstructure had also been mud packed. One crew consisting of two plasterers and one assistant could have completed the plastering works in 65 days.

**Painting**
The exterior of the superstructure and the substructure walls had been painted, equating to a surface area of 665m². A crew of two painters and one assistant would have required 16 days to complete the task, based on a daily rate of painting 40m².

**Timber Roofing**
When first excavated, eight beams of un-worked tree branches were found in-situ. As discussed in Chapter 3, the timber roof over the substructure chamber was assumed to comprise of 13 beams of 30cm diameter and 3.2m in length, above which nine planks (30cm x 15cm x 5.6m long) were placed. This amount of timber would have required the felling of approximately 18 trees, which would have taken four men a total of five days to cut. The roof construction would have taken two men five days at most, if they placed four timber beams or planks per day.

**Stone**
Stone slabs were found within the burial chamber measuring 46cm x 30.5cm x 84cm. If the burial chamber had been roofed with stone, the pressure created by sand above the stone slabs may have forced them to crack and split along their length. The cross-section of the stone slabs, measuring 46.0cm x 30.5cm x the original length, would have needed to be greater than 84cm in order to span the roof of the chamber. Calculations then, based on the slabs being placed upright along the 46cm edge, meant they could have supported a load of sand to a depth of 1m. At 30.5cm wide, a total of 17 beams would have been required at a length greater than 2.6m, the shortest span of the burial chamber.

The total volume of stone required equalled 7.5m³. Two men could have quarried and dressed this volume of material over a period of ten days. The placement of the stone

---

1073 Due to the denuded state of the superstructure it was impossible to determine if the structure had been subdivided into multiple magazines and roofed. As such, it was assumed that no timber was consumed in the superstructure.
1075 The reason a depth of 1m was assumed for the false floors.
roof, with slabs weighing approximately one tonne each, would have required at least ten men to spend 17 days placing one slab daily in position.

Construction Summary Tomb 1060

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>45 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>475 (50 porters) / 278 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>287 (4 men) / 128 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>10 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>25 (10 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>65 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>16 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Stone Quarrying</td>
<td>10 (2 man)</td>
</tr>
<tr>
<td>Stone Placement</td>
<td>17 (10 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>22 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>35 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>23 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>5 (4 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>5 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>460 DAYS</strong></td>
</tr>
</tbody>
</table>

The total construction time of Tomb 1060 equalled 460 days, however, this calculation excludes the time it would have taken to place a stone roof over the burial chamber.

Tomb 2038

- Excavation  
- Mud Bricks  
- Plaster (walls + mud packed floor)  
- Volume of Sand (false floor) \(^{1077}\) 

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
<th>VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>97m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>574,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>936m² + 98m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>292m³</td>
</tr>
</tbody>
</table>

Construction Summary Tomb 2038

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>49 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>365 (50 porters) / 183 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>180 (4 men) / 80 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>22 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>35 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>23 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>5 (4 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>3 (4 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>312 DAYS</strong></td>
</tr>
</tbody>
</table>

\(^{1076}\) Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.

\(^{1077}\) The interior of the superstructure had been filled with sand and gravel. W. M. F. Petrie, *Tarkhan II* (London, 1914), 4. In order to calculate the volume of material, a height of 2m was assumed by the author.
Tomb 2050

- Excavation
- Mud Bricks
  - Small Bricks (17.2cm x 8.4cm x 6.6cm)
  - Normal Bricks (24.5cm x 11.7cm x 6.6cm)
- Plaster (walls + mud packed floor)
- Rubble Fill

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>133m³</td>
</tr>
<tr>
<td></td>
<td>205,500</td>
</tr>
<tr>
<td></td>
<td>540,200</td>
</tr>
<tr>
<td></td>
<td>861m² + 150m²</td>
</tr>
<tr>
<td></td>
<td>430m³</td>
</tr>
</tbody>
</table>

Construction Summary Tomb 2050

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>67 (2 men) ; (3 porters)</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>370 (50 porters) / 185 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>233 (4 men) / 104 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>4 (10 men)</td>
</tr>
<tr>
<td>False Floor</td>
<td>32 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>34 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Painting</td>
<td>22 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>6 (4 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>5 (4 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>393 DAYS</strong></td>
</tr>
</tbody>
</table>
6.2.8 KARARA
A total of three Early Dynastic tombs were uncovered at Karâra. Of these, there was sufficient information presented in the excavation reports to estimate the construction time for Tomb 2 and Tomb 3 only.

<table>
<thead>
<tr>
<th>Karâra</th>
<th>Tomb 2</th>
<th>Tomb 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td>37 days</td>
<td>38 days</td>
</tr>
<tr>
<td>- 1 men (2 porters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>16 days</td>
<td>Nil</td>
</tr>
<tr>
<td>- 5 porters</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bricklaying</strong></td>
<td>6 days</td>
<td>Nil</td>
</tr>
<tr>
<td>- 500/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plastering</strong></td>
<td>2 days</td>
<td>Nil</td>
</tr>
<tr>
<td>(1 plasterer, 1 assistant)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stone Quarrying</strong></td>
<td>Nil</td>
<td>7 days</td>
</tr>
<tr>
<td><strong>Stone Placement</strong></td>
<td>Nil</td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Timber Cutting</strong></td>
<td>2 days</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>Roofing</strong></td>
<td>2 days</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>63 days</td>
<td>45 days</td>
</tr>
</tbody>
</table>

6.2.9 NAQADA

**Tomb of Menes**

- Excavation
- Mud Bricks
- Plaster
- Rubble Fill

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>2,227,400</td>
<td>2,227,400</td>
</tr>
<tr>
<td>2,370m²</td>
<td>2,370m²</td>
</tr>
<tr>
<td>500m³</td>
<td>500m³</td>
</tr>
</tbody>
</table>

1079 The burial chamber of Tomb 3 was lined with stone, equalling approximately four tonnes of limestone.
1080 It is possible that the construction of the tomb was halted to allow for the quarrying and transportation of stone, unlike the more wealthy Saqqara tombs, where quarrying was most likely undertaken during other construction activities.
1081 There was a total of five slabs of stone used to line the tomb, which, it was assumed, would have taken one day each to put into position.
1082 Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.
1083 Based on the published plan, the tomb of Menes did not appear to have a substructure. The plan showed mud brick walls extending up from ground level, but no depression beneath. L. Borchardt, “Das Grab des Menes”, *ZÄS* 36 (1898), fig. 21.
### Construction Summary - Menes

<table>
<thead>
<tr>
<th>TASK</th>
<th>DAYS – Menes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>Nil</td>
</tr>
<tr>
<td>Brick Transport</td>
<td>648 (50 porters) / 324 (100 porters)</td>
</tr>
<tr>
<td>Brick Laying</td>
<td>697 (4 men) / 310 (9 men)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>7 (10 men)</td>
</tr>
<tr>
<td>Rubble Fill</td>
<td>38 (20 men)</td>
</tr>
<tr>
<td>Plastering</td>
<td>79 days (2 men + 1 assistant), (15 porters)</td>
</tr>
<tr>
<td>Timber Cutting</td>
<td>45 (10 men)</td>
</tr>
<tr>
<td>Timber Roofing</td>
<td>35 (10 men)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>849 DAYS</strong></td>
</tr>
</tbody>
</table>

### 6.3 Comparison of the Large Mud Brick Mastaba Tombs

A comparison of the three major sites of Abydos, Saqqara and Helwan was undertaken. These results show that the time taken to construct the royal mortuary complexes, including tombs, subsidiary chambers and funerary enclosures, far exceeded that of the elite tombs at Saqqara, and further highlights the immense size of these royal structures (Graph 6.6). The few exceptions were Saqqara tombs S3504, S3035 (Hemaka), S3036 (Ankh-ka), and S3505, all in themselves substantial in size.

Note: The use of *italics* refers to tasks undertaken during other activities and not included in total number of days.

The only royal tombs constructed in Abydos which were not of a large scale belonged to Anedjib and Semerkhet. The funerary enclosures of these kings have not been found. However, based on the size of their tombs, they may not have been substantial in size.

For a visual size comparison of the footprint of the tombs see Kaiser and Dreyer, *MDAIK* 38, Abb. 13.
6.4 Conclusions

Strikingly, these results show that the number of workers employed to build these structures was not excessive. In fact, the number of tradesmen working on the construction of the tombs, including porters engaged in transporting materials to the sites, generally did not exceed 200 workers.

A smaller work force meant that the state did not have to subsidise additional housing for these men, since they could return home at the end of each working day. Unlike the massive undertakings of pyramid construction, which required on-site housing and eating facilities for thousands of construction workers, Early Dynastic period mortuary construction may not have required such a drain on state resources.

Construction, however, played an important role in Early Dynastic Egyptian society. Such projects generated employment for locals and spawned new industries throughout the country. This led to the emergence of towns and urban growth, which in itself required building projects in the form of domestic and community buildings. And it was not only the construction of the tombs that generated employment. Indirect labour, for the supply of clothes, food, tools and funerary goods needed to be provided, as well as a level of bureaucracy which only continued to grow in size. The implications of such large scale building projects and their impact on society and day to day activities are assessed in the next chapter.
Chapter 7: Impact of Construction on Society

Construction has a significant impact on the population of any society; its impact on Egyptian society during the Early Dynastic period was far-reaching. Construction led to the introduction of new industries associated with building such as tool making and maintenance, the procurement and manufacture of materials including raw materials for making mud bricks, the acquisition of timber, quarrying of stone, the need for storage facilities, transportation, and of course the building activity itself. This, in turn, fuelled the need for a bureaucratic system to manage the volume of people who would have congregated in areas where jobs, and the prospect of making an adequate, if not better, living were available. The immergeance of new towns and villages in the Early Dynastic period would have thrived on large building projects, just as they do today.

This chapter examines how construction played an important role in Egyptian society. The implications of large-scale building projects and their impact on day-to-day activities are assessed. Such projects generated employment for locals and spawned new industries throughout the country. Workers had to be clothed and fed, tools and materials supplied, and funerary goods provided. A good proportion of the workers employed for these types of jobs would have been locals and only those with specialised trades probably moved from one site to the next.

As discussed in Chapter’s Four and Six, the large mud-brick mortuary structures of the Early Dynastic period took considerable amounts of materials and time to build. Building activities, however, were not confined to mortuary structures alone. Construction works would have been on-going throughout the year in Egypt, with tombs, temples, and military installations alongside domestic projects making it a significant industry that directly and indirectly employed a vast number of people. An overview of the industries that were generated and affected by constructions is presented later in this chapter under Figures 7.1 and 7.2.

7.1 Methodology

Due to the limited number of surviving records dating to the Early Dynastic period, later periods of the Egyptian economy are at times utilised as a means of assessment, in addition to archaeological evidence from the 1st and 2nd Dynasties. Knowledge of the administrative organisation of Egypt during the Early Dynastic period is incomplete,
with information on the government largely derived from seals, seal impressions and inscribed wooden and ivory labels recovered from royal and private tombs of the period. This places an emphasis on the ownership of goods and provisioning, only giving partial insights into the administration and a far from balanced picture of the Egyptian government at this time.\footnote{B. G. Trigger, B. J. Kemp, D. O’Connor, A. B. Lloyd, \textit{Ancient Egypt, A Social History} (Cambridge, 1983), 56; T. A. H. Wilkinson, \textit{Early Dynasty Egypt} (London, 2001), 110; E. C. Köhler, “Theories on state formation”, W. Wendrich (ed.), \textit{Egyptian Archaeology} (West Sussex, 2010), 41–42.}

Modern day examples of developing nations were used for a comparative discussion on the effect construction played on ancient Egypt’s growing economy. However, the economy of an ancient society is likely to display characteristics that do not have parallels in modern economics.\footnote{B. Haring, “Economy”, E. Frood and W. Wendrich (eds.) \textit{UCLA Encyclopedia of Egyptology}, Los Angeles. http://digital2.library.ucla.edu/viewItem.do?ark=21198/zz001nf64c; sourced on 5 January, 2012.}

The purpose of this chapter, however, is not to attempt to calculate the number of people impacted by construction – such a figure would be pure conjecture based on little to no evidence, especially in light of the fact that only estimates on the population from this time exist. This chapter, rather, seeks to look at the implications of construction on a developing society and the impact on the population in general.

7.2. The Emerging Society

The single decisive factor that made it possible for humans to transform from the small and mobile groups of hunter-gathers to permanent sedentary communities was the advent of agriculture. Once people could control the production of food through specialised food cultivation using irrigation and storage, people were assured of a reliable annual food supply and human lives were forever changed.\footnote{P. Bellwood, \textit{First Farmers: The Origins of Agricultural Societies} (Oxford, 2005), 9, 11, 19–23.} A society which moves away from agricultural subsistence to a more skilled population (provided a large percentage of the population is employed) becomes wealthier, more educated, and better able to maintain itself by farming smarter rather than harder. Historically, improvements in tool design and manufacture and agricultural processes made possible the great increase in non-food producing populations of civilised lands.\footnote{The limit of urban populations of the world (although increasing) are fixed by the food producing capacity of the rural population, and the ability to transport and distribute surplus food to the towns populated by non-food producers. A society engaged in other activities outside of agriculture would need to produce enough surplus food to feed all those workers engaged in other activities, otherwise...}
lifestyle also made it possible to domesticate animals, supplement food supplies and provide non-food products. Farming not only made settlements and towns possible, but the production of surplus food supply meant populations could increase without fear of starvation. In addition, communities could now support a variety of workers in other industries.

Most importantly, farming the world over has always relied upon a dependable water supply. The Nile River provided irrigation that shaped the early landscape of ancient Egypt.\textsuperscript{1091} People began to establish permanent communities along the fertile river as they learned to use the water supply to irrigate crops.\textsuperscript{1092} Constructing a system of canals, dikes, ditches and reservoirs along the river, agriculture was able to flourish, providing the sustenance for a growing population. Over time, improved irrigation techniques and seed manipulation allowed for improved crop yields. Every improvement enabled workers to produce more with the same expenditure of effort, thus freeing up sections of the population engaged in agriculture and animal husbandry to move into other industries.\textsuperscript{1093} The vast majority of the ancient Egyptian population, probably more than nine-tenths, however, lived on the land in mostly rural village communities.\textsuperscript{1094}

7.3 Implications on Society
From the moment farmers began producing excess produce, and subsequently realised the importance of storing, it became essential that storage devices be procured. Originally, this would have involved large pottery vessels, which in turn needed secure storage. Eventually, granaries housing large quantities of excess produce would have been constructed. Society’s need for shelter would have demanded more robust and

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\textsuperscript{1091} The earliest evidence of artificial irrigation is symbolically illustrated on the mace-head of King Scorpion. Here, the king is shown holding a hoe in the act of cutting an irrigation canal. This suggests the transition from natural to artificial irrigation was completed by the end of the Predynastic period. Furthermore, deliberate flooding and draining by sluice gates and floods water contained by a series of dykes was established by the 1\textsuperscript{st} Dynasty. K. Butzer, \textit{Early Hydraulic Civilization in Egypt, A Study of Cultural Ecology} (Chicago and London, 1976), 20–21, 107.

\textsuperscript{1092} Bellwood, \textit{First Farmers}, 99–103.


\textsuperscript{1094} J. Janick, \textit{Agriculture and Horticulture in Ancient Egypt}, www.egyptianagriculture.com/horticulture.html: Sourced on 10 January 2011; The Nile Valley was so productive that on average, an estimated 200,000 farmers would have been able to produce enough grain to feed three million people per year. K. Cooney, “Labour”, T. Wilkinson (ed.), \textit{The Egyptian World} (New York, 2007), 162–163.
permanent structures, too. Construction would become an essential part of a growing society, requiring new industries to develop and demanding that existing ones become more productive as greater demands were imposed upon them.

If one takes the simple, yet labourious task of excavating, the numbers of trades required to excavate a site quickly becomes evident. Excavating a grave or an irrigation canal in ancient Egypt required excavators and porters as well as surveyors to demarcate the area. This activity, however, would not have been possible if the excavators were not equipped with the proper tools to cut through the soil or rock. Cutting tools would have needed to be manufactured, repaired and replaced, and porters would also have required appropriate tools to fill baskets with the spoil they carried away.1095

The number of labourers, the tools supplied and the volume of material excavated would have been calculated and recorded.1096 These records would have enabled labourers to be paid in the form of rations, ensured that tools were returned at the end of each work shift, and also ensured that the productivity rate proceeded at the desired rate.1097 Such records required a level of bureaucracy, which developed over time. The economy emerged as the central concern of the Early Dynastic administration. The annals make frequent reference to surveys of Egypt’s resources, recording all the details of Egypt’s agricultural base, including the size and location of herds, and the productive capacity of fields.1098 An entry from the reign of Den records a census of Egypt’s population, and a regular occurrence from the early 2nd Dynasty onwards of the biennial cattle-count.1099 The need to measure areas of land, when dividing property accurately for taxation purposes, calculating the amount of grain harvested, and co-ordinating the activities of groups and specialists encouraged the development of writing and numerous administration skills with the royal government. Within the overall system, craftsmen were subject to control by scribes and bureaucrats, who were charged with supplying them and coordinating their activities.1100

1095 These tools may have been broken pottery used to shovel the material excavated into the baskets, rather than the use of bare hands.
1097 A discussion on wages and rations is presented later in this chapter.
The emergence of a centralised government saw all of Egypt’s economic and political institutions fall under royal authority and control.\textsuperscript{1101} Two areas of economic administration are discernable in the Early Dynastic sources. The first involved the exploitation of Egypt’s agricultural resources, achieved by means of an organised network of royal foundations throughout the country.\textsuperscript{1102} The second concerned the processing and redistribution of government revenue to various state operations.\textsuperscript{1103} The experience gained in irrigation building works soon extended to the construction of temples and tombs, funded through the collection of revenue by the state.\textsuperscript{1104}

The organisation of labour would have been straightforward. During the time of the Nile flood, for example, when the land was covered with water and unfit for agriculture, the farmers would have been conscripted to work on the royal complexes.\textsuperscript{1105} It should be noted, however, that grain farming and cultivation were distinct from fruit and vegetable growing, and animal husbandry. Fruit production, for example, required perennial water, protection from Nile inundation and specialist farmers, while animals had to be tended year round.\textsuperscript{1106}

As discussed in the preceding chapter, a large portion of the workforce engaged in the construction of large mortuary structures were unskilled labourers, namely porters transporting materials to site. The proportion of skilled labour was relatively small in comparison. This would have allowed skilled labourers to work on building sites throughout the year, uninterrupted and without the need to transfer to harvesting fields during the busier times of the agricultural calendar. The unskilled workforce, however, most likely peasants, would have been made to work year round, either in the fields or on construction projects.

\textsuperscript{1101} Köhler, “Theories on State Formation”, 42.
\textsuperscript{1102} “The exceptional fertility of the annually deposited Nile silts together with the seasonal toil and organisation of the Egyptian farmer combined to create a unique agricultural system, which focused on the production, and processing of emmer and barley. These staple commodities not only served as a vital food and drink to the Egyptians but were also used as an integral part of a complex administrative system of wages and taxation.” M. A. Roth, “Cereal production and processing”, P. T. Nicholson, and I. Shaw (eds.),\textit{ Ancient Egyptian Materials and Technology} (Cambridge, 2000), 506.
\textsuperscript{1103} Wilkinson, \textit{Early Dynasty Egypt}, 116–117.
\textsuperscript{1104} The early rulers of Egypt and their local bureaucracy owed their power in part to the need to organise the population to construct and keep in repair irrigation canals, which channelled the floodwaters to the fields. M. Bierbrier, \textit{The Tomb-Builders of the Pharaohs} (London, 1982), 10.
\textsuperscript{1105} Bierbrier, \textit{Tomb-Builders}, 12.
\textsuperscript{1106} C. J. Eyre, “Village economy in Pharaonic Egypt”, A. K. Bowman and E. Rogan (eds.),\textit{ Agriculture in Egypt, From Pharaonic to Modern Times} (New York, 1999), 54.
With trade networks and economic resources across the whole of Egypt established, the court and the official hierarchy expanded, providing a larger market for specialised goods and services. A guaranteed income from taxation gave the court the funds to support specialist craftsmen on a full-time basis and undertake major construction projects. This meant increasing employment of Egyptian craftsmen, labourers and conscripted workers, all working within a mixed economy of market trade and state distribution.\textsuperscript{1107} The king and his court exercised authority and commissioned work to emphasise their power.\textsuperscript{1108}

The effective management of building projects commissioned by the state – mortuary complexes, temple construction, dams, irrigation channels and other civil schemes required an equally efficient administrative system to be in place. While little survives from the Early Dynastic period concerning the organisation and administration of these activities,\textsuperscript{1109} systems must have been in place to allow for the successful construction of the massive mud brick structures built during the 1\textsuperscript{st} and 2\textsuperscript{nd} Dynasties. An inefficient system would have seen a decline in building activities, rather than the increase we see in more complex and imposing achievements.

The reign of Djoser, at the beginning of the 3\textsuperscript{rd} Dynasty, shows an established and structured administration, comprising of different departments and each with its own bureaucracy designed to improve efficiency.\textsuperscript{1110} The capacity of the builders to construct the grand mud brick structures of the Early Dynastic period should provide, at the very least, circumstantial proof of an efficient system. Such a system was perhaps not as developed as in later periods but was certainly capable of handling and administering the labour and materials for the construction of the royal and elite mud brick mastabas, from as early as the 1\textsuperscript{st} Dynasty.\textsuperscript{1111} Such work could not have been

\textsuperscript{1107}Cooney, “Labour”, 162–163. From inscriptions, Egyptian society fell into three groups: firstly, literate men exerting authority derived from the king, secondly those subordinate to them including artisans, craftsmen, soldiers, and quarrymen, and finally, the illiterate peasantry. Trigger, et. al., Ancient Egypt: A Social History, 80; Distinctions in wealth distribution can be traced to the Neolithic Badarian burials, where approximately eight percent of burials display a greater material wealth than the rest. Köhler, “Theories on State Formation”, 43.

\textsuperscript{1108}It is likely, that most of the most senior administrators may have been relatives of the king, but not all. For example, Hemaka, a high official under King Den, does not appear to have been a member of the royal family. Wilkinson, Early Dynasty Egypt, 112; Köhler, “Theories on State Formation”, 46.

\textsuperscript{1109}Wilkinson, Early Dynasty Egypt, 112–113.

\textsuperscript{1110}Wilkinson, Early Dynasty Egypt, 133–134.

\textsuperscript{1111}For example, the mud brick mastaba’s of the elite and the 2\textsuperscript{nd} Dynasty royal tombs built at Saqqara, as well as the tombs of the kings and accompanying funerary enclosures at Abydos.
made possible without a relatively sophisticated system of organisation and management. One can conclude that an efficient system of bureaucracy was sufficiently developed in the Early Dynastic period and this system supported a growing population and enabled larger and more creative projects to be undertaken. Additionally, the period preceding the 1st Dynasty should not be overlooked as it must have seen a progressive evolution and the development of many of the core elements of the Egyptian institutions which were to flourish in the Dynastic periods that followed.1112

7.4 Impact on Society

The expansion from an agricultural society to one of extensive industries required increased levels of skilled labour. Artisans, craftsmen, project managers and tradesmen were forming a new wealthier class in society. This higher class of society demanded a greater number of luxury items including better accommodations in both this life and the next.

The Egyptian state depended on skilled and unskilled labour, of which the latter was most likely comprised of a large percentage of conscripts. Conscript labour, also known as corvée labour, was generally available as the majority of the ancient Egyptian population was composed of peasants who worked on the land. Peasants may have been transferred to work on building sites when the Nile inundation made farm work impossible, and during the growing seasons when fewer workers were needed.1113 Essentially, there would have been three types of workers on large construction sites: overseers and officials controlling the work; artisans and craftsmen who worked full-time; and seasonal corvée workers who were drafted into service from farms.1114

The ancient Egyptians saw a clear distinction between skilled and unskilled workers in terms of social place and labour structure. The social system valued artisans and craftsmen who were afforded more freedoms. A skilled state artisan could enter the private sector, and use their expertise to produce items in order to obtain additional

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An unskilled state worker, however, was afforded very few freedoms and no luxuries. Farmers, fishermen and herdsmen, who had no craft skills, were ranked lower on the Egyptian social scale. Peasants were severely taxed by local state officials, and required to paid high rents if they were tenant farmers, even though their farm yields amounted to bare subsistence levels year after year, even during optimal Nile conditions. The grain taxes collected were put into royal treasuries that were administered by a vast bureaucracy coordinated by the king and treasurer to institute state projects. Stringent state organisation was only practical for large labour projects, such as mining expeditions, and the building of large complexes.

Private economic activities were first developed in villages throughout Egypt where many craftsmen and labourers operated as unattached workers. This meant they had no formal connections to any state organisation. The private-sector economy and labour force worked alongside the formally organised state workforce. The state collected taxes from private landowners and the peasantry meaning the private sector economy supported state projects with tax revenue.

Evidence for the existence of a basic wage comes from literary and administrative documents. Texts from a Middle Kingdom quarrying expedition give some indication of workers' pay in the form of food rations. The men were paid according to the hierarchy of their position. The bulk of the unskilled workforce received ten loaves of bread and one-third of a jar of beer daily, a bare subsistence wage that would have been consumed on the worksite, given the amount of work involved. Skilled artisans and professionals in the widest sense of the word, including all officials, drew comparatively higher wages, increasing in multiples of 15, 20, and 30 units of bread.
Higher rations enabled surplus grain to be traded for other goods.\footnote{D. Mueller, “Remarks on wage rates in the Middle Kingdom”, \textit{Journal of Near Eastern Studies}, 34 (1975), 255, 257; C. J. Eyre, “Work and the organisation of work in the Old Kingdom”, M. Powell (ed), \textit{Labour in the ancient Near East}, American Oriental Series 68, (1987), 5–47; Cooney, “Labour”, 167.} When the Eloquent Peasant had delivered his first speech to the king, “they gave him ten loaves of bread and two jars of beer”.\footnote{M. Lichtheim, \textit{Ancient Egyptian Literature Volume 1: The Old and Middle Kingdom} (Berkeley, 1973), 173; Mueller, “Remarks on Wage Rates in the Middle Kingdom”, 255.} The diet of the workers, no doubt, included meat and vegetables, though not necessarily every day and in predetermined amounts; most likely paid for with part of his bread and beer ratio.\footnote{Mueller, “Remarks on Wage Rates in the Middle Kingdom”, 262; A. G. Fahmy, “What they ate: Plant remains from HK43” \textit{Nekhen News} 12 (2000), 19.} Where shortages of food presented themselves, for example, as revealed by the workmen of Deir el-Medina, the temples’ wealth provided little or no buffer stock for the population. The officials at the temples of western Thebes demonstrated their reluctance to assist when there was a food shortage, suggesting that temples did not normally play such a role.\footnote{Bierbrier, \textit{Tomb-Builders}, 41; Haring, “Economy”.}

Plant and animal remains found at the Giza Pyramid complex indicated the workmen survived on a diet consisting of two main cereals – emmer wheat and hulled barley – for bread and beer, but also pulses, for example, lentils, grass pea, and bitter vetch, and cattle, sheep, goats and catfish. In addition, the overseers of the workmen had much better cuts of meat, especially beef and pork and large Nile perch. Several areas of the Giza complex settlement revealed large mud-brick silos for storing grain.\footnote{M. A. Murray, “Feeding the town: New evidence from the complex of the Giza pyramid builders”, \textit{General Anthropology} 12 (2005), 7–8.} Food producing areas dating to the Predynastic and Early Dynastic periods, both in Upper and Lower Egypt have revealed large bread and beer making facilities.\footnote{Mueller, “Remarks on Wage Rates in the Middle Kingdom”, 262; A. G. Fahmy, “What they ate: Plant remains from HK43” \textit{Nekhen News} 12 (2000), 19.} The smaller scale of construction meant that although they were not directly connected with an actual building site, like those at Giza,\footnote{Mueller, “Remarks on Wage Rates in the Middle Kingdom”, 262; A. G. Fahmy, “What they ate: Plant remains from HK43” \textit{Nekhen News} 12 (2000), 19.} these food production areas would have served as distribution points for many of the industries of the Early Dynastic period, including the supply of rations to construction workers.


\footnote{M. Lichtheim, \textit{Ancient Egyptian Literature Volume 1: The Old and Middle Kingdom} (Berkeley, 1973), 173; Mueller, “Remarks on Wage Rates in the Middle Kingdom”, 255.}

\footnote{Bierbrier, \textit{Tomb-Builders}, 41; Haring, “Economy”.}

\footnote{M. A. Murray, “Feeding the town: New evidence from the complex of the Giza pyramid builders”, \textit{General Anthropology} 12 (2005), 7–8.}


\footnote{M. A. Murray, “Feeding the town: New evidence from the complex of the Giza pyramid builders”, \textit{General Anthropology} 12 (2005), 7–8.}


The ration distribution per day for porters transporting materials to site would have been substantial if one uses the rations described above. For example, the Funerary Enclosure of King Khasekhemwy at Abydos, estimated by the author to contain over 10 million mud bricks, required 500 porters and a total of 333 days to transport from the brickyards to site. Based on the basic wage of ten loaves of bread and one-third of a jar of beer daily, the number of bread loaves alone would have amounted to 5,000 per day. This figure is for a single project, and one group of workers, and excludes all other rations such as beer, occasional fruits and vegetables, and possibly meat as discussed earlier. When one includes other workers in more specialised trades, who, while fewer in number, received higher wages, bread production would have been significant, as evidenced through the archaeological remains of bakeries. These bakeries would have placed increasing demands on the pottery industry to produce greater numbers of bread moulds, storage jars and the like. Similarly, other established trades would have been equally impacted by construction, and required to increase their productivity. Increases in productivity were made possible through advancements in technology. The most obvious example of such advancement in ancient technology would be the introduction of the potter’s wheel. Where previously potters made vessels by hand, productivity would have increased dramatically with the innovation of the potter’s wheel.

So, while it may appear unproductive to channel a large portion of the countries resources into building and equipping funerary monuments on a modern scale of values, the utilisation of great numbers of unskilled labour and the training of many skilled workers and artisans would have ultimately been seen as a worthwhile enterprise. To begin with, the Egyptian state, following unification, recognised the potential offered by architecture for creating visual statements of power and authority throughout the land. Despite the demanding work undertaken by unskilled and conscripted workers, they and their families would surely have felt a sense of pride during the construction and at the completion of these projects, especially projects being

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1127 Refer to Chapter 6 – Tomb Construction.
1128 Mueller, “Remarks on wage rates in the Middle Kingdom”, 255.
1130 At Hierakonpolis, remains of pottery kilns and breweries suggest food production was undertaken on an industrial scale. M. Baba, “Pottery production at Hierakonpolis in the Naqada II period: Towards a reconstruction of the firing techniques”, R. F. Friedman and P. N. Fiske (eds.), Egypt at its Origins 3, (Leuven 2011), 648–649, 665–666.
built for the deified king. Furthermore, the construction of large mortuary complexes must have represented the single largest industry running more of less continuously throughout the Early Dynastic period, further adding to the growing economy.\textsuperscript{1132}

The importance of construction to the Egyptian population was not only limited to “on-site construction activity” but far reaching activities including quarrying of raw materials, manufacturing of building materials, distribution of construction products and various associated professional services, including an administrative system capable of directing labour, skill and resources to a single undertaking.\textsuperscript{1133} Figures 7.1 and 7.2 provide a brief summary of the different industries construction affected directly and indirectly. In essence, “Direct Labour” amounted to the main construction activities and associated trades. For example, excavation, bricklaying, plastering and painting, and each trade amassed a number of subsidiary activities including the collection of raw materials, transportation, manufacturing, and installation or placement of the materials. The omission of any one of these industries would have affected the system and the construction of building projects would have eventually come to a stop.

Taking the bricklaying trade as an example, if the site was not regularly supplied with mud bricks due to a lack of porters to transport the bricks to site, or if water was unable to reach the site to mix the mortar, the bricklayers would be unable to continue work. Just as importantly, a constant supply of raw materials was required at the brick making yards to ensure they were able to produce the volume of mud bricks required to keep the building sites supplied. Likewise, for other trades, it was essential that productivity was maintained, and this was achieved by ensuring all links in the production chain worked effectively.

So too for indirect labour activities, which provided support to activities directly associated with the construction activities on site. Failure to provide and maintain tools for cutting or excavating or painting, for example, would have rendered work impossible. Failure to administer and distribute wages could have seen workers strike until such matters were resolved.\textsuperscript{1134}

\textsuperscript{1132} Spence, “Architecture”, 367.
\textsuperscript{1133} L. Ruddock, “The Economic Value of construction: achieving a better understanding”, proceedings from The Construction and Building Research Conference of the Royal Institute of Chartered Surveyors (2007); Trigger, et. al., Ancient Egypt, A Social History, 86; Wilkinson, Early Dynasty Egypt, 133–134.
\textsuperscript{1134} Following repeated complaints made by workers of Deir el-Medina engaged on the New Kingdom tombs in Thebes, sit-down demonstrations were staged before the temples of Thutmosis III, possibly Seti I and Ramesses II. Their grievances were not being paid and not receiving rations which were owed to them. Bierbrier, Tomb-Builders, 41.
Fig. 7.1 Construction – direct labour flow chart
Fig. 7.2 Construction – indirect labour flow chart
7.5 Conclusions

In modern society, the construction industry is considered a driver for economic growth and acts as a catalyst for other industries to do well. The construction industry generates one of the highest multiplier effects through its extensive backward and forward linkages with other sectors of the economy. Construction and engineering services play an important role in the economic development of a country and are a primary source of employment generation offering job opportunities to millions of unskilled, semi-skilled and skilled workers.

In ancient society, “whilst pyramid building may be seen as a vital element in Egypt’s prosperity, it would be a serious mistake to introduce altruism as a motive, and to think that positive economic or social effects were intended, or even dimly perceived. Theology and the display of power were justifiable enough”. Even so, the desire by the king and his entourage to build large graves, whether consciously or unconsciously, did influence the ancient Egyptian economy. Furthermore, the impact on society created through the want of larger graves and an increased number of grave goods stimulated growth in both the construction and manufacturing industries. As the population grew, so too did the number of burials, resulting in increased need and subsequent growth of industries. Such growth was made possible through increased food production by means of improvements in farming techniques, better crop yields and larger farming areas.

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1135 Ruddock, “The Economic Value of construction: achieving a better understanding”.
1138 Trigger, et. al., Ancient Egypt: A Social History, 87.
1139 ‘Bureaucracy in the ancient world was an instrument of prosperity of a kind that has surfaced in modern economic debates, revolving around the question: are public works entailing massive state employment a good thing? … even if we reject public expenditure as a modern route to prosperity, we must recognise that part of the backcloth of history is the fact that the central direction of resources committed to massive labour-intensive projects was in earlier times the great engine of growth, creating many of the world’s civilisations. … The state had already become the great provider and it produced whatever it is that we wish to call Egyptian civilisation. Welfare (as yet innocent of social ideology) arrived early in human history.’ Kemp, Ancient Egypt: Anatomy of a Civilisation, 136.
1140 Köhler, “Theories on State Formation”, 43.
1141 The area of cultivable land from the Predynastic period to the Middle Kingdom was approximately 8,000km². Butzer estimated that ca. 3,000BC, 75 people could be sustained on a cultivable area of 1km². By ca. 2,500BC, the number of people who could be sustained by 1km² of cultivable land increased to 130. This provides a hypothetical population of 600,000 and 1.04 million people respectively. Butzer, Early Hydraulic Civilization in Egypt, Table 4, 81–84.
Societies prospered through success in agriculture and the ability to produce surplus food, thus enabling other trades and industries to grow and flourish. The spill-over benefits from the construction industry into other sectors of the economy were vast.

Large-scale construction projects were made possible through the mass production and acquisition of building materials. Mass production enabled products to be more economically produced and therefore gave a greater number of people access to them. The ability to mass-produce an item meant the product, for example, the brick – first made by hand, before recognising the advantages of producing in moulds – could be more readily used. The significance of this is that suddenly the supply for construction materials increased, which fueled the need for greater employment opportunities in this area and resulted in the creation of new industries.

Pit graves required few grave goods, if any. Constructing larger graves, however, meant an increase in the number of grave goods, large quantities of building materials, a dedicated workforce in the craft, artisan and building industry, as well as a significant quantity of conscript labour. An increase in the number of wealthier graves meant growth for the craftsmen and artisans industries. With craftsmen and artisans becoming wealthier, society also witnessed an increase in the ‘middle class’. The only labour group to remain largely unaffected was the farmer who continued to grow crops, be taxed, and live a simple and hard life. Growth in the economy may have slowed when farming conditions weakened due to low yields because of poor floods, or insect infestations, or external factors such as increased military activity diverting resources into other areas. In such cases, however, taxes would still have had to be paid to the treasury, at the expense of the farmer no doubt.

1142 In the Middle Kingdom text, a scribe embellishes on the hardships of numerous trades, and gives thanks to his parents for setting him on the path of becoming a scribe in *The Satire of the Trades*. M. Lichtheim, *Ancient Egyptian Literature Volume I: The Old and Middle Kingdom* (Berkeley, 1973), 184–192. A 20th Dynasty papyrus, in promoting the benefits of being a scribe, does so by expressing the hardships of other occupations: 'The carpenter who is in the shipyard carries the timber and stacks it… His outworker who is in the fields, his is the toughest of all jobs. He spends his day loaded with his tools, tied to his toolbox. …The scribe, he alone, records the output of all of them.' M. Lichtheim, *Ancient Egyptian Literature Volume II: The New Kingdom* (Berkeley, 1976), 168–173.

1143 Based on flood levels recorded over the Early Dynastic period and Old Kingdom, the annual water levels showed a general decline that was most prolific during the late 1st and early 2nd Dynasty. In addition to the decline, in the order of 30% or more after the 1st Dynasty, floods remained generally lower during the Old Kingdom until well into the Middle Kingdom. Butzer, *Early Hydraulic Civilization in Egypt*, 28, 33.
Throughout history, engineering and construction have led to social benefits, even when driven by economics or the need to express a ruler’s power. Roman aqueducts brought water to people, making the collection and redistribution less onerous. The building of bridges not only connected two land masses together but brought people together facilitating trade through faster means of transportation and communication. Where previously a journey was done by boat, now two connected landmasses enabled trade and encouraged people to settle in these areas. Later generations would see the introduction of rail bring towns and cities previously separated by weeks if not months of travel, to being just days and even hours apart. The telegraph and later the telephone made communication instantaneous. Most recently, air travel, refrigeration, the Internet and many more innovations continue to make trade more productive.

So too, ancient societies developed and grew in scale and number as time progressed. Such activities dictated better methods of acquiring and using materials. Developments in metallurgy, for example, resulted in stronger and better-designed tools; the potter’s wheel enabled pottery productivity to increase; and without the improvements in the area of agriculture, food production would have faltered. It was only through the production of surplus food that all other industries were able to flourish, amongst them construction.

The importance construction had on the economy was significant in itself. Building projects generated employment for locals and spawned new industries throughout the country. Construction allowed for an expansion of the economy making the society more industrialised, more competitive – leading to innovation and improvements, as well as a sense of nationalism and pride through the building of large state projects. This fueled a growing population. However, construction was not always a positive contributor. A project, which was too ostentatious and beyond the means of the government to finance, would ultimately lead to an unsustainable drain on the economy and lead to a detrimental impact on the population as a whole. One should, however, recognise the importance construction had on ancient Egypt. It was an industry that provided employment to an ever-increasing population, a large proportion of whom were unskilled, and created a new class of skilled workers, and stimulated other areas of the economy. The achievements of the construction industry in the Early Dynastic period would see the momentum continue into the Old Kingdom.
Chapter 8: Conclusion

Engineering has long been a neglected area in the field of Egyptology. Whilst much has been written on the architecture of tombs from the Early Dynastic period, engineering concerns have been mostly absent in the field of Egyptology from the Early Dynastic period. A clear distinction was made before undertaking this research between architecture and engineering. Architecture commonly encompasses the practice of planning buildings that meet functional, technical, social, and aesthetic needs. Engineering deals with the practical aspects, such as structural requirements, costs, material estimations, and construction administration. It is these latter pragmatic requirements that this research has gone some way to address. The efforts of an architect and engineer, however, are directed toward the same goal, namely, the creation of something which will serve the purpose for which it is built. Construction is the ultimate objective of design, responsible for the conversion of plans and specifications into a finished product.

Overview

During the course of this research the various stages of the building process were assessed: engineering, tools and resources, material expenditure, labour and finally construction.

In reviewing the engineering principles necessary to determine the structural adequacy of a building, the three major structural elements of the mortuary structures: retaining walls, free-standing walls and roofs, were examined. The results showed the capacity of the various structural elements of the individual tombs which were subsequently compared to the actual structures.\textsuperscript{1144}

Modern engineering principles were used to assess the question presented at the commencement of this research: “How well were these tombs built?” Without a point of reference, in this case, the use of modern engineering principles, one could simply argue that since the structures under investigation are still standing, they must have been "well-built" (disregarding the effects of weathering and reuse of materials over the

\textsuperscript{1144} The results are presented in Chapter 2 and the calculations are on the CD in the Appendix (refer to Contents page for full listing of file names). Furthermore, a brief overview of the engineering design methodology and approach adopted is presented in the appendix and explains in greater detail for the reader interested in delving into the process undertaken in re-designing the structures using modern techniques.
centuries on the structures). However, the definition of "well-built", as discussed in Chapter 1 and in the Questions Answered section below, would not have been satisfied.

The development of skills by the early builders was not only limited to the design and construction of the structures, but also limited by the tools used to acquire the materials and build the tombs. Tools used by the Egyptians, found as part of burial deposits as well as in non mortuary contexts, demonstrate the evolution in the types of tools employed by the builders over the various stages of Egyptian history. The technological improvements of these tools enabled larger, more complex structures to be attempted as more advanced tools meant that materials became more accessible, available and easier to procure. Without the proper resources and tools, the construction of the smallest pit grave through to the most elaborate tombs would have been impossible.

Following on from the design of the structure, it became the builder’s responsibility to oversee the acquisition of materials, make certain an adequate labour force was available to manufacture and transport the materials to site on time, and to ensure there was sufficient labour employed to construct the tomb itself. The builder’s job was that of Project Manager and he was responsible for delivering the building on time and on budget.

The scale of building activity that was taking place in the Early Dynasty period must have been enormous based on the material expenditure of mortuary structures at this time. Incorporating construction activity from other sectors, including temples, palaces, military fortifications, domestic and civil projects meant a constant supply of work would have kept the building industry sufficiently occupied.

The workforce commissioned to construct the tombs, including but not limited to bricklayers, plasterers, painters and carpenters, would have been skilled and semi-skilled tradesmen, just like construction workers today. Activities including the transportation of materials would have been undertaken throughout the building process, with the number of workers varying depending on the demands imposed by the state’s other projects. The availability of unskilled labour fluctuated throughout the

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1145 Refer to Chapter 3 for a listing of tools utilised by Egyptian builders.
1146 Refer to Chapters 4, 5 and 6 for Material Expenditure, Labour force and Construction times.
year, depending on agricultural demands placed on the population by the state. During harvest time, a larger portion of the population would have been occupied compared to the inundation season. Multiple construction projects being built simultaneously would have further added to the strain placed on the skilled labour available, and no doubt on unskilled conscripted labour.

The time taken to construct the tombs was estimated and a comparison of the various sites was presented in Chapter 6. Variations in the number of workers and the impact on the total construction times showed an economical compromise, that is, there were benefits in employing smaller work-crews against the time taken, or the speed at which these structures were built. The results show that the number of people employed to build these structures was not excessive, and generally would not have exceeded 200 workers. The implications of a smaller work force, at the most basic level, meant the state did not have to subsidise additional housing for these men. By comparison, the construction of the later pyramids, where on-site housing and eating facilities for thousands of construction workers became necessary, at the expense of the state.

**Questions Answered**

At the commencement of this research, questions on how the earliest large-scale mud brick structures of the 1st and 2nd Dynasties had been designed and built were raised to highlight the fact that a more in-depth understanding of engineering practice existed in ancient Egypt than previously thought. In other words, material and labour resources were effectively utilised. Tomb development has a long history, well into the Predynastic period, however, it is at the commencement of the 1st Dynasty that a marked change is evident, coinciding with the development of the state, kingship and monumental architecture. It is the progressive advancement of skills acquired by the builders in the Early Dynastic period that enabled them to reach the pinnacle of their engineering achievements with the building of the 4th Dynasty pyramids in Giza. The attention given to these stone monuments emphasises the fact that the engineering and building skills utilised in the creation of the pyramids was honed over centuries. The advancements, from the first attempts at pyramid construction to the grand pyramid built by Khufu, have marked a history that goes back further than the building of the Step Pyramid in the 3rd Dynasty.
It is these earlier developments in skills and knowledge, reviewed here through the engineering and construction of the tombs of the Early Dynastic period that has been the focal point of this dissertation and allowed specific questions, summarised below, to be answered.

1. Were the tombs of Early Dynastic period built well?

As discussed in Chapter 1, in order to determine if the Early Dynastic mortuary structures were well-built, it was first important to define "well-built". The dictionary defines “well-built” as being large or ample and having a good strong construction. In this research, a well-built tomb was also defined as being: engineered, that is, there was no evidence showing compensation for a lack of understanding of materials; and whether or not it demonstrated effective and efficient management of resources, both in materials and in use of labour. Those factors which were more relevant to an architectural and sociological analysis, such as beliefs, functionality, and usage were excluded. A pit grave and a large mud brick mastaba tomb would be equally functional as they both achieved their intended purpose – to act as a burial place – but the engineering required for a mastaba was far greater than that of a pit grave, and a study on the latter would, therefore, provide minimal insight into the capability of ancient Egyptian builders and how "well-built" a structure was. Similarly, the intended usage of the tomb was that it was to be used for eternity, regardless of the simplicity or complexity of the structure, so considering the intended usage was also not relevant in this analysis.

Based on the definition of “well-built” given above, the majority of the tombs built during the Early Dynastic period were built well. From the analysis conducted on the retaining walls, free-standing walls and roofs, it is evident that the ancient Egyptians built these structures based on the advancement of ideas, processes and experience. The results indicated that the Egyptian builders were designing based on a good understanding of the surrounding geology and material. The engineering analysis ultimately revealed the ancient Egyptians built the tomb structures based on experience, and possibly from past failures.\footnote{Little evidence remains of past failures with the passage of time. However, a number of the tombs in Cemetery U in Abydos did show signs of failure in the form of retaining walls bulging and collapsing. Refer to Chapter 2 for more details on U-tombs.}
2. How were the tombs built?
By undertaking an engineering analysis of the tombs, reviewing the types of materials and tools used to build the structures, estimating the quantity of material that went into constructing the tombs, the labour force required, and finally, by extrapolating the time taken to build them, it was possible to assess how the tombs of the Early Dynastic period were built.

These designs revealed that the builders possessed sound engineering knowledge. The retaining wall results showed that the Egyptian builders were designing based on a good understanding of the surrounding environment and geology of the area. Free-standing walls separating magazines compared with those built around burial chambers, showed differences in thickness, particularly in the elite cemetery at Saqqara compared with those at Helwan. The Helwan tombs were less conservative, but still structurally adequate, leading to a more efficient use of resources. This would suggest the thickness of walls was used primarily to enhance security, as walls built around other areas of the same tombs, such as the magazine walls, were thinner, nonetheless sufficiently robust and structurally satisfactory. The roof designs revealed the Egyptians must have had a thorough understanding of the way certain materials performed, as in the differences in the structural behaviour of stone compared with timber. Whilst not designed to the level of conservatism dictated by modern standards, the roofs were adequate and functional.\textsuperscript{1148}

The analysis exposed early Egyptian construction methods to be practical from an engineering perspective, as was demonstrated by their design precision as well as an efficient use of materials and labour. Without the proper resources and tools, the construction of these tombs would have been impossible. In the same way the engineering analysis displayed clear developments in knowledge, so too did the enhancement of tools. Over time, these developments allowed bigger and better structures to be built; ultimately, the scale of construction was limited only to the wealth and status of the deceased occupant.

Building activity in the Early Dynasty period would have been significant. It was therefore essential that an effective resource management system was in place to

\textsuperscript{1148} Refer to Chapter 2 for an engineering analysis of tomb structures.
oversee the construction of these grand structures, otherwise, large scale construction would quickly have become unsustainable.¹¹⁴⁹

3. Why were Early Dynastic tombs built this way?
The main factors that determine how successfully any structure is built are:

- Topography
- Geology
- Climate
- Sources of material
- Access to the site
- Housing facilities (if required)
- Storage facilities (if required)
- Labour supply
- Availability of local services.

*Topography, geology and climate* will have a major impact on the types of materials used, making the *sources of material* equally important. In Egypt, the tombs were built in the dry desert and this enabled the use of unfired mud bricks, which were relatively easy to produce, cost effective and a quick to build with. A wetter climate, as seen in other ancient civilisations, would have required mud bricks to be fired and built of stone to ensure durability.¹¹⁵⁰ The topography of the region impacted on the design requirements and construction time. If the site was level, minimal preparation work would have been necessary. Likewise, excavation into rock or stable soil would have reduced the need for shoring the cut and later the need for retaining walls. Sites closer to areas where building materials could be procured would have saved on transportation and thus labour to transport the goods to site. Smaller work crews would have further alleviated the need for specialised *housing facilities* and *storage facilities*.

¹¹⁴⁹ Refer to Chapter 6 for labour expended in the construction of tombs and time taken to construct.
¹¹⁵⁰ The monumental mud brick structures of Mesopotamia, the Ziggurat’s of Ur were faced with fired mud bricks to protect the internal structure, built of un-fired bricks, from the elements. In other societies, where the manufacturing of mud bricks may not have been the most economically viable option, stone was used simply because it was close at hand. Some of the Early Dynastic tombs at el-Kab are roofed with unworked Nubian sandstone slabs. They were most likely used due to the practical nature of acquiring them, which, when eroded, breaks into slabs. S. Hendrickx, *El Kab V: The Naqada III Cemetery* (Brussels, 1994), 150–152.
The evolution of construction can be said to have commenced in the Predynastic period, flourished in the Early Dynastic period, and boomed in the Old Kingdom. Monumental mud brick construction would not emerge until the 1st Dynasty, however, there is a distinct linear growth from the Predynastic period. For example, Cemetery U at Abydos shows tombs begin as pit cut graves, before enlargements led to improvements in design. Pit graves began to be lined with mud bricks, followed by partition walls, as internal dimensions increased. As tombs grew in size, recruitment of more labour would have been necessary, and the need to adequately engineer the structures would have become a major priority. Large-scale projects were made possible through mass production, the acquisition of increased amounts of building materials and the mobilisation of large groups of workers.

Ancient Egyptian builders were demonstrating a sophisticated degree of engineering knowledge. Such skills, developed throughout the Predynastic and Early Dynastic periods, peaked with the undertaking of Djoser’s Step Pyramid. What began as a mastaba built of stone, transformed into the first pyramid in Egypt. Such an achievement would not have been possible without the development and growth of knowledge in engineering and construction throughout the earlier periods.

Finally, the results of the construction of mortuary structures in the Early Dynastic period highlight a fascinating point; the number of workers employed to build these structures was not excessive. The number of people working on the construction of the larger tombs, including porters engaged in transporting materials to the sites, generally did not exceed 200 men. Such a small work force meant that the state did not have to provide shelter or food in addition to the normal payment for their daily work. Unlike the massive undertakings of pyramid construction which required thousands of construction workers and on-site housing and eating facilities, Early Dynastic period mortuary construction may not have required this additional infrastructure. This fact may account, at least in part, for why the tombs could be built in the time-frames proposed.

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1151 Excavations at Hierakonpolis from the Predynastic period have likewise shown sizable structures built, using timber post construction.

The construction of these structures would have been project managed, not unlike large scale projects today and meticulous records would have been kept. This meant such building activities had far reaching impacts not only on the direct labour force, but also on the people who supported this group. Overall, both the labour force and the support network needed to be well organised, a skill the ancient Egyptians learnt and developed effectively through their building activities beyond the Early Dynastic period.

4. What impact did the construction industry have on society?

The value of the building industry to the economy, in modern society, is considered a driver for growth. Construction and engineering services play a vital role in strengthening and expanding the economic base of a country by providing job opportunities to millions of unskilled, semi-skilled and skilled people. The same can be said of ancient societies.

The role construction played in Egyptian society, as discussed in Chapter 7, was important. In their desire to express their power through monumental architecture, the early rulers of ancient Egypt, possibly unintentionally, were providing the catalyst for construction to flourish. Consequently, the benefits from the building industry into other sectors of the economy led to the enhancement of existing industries and the development of new ones. Large projects, instigated by the state, generated employment for locals and spawned new industries throughout the country. The construction of mortuary and non-mortuary structures not only employed workers directly engaged with the building activity, but also indirectly supported external industries that provided food, clothing, tools, funerary equipment and services.

Future Research

The research undertaken here has looked at mortuary structures from the Early Dynastic period. The sites included in this study, in most cases, were excavated 50 or even 100 years ago. While many sites have been and are still being re-excavated (including Abydos, Helwan and Abu Rawash), new sites are emerging every day, including many in Lower Egypt, where new technologies are making it possible to excavate in water logged sites previously inaccessible.

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1154 There is a growing corpus of new sites excavated over recent years, where the published material is very young, allowing for this research to continue. Y. M. Hussein, The brick architecture of a new tomb
It is therefore feasible to apply this work to future new sites, and even expand the study to other periods in Egyptian history, to evaluate the extent of progress in the field of engineering and construction, and the implications on the economy and society.

Furthermore, the potential re-excavation in the future of the 1st Dynasty Saqqara tombs, first excavated by Emery in the 1940’s and 50’s, may shed some light on the accuracy of the information published in the original reports. More detailed plans would further enhance future research through the ability to analyse and better understand the construction processes of these earlier structures.

Concluding Remarks
Khasekhemwy’s death in 2686BC saw the end of the 2nd Dynasty. Monumental mortuary mud brick construction would not see resurgence until the Middle Kingdom. What began 464 years earlier in 3150BC with King Narmer of the 1st Dynasty finally came to a close.

Engineering and construction in Egypt, however, would continue to escalate in scale and complexity, well beyond the Early Dynastic period. The emergence of the 3rd Dynasty saw the dawn of the pyramid builders and with it, large scale stone construction. As Trigger aptly concludes:

The monumental architecture of the early civilisations represents a combination of engineering skill, bureaucratic management, and aesthetic qualities which indicate that more than massive labour went into creating it. ... It is only through the study of monumental architecture from an engineering point of view that we can hope to learn more about the specialists whose knowledge and skill played such a crucial role in shaping the archaeological record of the early civilisation.


Large scale mud brick construction saw a revival in the Middle Kingdom with the construction of mud brick pyramids encased with stone. Such construction would most likely have been driven by economic factors and time constraints. It would have been far cheaper and quicker to construct with mud bricks, than stone. Mud brick construction did continue throughout the Old Kingdom. Refer to bibliography for references on work undertaken on the mud brick mastaba at Balat by Michel Valloggia.

Bibliography


———. Predynastic Egypt (Princes Risborough, 1988).


Aldred, C., Egypt to the End of the Old Kingdom (London, 1965).


Cerny, J., A community of workmen at Thebes in the Ramesside Period (Cairo, 1973).


Clarke, S., “El Kab and the Great Wall”, Journal of Egyptian Archaeology 7 (1921), 54–79.


Crubézy, E., Janin, Th. and Midant-Reynes, B., *Adaïma. 2. La nécropole prédynastique*. Fouilles de l’Institut français d’archéologie orientale 47. (Le Caire, 2002).


——. “Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Königsfriedhof. 3./4. Vorbericht”, *MDAIK* 46 (1990), 53–90.


——. *Umm el-Qaab I. Das prädynastische Königsgrab U-j und seine frühen Schriftzeugnisse*, AV 86 (Mainz, 1998).


———. “Report on the 22nd campaign of re-examining the royal tombs of Umm el-Qaab at Abydos 2007/2008”, ASAE 84 (2010), 143–156.


———. “Merimde-Benisalâme II. Die Funde der mittleren Merimdekultur”, Archäologische Veröffentlichungen (AV) 51 (Mainz, 1988).


Ellis, C., “Expressions of social status: A statistical approach to the Late Predynastic/Early Dynastic cemeteries of Kafr Tarkhan” in Interregional Contacts in the


Emery, W. B., Excavations at Saqqara, The Tomb of Hemaka (Cairo, 1938).

———. Excavations at Saqqara, Hor-Aha Cairo, 1939.

———. Great Tombs of the First Dynasty Part I (Cairo, 1949).


———. Archaic Egypt (Harmondsworth, 1961).


———. “The royal tombs at Umm el-Qa’ab”, Archéo-Nil 18 (2008), 31–41.


Figueiredo, Á., “Locality 6 at Hierakonpolis: Results of the 2000 field season”, in S. Hendrickx, R. F. Friedman, K. M. Cialowicz, and M. Chlodnicki (eds.), Egypt at its


———. “Preliminary report on the 4th season of excavations at Helwan / Ezbet el-Walda by the Australian Centre for Egyptology, Macquarie University Sydney”, ASAE 77 (2003), 83–93.


Montet, P., “Tombeaux de la Iᵉʳ et de la IVᵉ dynasties à Abou-Roach”, Kêmi 7 (1938), 11–69.


Needler, W., Predynastic and Archaic Egypt in the Brooklyn Museum (New York, 1984).

Nicholson, P. T. and Shaw, I., Ancient Egyptian Materials and Technology (Cambridge, 2000).


———. Abydos II (London, 1903).

———. Gizeh and Rifeh (London, 1907).


———. Tarkhan II (London, 1914).


Quibell, J. E., Hierakonpolis I (London, 1898).

Quibell, J. E., Excavations at Saqqara (1912–1914), Archaic Mastabas (Cairo, 1923).

Quibell, J. E. and Green, F. W., Hierakonpolis II (London, 1902).


———. “La fouille du mastaba V de Balat (Oasis de Dakhleh)”, *BSFE* 84 (1979), 6–20.


———. “Balat I : Le Mastaba de Medou-Nefer”, *FIFAO* 31 (Cairo, 1986).


———. *Abou Rawash I: le complexe funéraire royal de Rêdjedef*, *FIFAO* 63 (Cairo, 2011).


Van Neer, Wim., Linseele, V. and Friedman, R. F., “Animal burials and food offerings at the elite cemetery HK6 of Hierakonpolis”, in S. Hendrickx, R. F. Friedman, K. M. Cialowicz, and M. Chlodnicki (eds.), *Egypt at its Origins, Studies in Memory of*


Wendrich, W., (ed.) *Egyptian Archaeology* (Chichester, 2010).


ENGINEERING AND CONSTRUCTION
IN EGYPT’S
EARLY DYNASTIC PERIOD

A Review of Mortuary Structures

Thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy

By

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BE Civil (Hons)
MA (Egyptology)

VOLUME 2

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June 2012
DECLARATION

I, Angela Sophia La Loggia, hereby declare and certify that my thesis, *Engineering and Construction in Egypt’s Early Dynastic Period*, has not been submitted for a higher degree to any university or institution other than Macquarie University.

This thesis is an original piece of research and the work of others is duly acknowledged where it has been used.

Dated:

Angela Sophia La Loggia
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Copyright: E. C. Köhler, provided here with permission. Unpublished at the time of this study. ©.
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Appendix 2: Engineering

Chapter 2 reviewed the capacity of three main structural elements of the tombs: retaining walls, free-standing walls and roofs. The engineering principles necessary to determine the structural adequacy of the various components was briefly discussed. The following is a more detailed review of the engineering principles, with examples. The formulae and calculations presented are contained in the excel worksheets in the accompanying CD, under the folder labelled Chapter 2 Engineering.

A2.1 Design of Gravity Retaining Walls

A2.1.1 METHODOLOGY

Gravity retaining earth structures or gravity walls as they are more generally referred to is based on the simple theory of mass. Thus, the heavier or thicker the depth of the wall, the higher it can be built, and therefore the greater the lateral pressures it can resist. A compromise to the mass law theory is achieved by setting back the wall. If a wall is set back, the lateral earth pressure distribution on the wall itself is reduced, thereby allowing it to be built higher with a reduced wall thickness.

So illustrating this:

The design methodology adopted in this paper is based on the Working Stress Method. Whilst in Australia all the design codes are written in Limit State, for the purpose of this analysis the Working Stress Method would seem more appropriate, as it is the method which is widely used overseas. It also has fewer factors applied to the various
components looked at during the design process and would there-by produce less conservative designs.

The main design criteria for the design of a gravity retaining wall are:
- Sliding
- Overturning
- Bearing Capacity

In the design of any earth retaining structures, there are three primary areas of concern:
1. Lateral earth pressures
2. Foundation bearing pressures
3. Global or overall stability

The analysis of each is based on the strength parameters of the soils:
- Angle of internal friction ($\phi$)
- Unit weight (density) of soil ($\gamma$)
- Cohesion (c); cohesion is typically assumed to be zero when designing due to the complexity of total stress analysis with the cohesive soils.

Active earth pressure ($k_a$) is typically calculated for a wedge of soil trying to slide down a potential failure surface and being retained by the wall system. Earth pressure analysis is traditionally based on effective soil strengths assuming drained conditions.

As with most design activities currently undertaken, the focus has been directed towards designing the structure around possible failure mechanisms. This is more commonly called Limit State Design and involves applying a factor to the material or system failure criteria. In the design of simple retaining walls, the basic design is based upon the equilibrium of the system to the effects of overturning and stabilization.
In the design of gravity earth retaining structures, the modes of potential failure that need to be considered are:

1. Overturning – the rotation movement of the wall in an outwards direction away from the retained soil mass with the hinge point towards the base.

As with most conventional retaining wall design methods, a major consideration is the ability of the structure to resist overturning under loaded conditions. This is basically addressed by grouping the forces acting upon the structure into overturning forces and stability forces and determining their point of action upon the system. From these forces and location of action, their moments are determined about the toe of the wall for the wall to be stable, the sum of the stabilizing moments need to be greater than the sum of the overturning moments. It is common design practice to apply factors of safety to both the stabilizing forces and overturning moments.

2. Base Sliding – the lateral movement of the entire wall.

3. Bearing Capacity and Excessive Settlement – the failure of the underlying foundation strata resulting in a downwards rotation of the wall structure. This also results in a local deformation of foundation material in the vicinity of the base of the wall.

One of the more typical failure methods when designing a structure in a geotechnical sensitive environment is the capacity of the founding or surrounding material to withstand the increased loading due to the development. With this in mind, it is essential to assess the material on which the new retaining structure will be completed.

In Egypt due to the limited rainfall and in some areas complete absence of rainfall and consequent general dryness of the land, this gives builders the great advantages, and the
dry, hard rock or rocky debris found almost everywhere, makes a firm and suitable base on which to build. It is in these dry areas that the pharaohs and general population alike choose to be buried, and not in the soft alluvial soil which forms the floor of the Nile valley.¹

A2.1.2 SOIL PROPERTIES
The purpose of a retaining wall system – which all these walls lining the substructures of these Early Dynastic tombs can be classified as, is to safely hold a wedge of soil in place. The angle of internal friction, cohesion, and the unit weight determine the force that will be exerted on the wall structure.

Some typical design ($\phi$) and ($\gamma$) ranges for compacted or dense soils are as follows:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>($\phi$)</th>
<th>($\gamma$) kN/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed stone, gravel</td>
<td>34° +</td>
<td>18 - 20</td>
</tr>
<tr>
<td>Sands</td>
<td>30 -34°</td>
<td>18 - 20</td>
</tr>
<tr>
<td>Salty sands</td>
<td>28- 30°</td>
<td>19-22</td>
</tr>
<tr>
<td>Sandy Clays</td>
<td>26-30°</td>
<td>19-22</td>
</tr>
</tbody>
</table>

Table A2.1 Soil Properties

In the design analysis only external stability will be considered. External stability is the walls ability to resist sliding and overturning forces. The wall must be proportioned to provide adequate safety against applied loads.

¹ Clarke, S. and Engelbach, R., Ancient Egyptian Construction and Architecture (New York, 1990), 69.
A2.1.3 TOMB ANALYSIS – RETAINING WALLS

Example 1: Helwan Tomb 1 H.3

The burial chamber of this tomb was cut into gravel substrata and retained by brick walls varying in thickness.²

i. General Design Data for Wall A

- Wall Height: = 3.2m
- Wall thickness:
  - Mud brick Wall = 0.65m
  - Stone lining = 0.21m
- Wall batter (assumed): = 3 Degrees

ii. Estimated Soil Parameters

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Soil Friction Angle ($\phi$)</th>
<th>Soil Density ($\gamma$)</th>
<th>Cohesion (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed stone, gravel</td>
<td>$40^\circ$</td>
<td>20 kN/m³</td>
<td>0 kPa</td>
</tr>
</tbody>
</table>

iii. Geometric parameters

$\phi = 40^\circ$

$\delta = 2/3 \phi = 26.7^\circ$

$\alpha = \text{wall setback} (90^\circ + \text{setback}) = 93^\circ$

$\beta = \text{batter on top of wall} = 0^\circ$

iv. Coulomb Earth Pressure Calculation

$$\frac{\sin^2 (\alpha + \phi)}{\sin^2 (\alpha) \sin (\alpha - \delta) \left[ 1 + \frac{\sin (\phi + \delta) \sin (\phi - \beta)}{\sin (\alpha - \delta) \sin (\alpha + \beta)} \right]^2}$$

² Refer to Tomb plan in Appendix C, Figure C1.9.
$$k_a = \frac{\sin^2(93 + 40)}{\sin^2(93) \sin(93 - 26.7) \left[ 1 + \frac{\sin(40 + 26.7) \sin(40 - 0)}{\sin(93 - 26.7) \sin(93 + 0)} \right]^2}$$

$$k_a = 0.180$$

v. Checking for Overturning of Wall A

Overturning Moment \( M_o \):

\[ M_o = \frac{K_o \gamma H^3}{6} \]

Resisting Moment \( M_R \):

\[ M_R = \frac{\gamma HB^2}{2} + \frac{\gamma_f B_f^2 H}{2} \]

Where:

\[ B = \text{depth of mud brick retaining wall} \]
\[ B_f = \text{depth of limestone facing} \]

For the wall to be stable the resisting forces must equal or be greater than the overturning forces.³

So: \( M_o = M_R \)

The purpose of this exercise is to determine the depth the retaining wall needs to be in order to remain upright. That is, what is the dimension ‘B’ in the formula above.

\[ \frac{K_o \gamma H^3}{6} = \frac{\gamma HB^2}{2} + \frac{\gamma_f B_f^2 H}{2} \]

³ Factors of safety are applied to the design of structures, including retaining walls to take into account variations in material properties, and allow for any unforeseen situation. For the purposes of the analysis undertaken here, factors of safety have been largely ignored.
What this demonstrates is that Wall A which has a total depth of 0.860m should conceivably collapse, whilst Walls B having a total depth of 1.27m are adequate. The reason this did not occur is due the two walls (marked B) on either side of Wall A are acting as buttresses thus assisting in keeping Wall A upright.

However the Egyptian tomb was not solely made up of the substructure. The Egyptians also constructed a mud brick mastaba – the superstructure, above these subterranean chambers. If one now considers the impact of the additional load from the enormous weight of this mud brick construction, will the walls still be theoretically structurally comparable of remaining upright?

Overturning Moment Equation becomes:

$$M_o = \frac{K_a \gamma H^3}{3} + K_a \gamma_m H_m$$

Where:       
$M_{om} = K_a \gamma_m H_m$  is the moment effect due to the mastaba. 
Assume:       
$H_m = 2.0m$

$$M_R = \frac{\gamma B^2}{2} H \quad \text{(Note: ignore impact of stone lining to look at worst case scenario)}$$
So: \[ M_o = M_r \]

\[ \frac{K_a \gamma H^3}{3} + K_a \gamma_m H_m = \frac{\gamma B^2}{2} H \]

Where: \[ \gamma = \gamma_m \]

Simplifying the formula, and making \( B \) the subject:

\[ B = \sqrt{\left( \frac{K_a H^2}{3} + \frac{2K_a H_m}{H} \right)} \]

\[ B = \sqrt{\left( \frac{0.18 \times 3.2^2}{3} + \frac{2 \times 0.18 \times 2.0}{3.2} \right)} \]

\[ B = 0.916m \]

So, by allowing for the additional weight of the mud brick mastaba, Walls B are still sufficient as they are 1.06m deep and 1.27m deep, demonstrating the knowledge of these ancient designers.

Overturning is usually the governing factor in these types of retaining wall structures whilst sliding is less likely to be due to the good quality of material these retaining wall structures have been built in – namely gravelly-sandy soil stratum.

For the purpose of completeness, sliding of these walls will be checked.

vi. **Check for Sliding**

\[ F_s = \frac{K_a \gamma H^2}{2} \]

\[ F_R = \gamma BH \tan \phi + \gamma_f B_f H_f \tan \phi \]
Where: \( \gamma = \gamma_f \)

Making \( B \) the subject of the formula:

\[
B = \left( \frac{K_a H}{2 \tan \phi} \right) - B_f
\]

\[
B = 0.107H - B_f
\]

\[
B = 0.343 - 0.210
\]

\[
B = 0.133m
\]

For the retaining walls to resist the sliding forces, they would only need to be 0.133m thick. So clearly overturning is the governing factor in the design of these walls. Furthermore the original roofing structure and its’ weight bearing down on these walls would have further assisted in resisting the walls sliding forces.

**Example 2: Helwan Tomb 40 H.3 - Analysis**

The burial chamber of this tomb is cut into the gravel and retained by stone walls.

i. **General Design Data of Wall**
   - Wall Height: \( = 2.6m \)
   - Wall thickness:
     - Mud brick Wall \( = 0.630m \)
     - Stone lining \( = 0.260m \)
   - Wall batter (assumed): \( = 3 \text{ Degrees} \)

ii. **Estimated Soil Parameters**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Soil Friction Angle(( \phi ))</th>
<th>Soil Density (( \gamma ))</th>
<th>Cohesion (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed stone, gravel</td>
<td>40(^\circ)</td>
<td>20 kN/m(^3)</td>
<td>0 kPa</td>
</tr>
</tbody>
</table>

\(^4\) Refer to Tomb plan in Appendix C, Figure C1.12.
iii. Geometric parameters

\[ \phi = 40^\circ \]
\[ \delta = 2/3\phi = 26.7^\circ \]
\[ \alpha = \text{wall setback} \ (90^\circ + \text{setback}) = 93^\circ \]
\[ \beta = \text{batter on top of wall} = 0^\circ \]

iv. Coulomb Earth Pressure Calculation

\[ k_a = \frac{\sin^2(\alpha + \phi)}{\sin^2(\alpha \sin(\alpha - \delta) \left[ 1 + \frac{\sin(\phi + \delta) \sin(\phi - \beta)}{\sin(\alpha - \delta) \sin(\alpha + \beta)} \right]^2}} \]
\[ k_a = \frac{\sin^2(93 + 40)}{\sin^2(93) \sin(93 - 26.7) \left[ 1 + \frac{\sin(40 + 26.7) \sin(40 - 0)}{\sin(93 - 26.7) \sin(93 + 0)} \right]^2}} \]
\[ k_a = 0.180 \]

v. Checking for Overturning

Overturning Moment \( M_o \):

\[ M_o = \frac{K_o \gamma H^3}{6} \]

Resisting Moment \( M_R \):

\[ M_R = \frac{\gamma HB^2}{2} + \frac{\gamma_f B_f^2 H}{2} \]

Where:

\[ B = \text{depth of mud brick retaining wall} \]
\[ B_f = \text{depth of limestone facing} \]
For the wall to be stable the resisting forces must equal or be greater than the overturning forces.

So: \[ M_o = M_R \]

The purpose of this exercise is to determine the depth the retaining wall needs to be in order to remain upright. That is, what is the dimension ‘B’ in the formula?

\[
\frac{K_a \gamma H^3}{6} = \gamma H B^2 + \gamma B_f^2 H
\]

\[
B = \left( \frac{\frac{K_a}{3} - \frac{B_f^2}{H^2}}{H} \right) H
\]

\[
B = 0.235H
\]

\[
B = 0.610m
\]

\[
B_{total} = 0.610 + 0.260
\]

\[
B_{total} = 0.870m
\]

The actual depth of the retaining wall in 40 H.3 is approximately 0.890m, once again demonstrating the ability of the Ancient Egyptian builders and more importantly designers.

If we consider the effect of a possible superstructure on this tomb the depth of wall would change and need to be deeper. However as with tomb 3 H.1 the corners of the burial chamber are behaving as buttresses, further strengthening the overall structure.

Overturning Moment Equation becomes:

\[
M_o = \frac{K_a \gamma H^3}{3} + K_a \gamma m H_m
\]
Where: \( M_{om} = K_a \gamma_m H_m \) is the moment effect due to the mastaba.

Assume: \( H_m = 2.0m^5 \)

\[
M_R = \frac{\gamma B^2}{2} H \quad \text{(Note: ignore impact of stone lining to look at worst case scenario)}
\]

So:

\[
M_o = M_R
\]

\[
\frac{K_a \gamma H^3}{3} + K_a \gamma_m H_m = \frac{\gamma B^2}{2} H
\]

Where: \( \gamma = \gamma_m \)

Simplifying the formula, and making B the subject:

\[
B = \sqrt{\left( \frac{K_a H^2}{3} + \frac{2K_a H_m}{H} \right)}
\]

\[
B = \sqrt{\left( \frac{0.18 \times 2.6^2}{3} + \frac{2 \times 0.18 \times 2.0}{2.6} \right)}
\]

\[
B = 0.826m
\]

So, by allowing for the additional weight of a 2m high mud brick mastaba, the retaining walls of the burial chamber would need to be approximately 0.90m in depth. The actual walls are 0.89m which due to the effect of the walls behaving as buttresses, demonstrates the walls to be adequate. Furthermore it also shows these structures to have been designed without over design and thus possible wastage of resources and time.

\( ^5 \) Due to the denudation of the mud bricks used in these tombs throughout history very few superstructures have survived. This is again seen with tomb 40 H.3, and whilst it is possible to establish with some degree of certainty the plan dimensions of the superstructure, determining the height is not also so clear. For the purpose of this analysis a height of 2m has been chosen.
vii. Check for Sliding

\[ F_s = \frac{K_u H^2}{2} \]

\[ F_R = \gamma BH \tan \phi + \gamma_f B_f H \tan \phi \]

Where: \( \gamma = \gamma_f \)

Making \( B \) the subject of the formula:

\[ B = \left( \frac{K_u H}{2 \tan \phi} \right) - B_f \]

\[ B = 0.107H - B_f \]

\[ B = 0.279 - 0.260 \]

\[ B = 0.010m \]

Sliding in this instance is once again not the governing factor in the design.
A2.2 Design of freestanding walls

A2.2.1 TOMB ANALYSIS – ROBUSTNESS

Structural capacity of tomb walls

The bricks and stone masonry that form the walls of tombs are subject to vertical loads from loads placed above them and horizontal loads such as wind loads.

In the extreme, this could cause the walls to:

- buckle (wall distorts or collapses);
- overturn about toe\(^6\) (overturning failure);
- slide forward (sliding failure); or
- rotate, digging into the foundation at the toe (bearing failure).

The risk of each of these failure modes occurring may be reduced by:

- Making the wall wider, thus increasing the structural stability of the wall;
- Supporting the top of the wall by a roof structure, although this is only effective while the roof remains in place;
- Increasing the strength of the foundation under the wall; and/or
- Providing buttresses to the wall.

In addition to these types of “global failure”, walls constructed of masonry or blocks may fail in bending. That is, adjacent blocks forming the wall separate under the action of the load. However, given that the walls are generally fairly thick, this mode of failure unlikely.

If the roof structure collapses, the walls are no longer supported at the top, and this will significantly reduce their stability. However, if there are cross-walls or buttresses at reasonably close centres, the stability of the walls will be maintained.

The comprehensive analyses of the walls of most structures is quite complex, and most designers develop simple rules to cater for this complexity. These simple rules are

---

\(^6\) The toe is the bottom front corner of a wall where it sits on the supporting foundation.
generally based on a combination of experience, intuition and some simplified calculations. The modern equivalents of such simple “rules-of-thumb” are the robustness rules found in some modern masonry standards and codes. The following is an example of one such simple rule:

A modern free-standing wall (without any roof support at the top, cross-walls or buttresses and relying wholly on the gravity of the wall itself to prevent overturning, sliding or bearing failure) would be designed with a thickness of approximately half its height. Walls whose thicknesses are less than half the height will require top support and/or cross-walls and/or buttresses.

Design for Robustness

The design undertaken is based on Australian Standards code AS3600: 2001 Section 4.6 Design for Robustness. The formulae are summarised in the table below and calculations presented in the worksheets found on the accompanying CD.

<table>
<thead>
<tr>
<th>For Walls Spanning Vertically</th>
<th>For Walls with at least one vertical edge laterally supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H = C_v t_r k_i )</td>
<td>( H = \frac{C_h t_r}{L_r - C_h t_r} + C_v t_r )</td>
</tr>
</tbody>
</table>

where:

- \( t_r \) = the minimum thickness of the wall (m)
- \( k_i \) = a thickness coefficient (as per Table 7.2 in AS3700 – Masonry Structures)
- \( C_v, C_h \) = robustness coefficients, values as given in Table 4.2 (AS3700) for edge restraints at top, bottom and vertical sides (either separately or in combination)
- \( L_r \) = the clear length of a wall between vertical lateral supports, in metres; or
  = for walls with openings, the distance from the laterally supported end of the wall to the centre of the opening, in metres

The robustness of walls of geometric section can be checked by determining an equivalent thickness of rectangular section from first principles and applying the provisions of this Clause.
A2.3 Design of roofs

A2.3.1 TOMB ANALYSIS – STONE ROOFING

Determination of Maximum Roof Spans Using Stone Slabs

In constructing stone roofs, the Egyptian builders were faced with choosing the right material, the correct proportions of the roofing beams, and the necessary type of roof. The conditions were remarkably different in a building whose roof had to carry its own weight alone and one whose roof was exposed to pressure either from masonry piled on it or from the natural rock of the mountain when the construction was underground.7

Whilst a larger number of tombs had stone roofs the majority of these utilized un-worked stone sandstone slabs such as in the case of the tombs at Elkab, Naq’ el Masaid and Sabaiya East or limestone slabs in the north at the site of Abu Roash. These tombs were not analysed due to the limited information on the pit graves and the size of the slabs used as roofing. More importantly however, these un-worked stone slabs appear to have been randomly placed based solely on their planar dimensions which in the case of the sandstone slabs would have been selected based on being of appropriate size with a thickness ranging between 0.1-0.2m. Some of the tombs at Elkab were also backfilled with earth prior to the roof being placed over the tomb as a marker8 thus rendering the roof slabs from a structural point of view obsolete.

Roof Analysis

Beams are structural members which transfer the transverse loads they carry to the supports by bending and their shear actions. Beams generally develop higher stresses than axially loaded members with similar loads, while bending deflections are much higher. These bending deflections of a beam are often, therefore a primary design consideration. On the other hand most beams have small shear deflections and are usually negligible.

The strength of a limestone beam in the plan of loading depends on its section properties and on its yield stress \( F_Y \). When bending predominates in a determinant beam, the effective ultimate strength is reached when the most highly stressed cross-section becomes fully yielded so that it forms a plastic hinge. The moment \( M_P \) at which this occurs is somewhat higher than the first yield moment \( M_Y \) at which elastic behaviour normally ceases.

The data required for an elastic analysis include both the distribution and the magnitudes of the applied loads and the geometry of the beam. In particular, the variation along the beam of the effective second moment of area \( (M) \) of the cross section is needed to determine the deflections of the beam, and to determine the moments and shears when the beam is statically indeterminate. These are explained below in the subsequent calculations. The stress at any point in the section is:

\[
f = \frac{M}{Z}
\]

Where:

\[
Z = \frac{I}{y}
\]

\[
I = \frac{bd^3}{12}
\]

\[
y = \frac{d}{2}
\]

\[
M = \frac{wl^2}{8}
\]

So the Tensile Stress formula becomes:

\[
f = \frac{0.75wl^2}{bd^2}
\]
Example 3: Saqqara Tomb 3121

The seven limestone slabs used in roofing the corridor leading to the burial chamber were of average dimensions 2x1x0.9m. The actual width of the corridor is 1.65m. So the span to the centroid of stone beam is 1.85m.

Determining the allowing tensile stress of the limestone slabs:

\[ f = \frac{0.75wl^2}{bd^2} \]

Calculating the load due to the self weight of the beam:

\[ w = \gamma bd \]

Where \( \gamma = 20kN/m^3 \) (Assumed density of limestone)

\[ w = 20 \times 0.9 \times 1.0 \]

\[ w = 18kN/m \]

So the tensile stress of limestone for these slabs equates to:

\[ f = \frac{0.75 \times 18 \times 1.85^2}{1.0 \times 0.9} \]

\[ f = 57kN/m^2 \quad \text{or} \quad 0.057MPa \]

The Ultimate Tensile Stress of limestone based on test data has shown limestone to have a value approximately in the order of \( f' = 3.5MPa \). So from this the true distance these slabs could have spanned, can be determined.

---

9 Refer to Tomb plan in Appendix A, Figure A1.27.
10 Emery, W. B., Great Tombs of the First Dynasty Part I (Cairo, 1949), 118.
Due to the quality of the limestone rock having a number of fissures and irregularities, for the purposes of obtaining more realistic results, this strength will be factored down by 10.

\[ f = \frac{M}{Z} \]

Where:

\[ Z = \frac{bd^2}{6} \]

\[ Z = \frac{1000 \times 900^2}{6} \]

\[ Z = 135 \times 10^6 \text{mm}^3 \]

\[ M = \frac{wl^2}{8} b = fZ \]

\[ l = \sqrt{\frac{8fZ}{wb}} \]

\[ l = \sqrt{\frac{8 \times 0.35 \times 135 \times 10^6}{0.018 \times 1000}} \]

\[ l = 4.59\text{m} \]

Therefore, conceivably the limestone slabs used to roof the passageway to Saqqara Tomb 3121 could have spanned a total distance of 4.6m. This seems fair when one considers that the slabs were almost 1.0m x 1.0m in cross-section.

However, whilst a span of 4.6m may have been possible when no additional loading from above was applied to these beams, the weight of the soil above the roof of the burial chamber may have added approximately 45kN/m of additional load. Added to the 18kN/m from the beams themselves, this changes the maximum allowable span somewhat as shown below:
Assuming: \( w = 18 + 45 = 63kN/m \)

\[ l = \sqrt{\frac{8 \times 0.35 \times 135 \times 10^6}{0.063 \times 1000}} \]

\[ l = 2.5m \]

\textit{Saqqara Tomb 3507}

\[ f = \frac{0.75wl^2}{bd^2} \]

Calculating the load due to the self weight of the beam:

\[ w = \gamma bd \quad \text{Where} \quad \gamma = 20kN/m^3 \quad \text{(Assumed density of limestone)} \]

\[ w = 20 \times 0.33 \times 0.33 \]

\[ w = 2.2kN/m \]

So the tensile stress of limestone for these slabs equates to:

\[ f = \frac{0.75 \times 2.2 \times 1.44^2}{0.33 \times 0.33} \]

\[ f = 31.1kN/m^2 \quad \text{or} \quad 0.031MPa \]

Based on tests results the Ultimate Tensile Stress of limestone is approximately \( f'_{t} = 3.5MPa \). Reducing the strength by a factor of 10, allows for any irregularities in the stone, \( f'^{t} = 0.35MPa \).
The maximum span these beams could therefore have achieved is:

\[ f = \frac{M}{Z} \]

Where:

\[ Z = \frac{bd^2}{6} \]

\[ Z = \frac{330 \times 330^2}{6} \]

\[ Z = 5.99 \times 10^6 \text{ mm}^3 \]

\[ M = \frac{wl^2}{8}b = fZ \]

\[ l = \sqrt{\frac{8fZ}{wb}} \]

\[ l = \sqrt{\frac{8 \times 0.35 \times 5.99 \times 10^6}{0.031 \times 330}} = 4.04 \text{ m} \]

These beams would therefore could have conceivably have been able to span a distance of 4.04m. As there was no additional weight applied on them from above as in the Tomb 3121, these beams would have been able to have spanned the full length of the burial chamber.
A2.3.2 TOMB ANALYSIS – TIMBER ROOFING

Structural capacity of tomb roof structures

The timber planks, beams and logs that form the roof of a tomb may fail in one of two ways when a load due to sand and self weight is applied from above.

1. The bottom fibres of the timber planks, beams and logs may slowly stretch, causing the roof to “sag” until it reaches an unacceptable deflection. As soon as the load is applied, an initial sagging takes place, followed by a gradual increase over a long length of time. Just as modern designers assess what level of deflection is acceptable in modern structures, ancient designers may also have given consideration to the acceptability of excess deflection.

2. In addition to roof sagging, the bottom fibres of the timber planks, beams and logs may “snap” when the stress induced by the load exceeds the strength of timber in bending. As each of the members snap, parts of the roof may collapse.

Both of these failure modes must be checked independently.

For a given simply supported single span of a timber plank, beams or log, the design distributed load is given by the following formulae for deflection and strength respectively.

For a section of any shape:

For limiting deflection, the design distributed load, \( w = (76.8 \frac{E}{L^3}) \cdot \Delta/L \)

For limiting strength, \( f \), the design distributed load, \( w = (8.0 \frac{I/y}{L^2}) \cdot f \)

Where:

- \( w \) = design distributed load (kN/m)
- \( L \) = span (m)
- \( E \) = elastic modulus of the material (kN/m²)
- \( I \) = second moment of area of the section (m⁴)
- \( y \) = distance from the centroid of the section to the extreme fiber (m)
- \( \Delta/L \) = limiting deflection / span
- \( f \) = limiting strength (kN/m²)
For rectangular timber sections

For limiting deflection, the design distributed load, \( w = (28,236,800 \cdot b \cdot d^3 / L^3) \cdot \Delta/L \)

For limiting strength, \( f \), the design distributed load, \( w = (1.33 \cdot b \cdot d^2 / L^2) \cdot f \)

Where:

- \( w \) = design distributed load (kN/m)
- \( L \) = span (m)
- \( b \) = width of beam (m)
- \( d \) = depth of beam (m)
- \( E \) = elastic modulus of the material = 4,130 kN/m²
- \( \Delta/L \) = limiting deflection / span
- \( f \) = limiting strength (kN/m²)
Example 4: Tomb of Den

The following sample results from the tomb of Den in Abydos, is taken from the calculation worksheets submitted with this thesis.11

| **BURIAL CHAMBER** |
| **CALCULATIONS** |
| **Member** | **Is member rectangular or circular (R / C)** | **C** | **Beams** |
| **Width (or diameter if circular)** | dia. | 0.30 | m |
| **First moment of area** | I | 397608750 | mm$^4$ |
| **Section modulus** | Z | 1325362 | mm$^3$ |
| **Bending moment capacity reduction factor** | φ | 1.00 |
| **Ultimate bending strength** | $f_b$ | 28.96 | MPa |
| **Ultimate deflection ratio** | $\Delta / L$ | 0.004 | Modern Factor |
| **Ultimate bending moment capacity** | $\phi M$ | 38.38 | kN.m |
| **Spacing** | B | 0.30 | m |
| **Unfactored load above** | $w_a$ | 9.00 | kPa |
| **Uniform distributed load** | $W_a$ | 2.70 | kN/m |
| **Self weight** | $W_s$ | 0.37 | kN/m |
| **Total uniform distributed load** | $W_t$ | 3.07 | kN/m |
| **Bending moment factor** | $k$ | 0.13 |
| **Deflection factor** | $k_d$ | 0.01 |
| **Limiting span (bending)** | L | 9.99 | m |
| **Limiting span (deflection)** | $L_d$ | 5.55 | m |
| **Limiting span** | L | 5.55 | m |
| **Actual span** | $L_{act}$ | 8.67 | m |
| **Is the span less than the limit** | **No** | **Problem** |

11 Due to the complexity of the designs examples are available to view on the CD in the Engineering folder.
Example 4: Tomb of Den

The following sample results from the tomb of Den in Abydos, is taken from the calculation worksheets submitted with this thesis.\(^\text{11}\)

<table>
<thead>
<tr>
<th>Member</th>
<th>C</th>
<th>Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is member rectangular or circular (R / C)</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Width (or diameter if circular)</td>
<td>dia.</td>
<td>0.30 m</td>
</tr>
<tr>
<td>First moment of area</td>
<td>I</td>
<td>397608750 mm(^4)</td>
</tr>
<tr>
<td>Section modulus</td>
<td>Z</td>
<td>1325362 mm(^3)</td>
</tr>
<tr>
<td>Bending moment capacity reduction factor</td>
<td>(\phi)</td>
<td>1.00</td>
</tr>
<tr>
<td>Ultimate bending strength</td>
<td>(f_0)</td>
<td>28.96 MPa</td>
</tr>
<tr>
<td><strong>Ultimate deflection ratio</strong></td>
<td>(\Delta / L)</td>
<td>0.004</td>
</tr>
<tr>
<td>Ultimate bending moment capacity</td>
<td>(\phi M)</td>
<td>38.38 kN.m</td>
</tr>
<tr>
<td>Spacing</td>
<td>B</td>
<td>0.30 m</td>
</tr>
<tr>
<td>Unfactored load above</td>
<td>(w_a)</td>
<td>9.00 kPa</td>
</tr>
<tr>
<td>Uniform distributed load</td>
<td>(W_a)</td>
<td>2.70 kN/m</td>
</tr>
<tr>
<td>Self weight</td>
<td>(W_s)</td>
<td>0.37 kN/m</td>
</tr>
<tr>
<td>Total uniform distributed load</td>
<td>(W_t)</td>
<td>3.07 kN/m</td>
</tr>
<tr>
<td>Bending moment factor</td>
<td>k</td>
<td>0.13</td>
</tr>
<tr>
<td>Deflection factor</td>
<td>(k_d)</td>
<td>0.01</td>
</tr>
<tr>
<td>Limiting span (bending)</td>
<td>L</td>
<td>9.99 m</td>
</tr>
<tr>
<td>Limiting span (deflection)</td>
<td>(L_d)</td>
<td>5.55 m</td>
</tr>
<tr>
<td>Limiting span</td>
<td>L</td>
<td>5.55 m</td>
</tr>
<tr>
<td>Actual span</td>
<td>(L_{\text{act}})</td>
<td>8.67 m</td>
</tr>
<tr>
<td>Is the span less than the limit</td>
<td><strong>No</strong></td>
<td><strong>Problem</strong></td>
</tr>
</tbody>
</table>

\(^{11}\) Due to the complexity of the design examples, they are available to view on the accompanying CD in Appendix 3, under the folder Engineering.
<table>
<thead>
<tr>
<th>BURIAL CHAMBER RECALCULATED WITH LESS CONSERVATIVE DEFLECTION FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Is member rectangular or circular (R / C)</strong></td>
</tr>
<tr>
<td>Width (or diameter if circular)</td>
</tr>
<tr>
<td>First moment of area</td>
</tr>
<tr>
<td>Section modulus</td>
</tr>
<tr>
<td>Bending moment capacity reduction factor</td>
</tr>
<tr>
<td>Ultimate bending strength</td>
</tr>
<tr>
<td><strong>Ultimate deflection ratio</strong></td>
</tr>
<tr>
<td>Ultimate bending moment capacity</td>
</tr>
<tr>
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</tr>
<tr>
<td>Unfactored load above</td>
</tr>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>Limiting span</td>
</tr>
<tr>
<td>Actual span</td>
</tr>
<tr>
<td>Is the span less than the limit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUBSIDIARY CHAMBER CALCULATIONS</th>
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</thead>
<tbody>
<tr>
<td><strong>Is member rectangular or circular (R / C)</strong></td>
</tr>
<tr>
<td>Width (or diameter if circular)</td>
</tr>
<tr>
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<tr>
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