3. Soil (including mud-brick architecture)

BARRY KEMP

Introduction

Soil has been one of the most widely used building materials since the Neolithic, particularly in arid and semi-arid parts of the world. Commonly termed adobe, it still has considerable potential. Almost any kind of soil can be used (although some modification is often necessary to add strength), it is relatively easy to work with, and its plasticity and chemical stability give it great versatility. It can be moulded by hand or within rigid moulds into building blocks (bricks), can be rammed between formwork to create walls directly, and is equally suited for plastering to produce smooth or moulded finishes. Its vulnerability to erosion and damage do, however, create a constant need for maintenance in the form of replastering and actual repair.

Architectural applications do not exhaust the industrial uses to which soil was put in ancient Egypt. It was, of course, a prime ingredient of pottery, and in the study of composition and methods of handling there is a degree of overlap with pottery research. It was used in certain small applications which also relate more closely to pottery-making in the degree of manipulation of the clay that was involved. These include the administrative practice of sealing, and the making of small mud objects, such as figurines and beads. This section is, however, limited to soil architecture. Most of the evidence that can be cited in this context is archaeological, but it is important to note that a vocabulary of words exists in Egyptian texts which probably or certainly deal with soil architecture (Badawy 1957; Simpson 1963: 56–8, 72–8c; Spencer 1979a: 3–4). Uncertainties in translation, however, make it hard to use these sources constructively.

The mud-brick ruins which have been most accessible to archaeologists have principally been constructions on new sites, frequently in the desert and including the brickwork of tombs. This gives a very distorted frame of reference. Most building in brick at any period was done on sites, often long-occupied, which were situated on the floodplain. Moreover, brick architecture in ancient Egypt included huge palace complexes which are still very poorly documented. Even when fragments are excavated they are normally no more than foundations. We must make allowance for such buildings originally having risen to considerable heights and possessing elaborately constructed interiors which utilised a level of building skills now meagrely represented by what has survived. A modern account of soil architecture in ancient Egypt is almost bound not to do it justice.

History of soil architecture in Egypt

Soil was used for building in Egypt before the making of mud bricks was developed (Lacovara 1984). Although a precursor to brick, these simpler uses are bound to have continued into historic periods. Thus the practice of setting criss-crossed twigs in the tops of walls seen in some New Kingdom representations of houses is clearly related to wattle-and-daub technique (Davies 1929), which was perhaps the building medium originally in empty foundation trenches of the New Kingdom or later at western Thebes (Hölscher 1939: 71–2). We find its beginnings at a number of Predynastic sites, at its simplest in the lining of fire-pits and in the coating of the basketry and matting that was employed to line grain silos or to cover circular hut-bottoms. Examples are known from settlements where no more substantial use of soil has been detected, suggesting that, locally, this technology might have preceded a full and independent structural use of soil. The sites in question include the middle levels at Merimda and Wadi Hof (el Omari) (Hayes 1965: 104–15, 117; Debono and Mortensen 1990: 17–20). The remains of clay coating to interwoven branches was reported at Maadi (Rizkana and Seehler 1989: 40; Rizkana 1996: 178), although at the same site mud bricks had also been used (see p. 79).

At Hemmamia North Spur, nine hut circles and a straight wall 8.2 metres long had been built from a mixture of mud and limestone fragments during a period defined initially by sequence-dates 33–45 and now known to have commenced during the transition from Badarian to Amratian. A radiocarbon date for a layer of fill in one of them (re-examined in 1989) is 3830–3625 BC (Brunton
and Caton-Thompson 1928: 82–8; Holmes and Friedman 1994: 118–24, 134–5). The imprint of stalks, pressed vertically against the mud on the outside of the huts whilst still moist, showed that reeds had been used to give added height, whilst wooden posts had been set at thirty-centimetre intervals along one face of the straight wall. The shallowly sunken hut floors had been made of beaten mud. A slightly more advanced technique was employed for similar hut circles at Merimda (Juncker 1930: 45–7; 1932: 44–6; Hayes 1965: 105–6; cf. Badawi 1978: 48–9). Whilst some had been built from superimposed rings of Nile mud, others had used rough blocks of the same material containing a binder of chopped straw. Mud had also been used to plaster the interiors and floors of the huts. These huts belong to the latest phase of Merimda (late fifth millennium BC).

Evidence for the moulding of bricks in small numbers for limited use appears quite early on settlement sites in Upper Egypt, sometimes accompanied by evidence that buildings (often rectangular in plan) were still primarily made with reed walls supported by posts and sometimes plastered with mud (wattle-and-daub). Sites 29 and 25A on the desert at Hierakonpolis illustrate this situation well and belong to the Gerzenian and possibly Amratian periods (Holmes 1992; Hoffman 1980). Also at Hierakonpolis (site 24) and at several other Gerzenian settlements which lack evidence for brick houses, long narrow bar-like bricks were used to support clay vessels built into brick-lined tunnels which were then fired, probably in the process of brewing beer (Peet and Loat 1913: Chapter I, pl. 1; Peet 1914: 7–9, pl. 18; Geller 1992: 21–3). The survival of a wattle-and-daub tradition long after brick-making developed leaves ambiguous the original material of the fired-clay model of a rectangular house found in a tomb at el-Amra of the Gerzean period (Randall-Maciver and Mace 1902: 42, pl. X,1,2; Baumgarten 1960: 132–3, pl. XII,3).

True mud-brick buildings of the Predynastic period still remain few. Petrie excavated the corner of a walled mud-brick settlement in the ‘South Town’ at Naqada which subsequent fieldwork has indicated belonged most probably to the late Gerzean period (Petrie and Quibell 1896: 54, pl. LXXV; for dating, see Baumgarten 1970: 6, pl. LXXII; Hassan and Matson 1989: 312). Bricks were also used to line the burial chambers of elite tombs at Naqada (cemetry T) and Hierakonpolis (tombs 100, the Decorated Tomb) at a time which must fall within the Gerzean period (c. 3400 BC), and on the Umm el-Qa‘ab (cemetry U) at Abydos in the period preceding the First Dynasty (Dreyer et al. 1996), but no evidence of superstructure has been found. We can also infer the use of mud brick in the construction of buttressed enclosures depicted in the art of the late Predynastic period (Spencer 1979a: 5).

In northern Egypt the advent of mud-brick architecture is one of the principal signs of major culture change shortly before the First Dynasty. It appears with apparent suddenness in excavated sequences at a number of sites in the Nile Delta, including Buto (von der Way 1992, 1993). Brick fragments from here have been compared with a remarkable use of long mud slabs to revet the wall of an underground chamber at Maadi (Rizkana and Seeliger 1989: 54–5, pl. XV,1–2). They measured 50–65 × 9–10 cm along their sides, were probably about 10–15 cm thick, and had been laid in mud mortar. It was not recorded whether straw temper had been used, but this was certainly a feature of a few fragments of bricks found loose in other parts of the settlement. From earlier strata at Buto (Naqada IIb at the latest) come several cylinders or ‘nails’ of baked clay closely similar to objects which were used as a form of mosaic decoration in brick temple walls in the Unik culture of Mesopotamia. There is the inevitable suggestion that, in another part of the site, a brick building of Mesopotamian style had been constructed.

In general it would seem that brick came into limited use in the Nile Valley and probably Delta from at least the beginning of the Gerzean period, and probably before, but also that wattle-and-daub remained the preferred medium for most buildings until close to the beginning of the First Dynasty, when all-brick towns began to appear throughout the country.

The hardening of soil through heating must have been a very ancient observation. The use of bricks and clay bars in late Predynastic brewing kilns such as at Abydos, the results of major constructions in some of the large First-Dynasty tombs which were subsequently repaired (Emery 1961: 180), and of several major burnings of town walls and houses, visible now on archaeological sites (e.g. Tell Edfu, Elephantine, Abydos and especially Kom Ombo), would have been especially dramatic evidence of the effects of burning on brickwork. The widespread preference for unfired soil architecture was thus through choice rather than ignorance. This is borne out by occasional exceptions, such as the fired clay tiles used in streets in Middle Kingdom fortresses in Nubia (Reisner et al. 1967: 118–19, pl. XLIXB; Emery et al. 1979: 8, 15–16, 35, fig. 19, pl. 92B). From the New Kingdom onwards these exceptions become a little more frequent: specially shaped bricks for friezes on tomb façades (Borchardt et al. 1934; Spencer 1979a: 140–1, pl. 37); the lining of burial chambers at Tell Nabash (Petrie 1888: 18–19; Spencer 1979a: 44); and on to a little catalogue of examples from the Twenty-first Dynasty to the Hellenistic period (Spencer 1979a: 141; Petrie 1966: 49). One factor inhibiting the use of fired brick has presumably been the added cost of the fuel needed for the firing, as well as the need for a more suitable (and expensive) mortar, which, in the Hellenistic period, was lime.

The composition of mud bricks

Although ‘mud-brick’ is the term most often used in Egyptology, ‘adobe’ has a more widespread currency. The
ancient Egypt word for mud brick, *djebet*, passed, via the Coptic *tobe* into Arabic as *طبَ(ع)* and thence probably into Spanish to give the word adobe (Wiesmann 1914; Černý 1976: 18; Vycichl 1983: 210–11; Mond and Myers 1934: 48, n. 2; Simpson 1963: 76, n. 16).

The study of adobe architecture has wide geographical range and its literature extends to manuals of use for constructing sophisticated modern buildings in dry environments, especially in the USA (McHenry 1976, 1984). Modern views stress the simplicity of the techniques.

Adobe building bricks are a very simple material. They are simple to make, and by following a few rules can be laid by anyone with a strong back, using a reasonable amount of care. A great deal of misinformation, myth, and old wives tales has been circulated about this great building material. (McHenry 1976: 50)

Suitable soils are widespread. They should contain four elements:

- coarse sand or aggregate, fine sand, silt, and clay. Any one may be totally absent and the soil may still make satisfactory bricks . . .
- The aggregate (sand) provides strength, the fine sand is a filler to lock the grains of aggregate, and the silt and clay (generally identified by particle size rather than chemical analysis) acts as a binder and plastic medium to glue the other ingredients together. Soil structures with a high percentage of aggregate (sand) may be strong when dry, but are more vulnerable to erosion from rain. Soil structures high in clay may be much more resistant to water and erosion, but less strong. (McHenry 1984: 48) (Also Brown and Clifton 1978: Hughes 1988.)

This is a valuable perspective from which to view the practice of ancient Egyptian builders, who seem not to have worked to a standard formula. It should be noted, however, that the characteristics of soils differ to the point that expert opinion derived from the study of one region (and much of the technical study of soil architecture has been done in the Americas) is not necessarily transferable to other regions. Local studies are essential, and so far few have been done in Egypt. Moreover, physical composition is not the only variable. 'Soluble salts are a major component of most soils and are as important as clay minerals for cementing the silt- and sand-sized particles' (Hughes, pers. comm.). They, too, vary from one region to another. Many of those who work the land develop an intuitive sense of soil character and whether a particular one is suited to brick-making and, if so, how it might be modified. Anecdotal evidence and personal observation suggest that in modern Egypt the generally preferred material, which produces the hardest bricks, is cultivated topsoil (*khart*) which will have been a thorough mixing of particle sizes through regular turning by the farmer and will have been enriched with deliberately added organic material. Other soils can, however, also be made usable.

The most significant departures from the norm in ancient Egypt occurred on a minority of sites which were constructed in the desert and where local soils differed markedly from those available in the floodplain. In turning to nearby materials, as they often seem to have done, the ancient builders produced bricks with a different appearance from those normally employed, but it is probably a mistake to consider such bricks as necessarily inferior for the job that they were intended to do. They were simply different.

Many naturally occurring soils will require some modification, more often to deal with the presence of too much clay, rather than the lack of it. The soil abundant in clay may be modified by the addition of sand, coarser aggregates, or vegetal matter such as straw, hay, or manure. It is perhaps unrealistic to try to establish rigid proportions in view of the nature of the material sources and the lack of difference in the performance of the finished product. (McHenry 1984: 50)

In order to judge the extent to which the soil of ancient Egyptian bricks was modified, particle analysis is required not only of samples of ancient bricks but also of local soils to provide a basis for comparison. A set of analyses by French at East Karnak (1951) and at Amarna (1958) has attempted to do just this (compare a similar study at Lachish in Palestine, Goldberg 1979). The contrasting characteristics of the two sites make these studies particularly valuable: East Karnak is part of a *tell* of long occupation located near the river and sufficiently far from the desert to imply an alluvial origin for the mud of its bricks. Amarna, by contrast, was situated on the desert edge, and the ancient brick-makers had available to them a much wider variety of soils. Figure 3.1 is a summary of the results.

The samples were first crumbled. Once any gravel fraction and other large inclusions had been removed by passing the resulting soil through a two-millimetre mesh sieve they were separated by means of the hydrometer method of particle size analysis into three basic components: fine to very fine sand (*2–4 φ*), medium silt (*5–7 φ*) and clay. At Amarna, the natural sediments from the river bank displayed a wide variety of mix when taken from different beds: pale brown sand, brown silt and dark brown silty clay loam, the products of a combination of seasonal changes in the amount of sediment carried by the Nile and the changing velocity of river flow. The most appropriate comparison at Karnak was with agricultural soil used for the manufacture of modern local bricks, a brown silt loam, probably alluvial, containing pottery fragments. In three out of these four samples medium silt was the dominant material.

At Karnak, a sample of eight bricks, ranging in date from the top of the second millennium BC to the late centuries BC/early centuries AD, together with a modern local brick, gave particle-analysis results showing very small to zero amounts of clay, and a silt proportion that varied between 28 per cent and 52 per cent. There is a difference in the silt–sand ratio—a reduction in silt—between the bricks and the sample of natural alluvium from which they are made. Unless the brick-makers were, on other occasions, choosing soils of *60–70* per cent sandiness, they presum-
ably added sand to the mix (French's own explanation that the silt is puddled out during manufacture is hard to envisage on the scale required). Except for the two latest (which had been partially fired to an orange-brown colour, 7.5 YR 3(4) on the Munsell scale), all of the ancient bricks and the modern brick and sample of alluvium were a similar greyish-brown in colour (10 YR 4/2–3 or 5/2–3). A further comparison comes from samples taken at intervals down stratigraphic trenches in the settlement strata (represented by Trench E) which in large part must be derived from the decay of mud brick structures. The generally larger proportions of sand presumably represent the combined effects of the wind in depositing sand and removing the finer silts.

At Amarna all of the bricks sampled were of the same period (c. 1350 BC), but came from widely dispersed parts of the site. The most valuable reference set derived from the Workmen's Village, where bricks could be divided into two broad groups on the basis of colour. One, from the village enclosure wall and of the common greyish-brown colour, was deemed to have been made from mud from the alluvial plain; the other group, of varying shades of orange and grey and often quite pebbly, was almost certainly made from marl locally dug from quarries adjacent to the village. Neither had been given a straw temper. They differ principally from the Karnak bricks in the higher proportion of clay (6–10 per cent) at the expense of silt (15–20 per cent), but still were generally sandier than two of the three samples from the local alluvial beds from the banks of the Nile. Again we should accept intervention by the brick-makers. In the case of the marl bricks, comparison with source material can be made more confidently than is usually possible because the quarries which provided it are identifiable. A set of marl bricks, despite their distinctive appearance, broke down into proportions of clay and silt (13.75–18.75 per cent and 15–25 per cent) which were higher than the alluvial bricks but not substantially so. The natural samples from the quarries (6.25–12.5 per cent clay and 28.75–52.5 per cent silt) are again somewhat siltier than the bricks derived from them but the contrast is less marked. At a separate but similarly located site (the Stone Village) the analysis of a single marl brick gave a result closer to that from the Workmen's Village quarries. Samples from an ancient ground surface show, as with its equivalent (Trench E) at Karnak, an increase in sand.

Within the main parts of the city, which were much closer to the course of the river, the composition of bricks varies considerably. From the quantities of grit and pebbles and from the pale greyish colour which can so commonly be seen in the bricks it is likely that local desert materials were a common and deliberately added part of the mud mix (gravel was not present in the samples analysed). The analyses done were confined to fourteen samples of bricks which, from their superficial appearance, seemed to be alluvial. They showed the same persistence of clay (3.75–13.75 per cent) but a general tendency to greater siltiness (18.75–65 per cent) than the alluvial bricks from the Workmen's Village. Quite striking is the variation in the silt/sand ratio of three bricks from different parts of the Small Aten Temple, the third sample being almost identical in composition to one of the natural deposits from the river bank. One ancient ground deposit from the North City showed the increase in sand.

Several lessons can be drawn from these analyses. One is the regular appearance of a mix in which sand was generally in the region of 60–70 per cent implying that the brick-makers had a preferred mix, detectable by the feel of handfuls of the mud, to be achieved either by selection of soils or by the addition of sand. The East Karnak–Amarna comparison also shows that the near absence of clay did not hinder brick-making. A third lesson is that, whilst gross colour differences in bricks (sometimes expressed simply by terms such as 'marl', 'sandy') can be a general guide to the origin of their soils, it actually tells one little about their particle composition, which tends to be the same. Colour differen-
A further method that has been used for analysis of clay samples is to place them in a brick oven. However, this method is likely to have limited value, as the brick samples may be affected by factors such as temperature and humidity.

The source of the soil used in making bricks is connected to the location where they were made and who made them. Some soil is invariably required at a building site for the brick molder and plasterer, and one of the factors in making the bricks is the location of the site, which determines the quality of the clay used. The clay used in the brick molder and plasterer is likely to be of inferior quality, as the brick samples are not subject to the same standards as those made for the brick molder and plasterer.

Soil particle analysis of this kind describes the conditions under which the samples were made. Extraneous material, either deliberately or accidentally, can often be observed in ancient brick samples, and even the occasional clay or other small artefact. Reissner comments on personal observation:

"The only material which is now deliberately added to the mud is dust and broken straw, by preference the screenings of the threshing-floor; but even street-screenings, which usually contain a certain amount of wind blown straw, are used by poor people. (Reissner 1931: 72)"

The value of added temper is that it redirects the stresses that arise as the bricks shrink as they dry. This reduces shrinkage and provides a reinforcing structure which limits cracking.

Particular interest attaches to the addition of vegetal matter, especially chopped straw and chaff (ancient Egyptian dh3, Arabic tibn). To judge from the impressions of tibn left in ancient bricks this was a widespread form of added temper and represents a practice that has survived to modern times. It was evidently a preferred temper. One New Kingdom model letter contains a complaint about local unavailability of straw for the making of bricks (Caminos 1976, 198; example of example 17). The Old Testament story of the failure of straw deliveries to the Israelite brick-makers means residents in Egypt (Exodus 5:1-6; Nims 1933: 216) has given added significance to the practice (although, since other forms of temper can be just as good, the story reflects ancient prejudice). Indeed, despite much expert comment to the contrary, the omission of straw is sometimes seen as producing bricks of lesser quality, even on desert sites (e.g. Meidum, Borkowski and Majcherek 1991: 27; cf. Nims 1930: 26). A robust comment is provided by McHenry:

"Straw is sometimes suggested as a necessary ingredient. It is not! Most adobes made with reasonable adobe soil don't need it. If the organic content is too high, or the clay content too low, it may be necessary to add straw for strength, and for speed in drying. (McHenry 1976: 51)"

This is borne out by Clarke and Engelbach:

"With a good sand and alluvium he [the brick-maker] can make tolerably hard bricks, and dispense with the chaff which, in the southern parts of Egypt, is expensive . . . if there is no tibn the bricks are made without it, but sand is often added with good effect. (Clarke and Engelbach 1930: 208, n. 2 and 209)"

In modern Egypt tibn is widely available only for a time following the harvest. For it to have been available round the year in ancient times it would have been necessary to maintain stocks. The city of Amarna, it should be noted, was largely built of bricks without straw, the normal temper having been coarse sand with some gravel. The possibility of insect infestation of the organic content of bricks has not (to my knowledge) been investigated for Egypt, although on desert sites it can lead to its total loss from termites.

The generally simple approach to the distribution of loads by ancient Egyptian builders meant that compressive strength was the prime physical requirement of mud bricks, which have normally weak tensile strength (large bricks often break in two if carried carelessly). Even so, one set of tests of compressive strength of Fourth-Dynasty mud bricks with chaff temper, and of mud and sand mortar, concluded that the results 'belong to the lowest-known compressive strength values for materials used in architectural monuments' (Borkowski and Majcherek 1991: 29). Making walls thick obviously compensates, but, apart from this, it is also clear from particular examples that walls of say thirty centimetres in thickness, were capable of reaching heights of between three and four metres and of supporting the added weight of two roofs (Kemp 1995: 147-9). Moreover, modern mud bricks made with similar mixes of materials emerge as perfectly adequate in this respect (Fathy 1969: 241-2, 287-8). It is important to realise that the characteristics of ancient mud bricks are likely to have altered over time, so that one is making judgements which, whilst important in assessing present conservation needs on a mud-brick building, need not have been relevant at the..."
time when the bricks were made and used. Thus a binder of 

tilm (or any organic material) can be lost to insect infesta-
tion; on the other hand, long exposure to low levels of
humidity, which are likely to be present even on open
desert sites, probably leads to the concentration of soluble
salts (principally calcium carbonate) in exposed brickwork,
especially towards the surface of bricks, and hence to an
increase in hardness.

The making of mud bricks

Evidence from ancient Egypt that relates to brick-making,
other than the bricks themselves, is not extensive. It is rarely
illustrated in tomb scenes. The principal example is in the
mid-Eighteenth-Dynasty tomb of Rekhmira (TT100; Davies
1935: pls. XVI, XVII, XXII; Davies 1943: 54–5, pls. LVIII,
LIX, LX; Mekhitarian 1954: 48; Lhote 1954: pls. 97–9, 101;
Arnold 1901–02, fig. 352). There is also a questionable
Twelfth-Dynasty example at Deir el-Bersha (Newberry
[1895]: pls. XXIV, XXV; Klebs 1922: 118). Rekhmira
changed his colour convention from pinky-grey for
bricks as they were being made, to pink and white once they
were dry and in the hands of the builder, an attempt to
convey the substantial change that does take place during
drying. The scene helps to define the meaning of the key
word used for making or ‘striking’ a brick, nbt (Badawy 1957:
63–4; Simpson 1963: 77–8; Spencer 1979a: 3–4). Brick-
making was also an occasional subject for the wooden tomb
models of the early Middle Kingdom (e.g. Breasted 1948:
52, pl. 46C, from Deir el-Bersha; Garstang 1907: 131, fig.
129, from Beni Hasan; Nims 1950: fig. 2). A small number
of actual ancient brick moulds, all made of wood, are known
(Petrie 1890: 26, pl. IX:23; 1917: 42 pl. XLVI:35; David
1986: pl. 18; Clarke and Engelbach 1930: fig. 263a), some of
them models from temple foundation deposits (Weinlein
1973: 98–9, 232, 296, 419). The remains have also been
recorded of at least one place where bricks had been made in
ancient times (Vercoutter 1970: 214–16). This very limited
documentation shows a way of working that seems to be
identical to that of traditional brick-making in modern
Egypt which has often been described (e.g. Clarke and
Engelbach 1930: 208–9; Reisner 1931: 72–3; Petrie 1938: 4;
Nims 1950: 26–7; Spencer 1979a: 3).

One estimate of daily output by a pair of early modern
brick-makers and a mud mixer is from 4,000 to 6,000
(Reisner 1931: 72–3; comparable to Nims 1950: 27). Since
modern bricks are small this is likely to be a considerable
overestimate if applied to the numbers produced in
Pharaonic times; on the other hand, if output is measured
in terms of volume, the ancient rate of production is likely
to have been higher, since the larger moulds would have
meant a more efficient use of the brick-maker’s labour.

A question that is bound to arise in the case of a society
which, like that of ancient Egypt, was much given to large-
scale public works and to the administration of labour and
commodities, is the existence of administered brickyards,
either permanent or set up for large-scale projects. Esti-
mates of 24.5 million bricks originally in the pyramid of
Senusret III at Dahshur and 4.6 million for Bubhen fortress
give an idea of the size of demand that could arise (de
Morgan 1855: 47, n. 3; Emery et al. 1979, 40), and a few
texts record the exact number of bricks used on a project
(e.g. Reisner 1923: 51). The written evidence is, however,
ambiguous. A Middle Kingdom administrative papyrus
from Kahun concerned with large numbers of bricks could
as easily be dealing with brick-laying as brick-making or
delivery (Griffith 1898: 59 pl. XXIII:24–40; Simpson
1960). A section of Papyrus Reisner I (of the reign of
Senusret I) from Naga el-Deir also covers several operations
involving the structural use of soil, including the making of
mud bricks, each operation being the subject of precise
calculation (Simpson 1963: 76–7, 72–8), but imprecisions
in our understanding of the technical vocabulary again
hinder understanding.

Being in charge of brick-making did not earn a specific
official title. It is possible, particularly in view of the fact
that brick-making in traditional societies is a very wide-
spread skill, that it was normally treated as a form of
peasant labouring, and the necessary output was obtained
through whatever means of coercion was practised at a
given time. In the Rekhmira brick-making scene (Davies
1943: 54–5) the labour used is explicitly identified as being
foreign captives, their output intended for storerooms for
the temple of Amun at Thebes. Given the nature of the
administered sector of the ancient Egyptian economy,
which was able to transport materials over long distances
to meet the needs of individual schemes, the existence of
administered brickyards raises the possibility that sometime
bricks or, at least, some of the raw materials, were
brought in from a distance, and thus that their composition
owes nothing to local sediments.

Perhaps the clearest evidence for administered supervision
is the practice of impressing bricks with an official stamp
(Fig. 3.4a), which is known from the beginning of the
Eighteenth Dynasty to as late as the Thirtieth (Spencer
1979a: 144–5), the Eighteenth Dynasty providing the
broader spread of examples. If at a brickyard the person
wielding the stamp from time to time walked down an aisle
between fields of recently made bricks and impressed a
stamp every few paces, the relatively small number of
stamped bricks that would result, and their irregular dis-
tribution in loads which might be made up by workmen
carrying them away in a different order from that in which
they were visited by the stamp-wielder, could well produce
the haphazard way in which they appear in constructions.
Just as interesting are buildings in which they were not
used, the Great Palace, Kom el-Nana, the North Palace and
the Great Wall around the North Riverside Palace at Amma-
rna being conspicuous examples. Should we deduce that
not all brickyards possessed stamps, and see this as evi-
dence that the sources of supply available to the king did not all have the same status?
A possible precursor to the use of stamps was the tracing of a simple design on to the top of a brick by means of a finger. Examples have been found on the bricks used in Middle Kingdom pyramids (de Morgan 1893: 49, fig. 110; Arnold 1979: 7, pls. 2–3; 1987: 82, Abb. 40). Finger-markings occur on bricks at Amarna, often a single diagonal line (visible in Nicholson 1989: 67, fig. 3.3; 68, fig. 3.4).

Bricks as artefacts
In rare instances individual bricks served a special need. They were used as markers in the course of laying out structures (e.g. parts of the Small Aten Temple at Amarna; the alignment of the boat slipway at Mirgissa, Fig. 3.8a); they had a restricted use in ritual contexts: bricks in early Middle Kingdom temple foundation deposits sometimes contained inscribed plaques (Weinstein 1973: xvi, ‘Mud bricks’; Arnold 1979: 50), and in New Kingdom tombs ‘magical’ bricks were inscribed with short texts of protection which actually specify ‘bricks of unbaked clay’ (Thomas 1964).
When in their normal use as a building material bricks, as artefacts, are open to systematic recording by the archaeologist. Spencer (1979a: 1) has put forward a set of standard headings under which brick details should be routinely recorded:
1. The composition of the bricks, and whether burnt or unburnt.
2. The dimensions of the bricks.
3. The bonding, preferably described by means of a Corpus of bonds.
4. The distribution of any reed-matting or timber tie-beams in the brickwork.
5. The nature of the mortar.
6. Details of any plaster.
7. Whether stamped bricks occur.
8. Any special usages, or bricks of special form.

We will consider brick sizes first, since measuring ancient bricks is perhaps the most obvious thing to do with them. The first aim of brick measurement is to identify the output of individual factories or brick-making teams, initially for the purpose of internal comparisons. These usually relate to a site’s chronology. Although the potential is also perhaps there for a study of how many sources of supply there might have been for a given building project, the variables are probably uncontrollable. Moreover, brick measurement itself is complicated by the nature of the data to be collected.

Even if bricks are formed from a mould that has been made true, the result, from the traditional style of brick-making, is not a simple geometric shape but one with a complex topography that is individual to each and every brick. The reasons for irregularity lie partly in the shrinkage that is bound to have taken place as the bricks dried, particularly since a fairly wet mix is likely to have been used (if one takes modern traditional brick-making as a guide). Moreover, each time that a mix of mud was prepared the proportions of its constituents are likely to have varied slightly, leading to a slightly different degree of shrinkage. A further cause of irregularity is disturbance whilst drying. Modern traditional brick-makers tend to lay out their bricks very close to one another. As the brick-maker lifts the wooden mould free from the most recently made brick, jiggling it to prise it free, it is very easy for him to bump it against the neighbouring brick in the previously made row, distorting it slightly. With the larger-sized bricks favoured at certain periods in the past the jiggling of the mould as it was removed will probably also have distorted each brick as soon as it was made. Furthermore, bricks are normally made on an earth surface which has not been prepared with great thoroughness. The undersides of bricks can therefore be more irregular than the other faces and bear the impressions of loose debris left on the working surface, whilst a slight convexity sometimes develops on the top surface during drying.

Given the imprecisions of manufacture, the proposal to measure ancient bricks to the nearest millimetre (Mond and Myers 1934: 49; Hesse 1970, 1971, endorsed by Spencer 1979a: 147) is not easily met, for brick faces are often not true planes. A dimension exactly recorded, therefore, can itself be a compromise. A high level of precision implies that many measurements will be taken of each individual brick and then be subject to a procedure of statistical reduction. Furthermore, complete bricks, the best basis for measurement, are available only if removed from a wall. If one chooses bricks from the uppermost preserved course, which will at least offer complete top surfaces to measure, one is making the assumption that this arbitrarily chosen layer is representative of the wall as a whole. A random selection of bricks chosen for measurement from the wall is not then possible. If one measures lengths and breadths below the uppermost preserved courses then inevitably these dimensions will not come in true pairs, but each length and breadth will belong to a different brick. Furthermore, weathering or the original smearing of mortar over the wall face often makes it difficult to discern the original edges of the bricks. My own view, formed in the course of trying to measure large numbers of bricks, is that accuracy beyond the nearest half centimetre runs the risk of being illusory (accepted by Hesse 1970: 104, his objection to rounding being the temptation to round to the same value; his histograms have half-centimetre divisions; note his view, however, that the arbitrariness of measurement in millimetres makes it easier to plot individual bricks as a scatter of points since few will be identical and thus occupy the same position on the graph). On the other hand, as outlined below, one of the things that one is looking for is...
slight but significant deviation from a length/width ratio of 2:1, and millimetre accuracy is here more appropriate.

The variability in brick sizes from a single manufactory means that, in order to describe the size of bricks in a given wall, many sets of measurements ought to be taken (Hesse 1970, 1971, recommends 100), although often in practice the number will be limited by the size and condition of the wall fragment in question. The range of variability can then be expressed both diagrammatically and as a statistical mean. The common practice in the past of simply stating an average size of brick is insufficiently precise and, at worst, can lead to the conflation of dimensions from bricks that were not made from a mould of the same size. If, on the other hand, one is interested in the original dimensions of the wooden brick moulds used, the figures to select from a given batch of measurements should be the largest and not the mean, in view of the fact that a good deal of the variation will have been caused by shrinkage of the bricks as they dried.

Petrie’s work on the town site at Abydos represents an early pioneering attempt to reach conclusions on a complex multi-period site (Petrie 1933: 20–2, 1938: 5). He principally wished to identify connections between walls, but he was also able to sketch out the limits of variance from one period to another. His tabulated results provide measurements to one tenth of an inch, but for ease of reference he also introduced the concept of the ‘nominal’ size, a figure which approximated to an average width in a set of measurements but was also chosen so as not to duplicate the nominal size of another set where the actual width measurements might overlap. The nominal sizes were included amongst the annotations added to the plans of walls. Many years later, at another multi-period site in Palestine (Tell el-Fara), Petrie chose to present the length and width measurements of bricks from different contexts as a scatter of points on a graph, prefiguring the much later work of Hesse (Petrie 1930a: 21, pl. LXIII).

An important clarification of what lies behind the taking of brick measurements has been provided by Hesse (1970, summarised in Hesse 1971), based on his fieldwork at the largely Middle-kingdom brick fortress at Mirgissa in Nubia. This is a textbook presentation which should be read by anyone interested in the subject of mud bricks. Hesse sets out his data in two ways: as histograms of length, breadth and (ideally) thickness, at half-centimetre intervals (as in Fig. 3.2a, although there the millimetre divisions have been kept); and (as Petrie had done at Tell el-Fara) as points on a graph where the axes record length and breadth (as in Fig. 3.2b; this is possible only when paired measurements of individual bricks have been recorded, see p. 84). Given the accidental sources of variation, when dealing with bricks from a single ancient manufactory the range of measurements ought to follow a statistically normal distribution, and in practice they approximately do, enabling a mean to be calculated, along with measures of standard deviation.

Normally on an archaeological site a series of sets of brick measurements will be taken, representing individual walls or buildings. It is then useful to compare the sets as a whole, with a view to detecting clusters of similar sets and their separation from other clusters. Hesse’s procedure is to represent each set or sample as a circle with radius proportional to the coefficient of correlation between length and breadth. The circles themselves are plotted on a graph of length–width axes by reference to the centre of each circle, which is the mean value of the set of measurements. The centre is actually marked by a cross, the length of whose arms represents the standard deviation (Fig. 3.2c). This is a neat and efficient graphical way of presenting sets of measurements and is suited to the common situation in which it has not been possible to collect them in strict length/width pairs.

Archaeological judgements based on brick sizes are often bound to be tentative. Normally the principal aim will be to separate constructions of different date, bearing in mind examples in which more than one brick source is evident. The cause might be the inclusion of older, re-used bricks, or the simultaneous or phased access to the products of different brickyards which used different moulds. We really have no idea whether the sizes of brick moulds were dictated by authority or whether, through convenience, they approximated to one another at any given time. Wooden brick moulds have a limited working life and, on a major job, would probably have to be replaced. In the end, as with all archaeological data, inherent uncertainties should breed caution in interpretation (as admitted in Mond and Myers 1934: 49).

Beyond seeking information to help interpret an individual archaeological site there is the possibility of establishing norms in brick sizes, period by period, which will act as a general guide to absolute dating. Although this approach is attractive, there is little reason for thinking it to have much value, for lack of consistency in the brickwork of ancient constructions has often been noted. A modest Early Dynastic tomb at Arment, built from a mixture of three different types of brick made from Nile silt and desert marl, is an extreme case (Mond and Myers 1937: 24), but even major buildings can display variations, in size or material, or both, sometimes but not always when alterations were made. Examples are the Valley Temple of Menkaure at Giza (Reisner 1931: 73): the massive mud-brick core of the pyramid of Amenemhat III at Dahshur (Arnold 1987: 10, 82): the mortuary temple of Thutmose III (Ricke 1939: 33–4): the platform shrine at Malkata South (Watanabe 1986: 6): the Memphite tomb of Horemheb (Martin 1959: 6–9): site K (and site E) at Malkata. The acceptance of variability of brick sizes on the same project perhaps receives some confirmation in a textual source, the building records of Papyrus Reisner I of the early Twelfth Dynasty, where the scribe makes a distinction between ‘brick’ and ‘large-size brick’ in the same operation (Simpson 1963: 76; or does the
Figure 3.2  Brick data from three buildings of Amenhotep III: sites E and K at Malkata, and Kom el-Abd to the south of these (based on a study by John McDonald for the University Museum of Pennsylvania). (a) Histograms of dimensions for site K (where the source material consisted entirely of loose bricks); (b) Point scatters for length and breadths of the three brick samples. The continuous diagonal lines represent a 2:1 ratio between length and breadth; the broken lines represent the actual means which, with the E and K samples, suggest the use of brick moulds in which the length was somewhat greater than twice the width; (c) Plot of the means and standard deviations for the three samples, and for a sub-sample from site K bearing impressions from a royal stamp. Note that the bricks from site K probably derive from the use of moulds of more than one size; (d) Histogram of length:breadth ratios of bricks from site K. Note that the peak of frequencies falls not at a ratio of 2:1 but around 2:1.
latter term refer to a significantly different category, e.g. large square flooring bricks?). Since brickwork was normally plastered any variability would not actually have remained visible.

An ancient acceptance of non-standardisation in brick sizes, which implies simultaneous use of the products of different brick-makers, has practical implications for the archaeologist. It not only makes it difficult to use brick sizes as a means of dating. If one were trying to link rubble or reused bricks on a site to their original home building, one would have to consider that a lost upper part of a wall might not necessarily have used the same bricks as surviving stretches of foundations.

Spencer (1979a: 147–8, pls. 41–4) has presented a wide range of brick measurements in a series of point scatters to represent length and breadth, period by period (Fig. 3.3). For the Archaic period the values cluster around a norm of about 24 x 12 cms. During the Old Kingdom this size remained in use, but the range of sizes was increased up to a maximum of about 42 x 21 cms. Thereafter, until the Byzantine period, the smaller sizes were avoided, and instead the broad spread of values only commences at around 30 x 15 cms. The preference for a size of brick that was considerably larger than that current in Egypt in recent times was perhaps a consequence of regular large-scale public works in this material. The sizes range up to what would probably have been the largest that could be made by simple technique without the risk of them regularly breaking whilst being handled, given the extremely weak tensile strength of mud bricks.

It has been claimed that, throughout Egyptian history, bricks fall into two groups: large ones for major public works, and small ones intended for houses and small private tombs (Clarke and Engelbach 1930: 209; Spencer 1979a: 147), although examples of cross-usage occur. This is natural enough, in view of the often thinner walls and smaller features of the latter, whereas, with major buildings (up to the scale of complete brick pyramids in the Middle Kingdom) a prime consideration would have been how to contribute quickly to the mass of the building. Larger bricks use less mortar and thus reduce shrinkage during drying, and their greater area brings better bonding and thus greater strength. A case which does seem to illustrate this divided preference is provided at Kahun. Petrie found an actual wooden mould which he states produced a brick of 28.4 x 14.2 x 8.64 cm and then quotes these dimensions for the brick size of Kahun. Presumably these are the internal dimensions of the mould, but he does not make explicit whether he separately measured batches of bricks in the walls for comparison (Petrie 1890: 26, 1938: 5; Griffith 1898: 59). It would be useful to have this information. This size is at the very bottom of the range for the Middle Kingdom, but Kahun also produced a papyrus fragment with a set of accounts concerned with bricks, where they are described according to their length in palms. Two sizes are cited, of five and six palms, thus of 37.3 and 44.8 cms. Sizes in this range are found in contemporary brick pyramids, including that of Senusret II, builder of Kahun itself (Griffith 1898: 59; Arnold 1987: 10, 82; Arnold 1988: 24, 29, 31).

A rather specialised case of deliberate choice of two brick sizes in the same building is illustrated by some large Early Dynastic tombs, where a smaller size was used for the panelling which decorated a wall made from larger bricks (Fig. 3.11b; Emery 1938: 3, fig. 1; Emery 1958: 41; 1968; Spencer 1979a: 20–1; but note Emery 1949: 90, fig. 52a for a contemporary example where this was not done). Separation of size according to the grandeur of construction was, however, only a tendency. When brick measurements from one period are grossed together they do not actually form two clusters, representing a large and a small norm, but spread themselves between the two extremes.

It is in the nature of bricklaying to seek to use bricks whose length is approximately twice the breadth. Even if bricks are all laid in the same direction, e.g. all as stretchers, in which the length is parallel to the wall face, for a neat finish at the corners in which the bricks dovetail into one another this ratio of l=2w will be necessary. However, modern factory-made bricks in Britain (for example have a length which is actually twice the width plus the thickness

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**Figure 3.3** Point scatter of sample brick sizes from the Early Dynastic period, Middle Kingdom and Late Period. Each point represents average (or approximate) measurements (after Spencer 1979a: pl. 41). The continuous diagonal line represents a 2:1 ratio between length and breadth; the broken line represents an approximation to the mean.
Bricklaying

It was normal practice not to build brick walls up from a foundation of stones but to use bricks from the outset. The exceptions are a few desert sites (e.g. Kurma in Nubia, some Deir el-Medina houses). For the first course of a wall of two bricks or more in width the bricks were sometimes laid as headers on their long edges. This was particularly useful for compensating for variable depth in the trench. The depth of foundations could vary a great deal, from virtually nothing to several metres (Fig. 3.13a). Foundations were commonly laid without doorways being marked. As a result, when the upper brickwork has been lost, the pattern of access across the continuous lengths of wall can only be guessed at (e.g. at Nag el-Madamud, Robichon and Varille 1939).

For free-standing walls, when the thickness of the wall itself was thought to be insufficient, buttresses gave support, though normally built separately and bonded only by mortar and plaster. In the Middle and New Kingdoms an ingenious means of adding lateral stability to a relatively thin enclosure or revetment wall was to build it on a serpentine or undulating line. Examples are known at both civil (Hölscher 1939: 70–1; Vercoutter 1970: 97–101; Frankfort and Pendlebury 1933: 5, pl. 111) and religious buildings (Ayrton et al. 1904: 12, 17, pls. XXXVI, III; Petrie et al. 1912: 41, pls. XXXIX, XLIV) and the suggestion has even been made that, in the latter cases, the shape might have had religious associations (Arnold 1979: 24–5, n. 81).

Some walls of very great thickness were pierced with narrow channels one or two courses high (Clarke and Engelbach 1930: 210; Spencer 1979a: 73, citing Karnak; Spencer 1979a: 78; Dendara; Reisner et al. 1967: 137: pl. LXXXIII, reporting on Mirgissa in Nubia; Pendlebury 1951: 92, Small Aten Temple). Although it has been suggested that they aided the drying of the bricks, they were not placed equidistantly, as is to be expected. The building of brick walls could involve the erection of wooden scaffolding (large post-holes have been found in front of major walls at Amarna) and a good way of anchoring it into the brickwork as it rose would be to fix cross-members into temporary holes between the bricks (putlocks). It is quite likely that many of the ‘channels’ served this purpose, though the Mirgissa examples stand out as a special case where this explanation does not fit.

A very wide range of possible patterns of laying bricks is available to a bricklayer, especially with thicker walls. The aim is always to avoid the danger of cracking if vertical joints are stacked above each other. Most walls from Dynastic Egypt alternated courses of headers and stretchers offset sideways (Figure 3.5 is an exception from the Ramesseum in which alternate header courses were laid on their sides). 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 (Figs 3.4c, 3.10a, 3.15). The full set of ancient variations has been codified into...
Figure 3.4 The laying of bricks. (a) Features of a mud-brick wall of the New Kingdom; (b) Pattern of bricklaying to achieve the niched facade effect, Early Dynastic Period, Hierakopolis (after Weeks 1971-2); (c) Part of the enclosure wall of the North Riverside Palace at Amarna (the back wall of the niche north of the Great Gateway), showing the pattern of bricklaying and insertion of timbers; (d) Side wall of a buried portion of a ramp at Amarna (Kom el-Nana), showing how bricks laid on their edge were used to increase the thickness of brick courses.
a corpus of bonds (Mond and Myers 1934: 47–52, pls. CXII–CXIV; Spencer 1979a: 7, 136–9, pls. 1–20). It should, however, be normal for the archaeologist to make explicit the pattern or patterns (bonding) used, and most definitely not to draw unmeasured brick shapes on plans simply as a space-filling convention to indicate brickwork. This can easily disguise the fact that, on larger projects, considerable variation in the pattern of laying was tolerated, and even conspicuous departures from the horizontal in courses which had to pass over uneven ground and instead ran parallel to the natural slope (Fig. 3.12 = Meryissa; Reisner et al. 1967: 155–6; Vercoutter 1970: pl. VIII; Serra East: Hughes 1963: pls. XXVIIb, XXIX). Complicated patterns made it even more difficult for the builders to maintain accuracy and regularity. An example is the Early Dynastic palace-façade wall inside the town at Hierakonpolis, where the detailed archaeologist’s plan shows numerous anomalies in the bricklaying (Fig. 3.4b; Weeks 1971–2). Another case of intricate patterning in brick is provided by the elaborate sets of archer’s loopholes in some of the Middle Kingdom fortresses in Nubia (Fig. 3.11c; Emery et al. 1979), but the regularity with which they were laid out raises the possibility that they were formed around wooden shapes. Bricks could also be made to special shapes, some of them curved, but this aspect is reserved for a later section.

Part of the bricklayer’s job was to compensate for unevennesses, accidentally developed through variability in brick sizes, uneven foundations, or poor workmanship (Fig. 3.4d); others arose deliberately, when walls were built with inward-sloping (battered) surfaces or the bedding planes were sloping or curved (see pp. 91–2). Mud bricks are easy to break or cut in order to provide pieces to fill small or uneven spaces, but there were a few simple tricks to employ as well. Bricks laid on their long edge added thickness to a course (and were useful in making staircases, Fig. 3.5); wide internal spaces either left open or filled with mortar (Fig. 3.48) enabled wall thickness to be adjusted and irregular brick lengths in header courses to be lost to sight; bricks laid diagonally were also a means of adjusting thickness (Hölscher 1910: 29, Abb. 23; Thorel 1976: 44). Because vertical joints were often narrow or negligible it was easier to maintain regularity of bonding with bricks which approximated to the 2:1 ratio of length to width (see the discussion above on brick sizes). Nevertheless, actual examples show that it was sometimes necessary to introduce a half brick in a stretcher course to return the courses to their intended pattern of bonding (Fig. 3.4c, courses 3 and 11 from the top). Although walls were normally plastered, many well-preserved examples display considerable care and skill in achieving an even pattern of laying, and the likelihood that the makers of brick moulds sometimes departed from the 2:1 ratio to accommodate an extra header joint adds to the impression that we are often looking at the work of a skilled trade.

One danger which builders strove to avoid was the cracking of walls through uneven distribution of loads. A common measure to prevent this was to insert amongst the courses horizontal timber beams or narrower poles, both laterally and longitudinally, at vertical intervals that could vary from five to fourteen courses (the latter at Elkeb; Figs 3.4c, 3.13c). They were particularly needed in very thick masses of bricks where, for the bricks in the interior, careful bonding of courses was normally abandoned, and sometimes even the use of mortar. Since timbers only started at the first interval above ground level, a wall needs to be

Figure 3.6 Section of niched ‘palace-façade’ brickwork in First Dynasty tomb 3507 at Saqqara. Note the impressions of wooden poles over the tops of the niches.
preserved to a height of at least half a metre for this to be detectable. The practice was often accompanied by spreading a layer of thick grass or reeds over an entire working surface that might or might not coincide with the level at which the timber was being inserted (Figs 3.4a, 3.7; Clarke and Engelbach 1930: 210; Spencer 1979a: 131–2, 133), a practice which is probably illustrated in the brick-making and building scene in the tomb of Rekhmira (TT100), where yellow fronds are shown protruding from a wall (Davies 1943: 55–6, pl. LX). Examples of timber and grass insertions are sufficiently widely spread chronologically to suggest that this was a continuous tradition in larger constructions from the Early Dynastic period onwards. The amount of timber (probably acacia in many instances) required would have been substantial: an estimate of 3,700 logs has been made for Mirgissa fortress, for example (Reisner et al. 1967: 157, Uronarti). More rarely, vertical timbers protected corners (Reisner et al. 1967: 21). In the brickwork of a Fourth-Dynasty tomb at Meidum (no. 6, Rahotep) logs of trees up to three metres long had been set, nearly upright (Petry 1892b: 16).

From the New Kingdom onwards builders seem to have begun to understand better the forces at work inside very thick masses of brickwork and to have adapted their techniques. The most obvious signs are to be seen in later temple enclosure walls. These were built as a series of blocks of brickwork in which the bricks of each alternate block were laid in beds that were concave along the wall’s length, the courses of the other blocks being either all horizontal or all convex (Figs 3.13, 3.15). This alternation was often emphasised, too, by alternating the thicknesses of the blocks. The term ‘pan-bedding’ has sometimes been applied. Careful preparations were made to ensure that the curve of the bedding-planes was even and regular. At Philae a massive stone bed had been laid out in a curve as a foundation for the pan-bedding of the brick wall above (Petry 1938: 11, pl. IV.15); at Edfu the pan-bedded sections of brickwork stand on a deep foundation of horizontally-laid bricks (Spencer 1979a: 81); in other cases stonework reinforcing the corners also retains the slope of the curve (Spencer 1979a: 78). Examples occur between the Nineteenth-Dynasty (enclosure wall of the temple of Seti I at Abydos, Frankfort 1933: 13, pl. XIII.1) and Roman times (the wall of this type at the Kom el-Sultan, Abydos – Figure 3.15 – is of the Late Period not the Middle Kingdom, as Petrie 1903: 6, pls. XLVIII.3, XLIX supposed). The style was applied to the building of cellular foundation platforms where the sides were also given concave lines in plan (e.g. Fougerousse 1933; Spencer 1979b), a feature which sometimes appears in the plans of walls, too (Fig. 3.13). It also came to be used for the walls of towns and large houses and other buildings, at least in Greco-Roman times (e.g. at Karanis in the first century AD, Husselman 1979: 33–5, pls. 12–14; Clarke and Engelbach 1930: 211; Spencer 1979a: 117; house models: Davies 1929: 250, fig. 14; Engelbach 1931: pl. III). An alternative, illustrated by the Medinet Habu outer enclosure wall of Rameses III, was to run the concave beds perpendicular to the wall face (Fig. 3.13a; Hölscher 1951: 3, pl. 41). Concave beds did not replace the use of timber inserts; they continued to be laid into the brickwork as an added binder (Fig. 3.13c).

The design is very well-suited for overcoming structural problems: of uneven settlement of the underlying ground, scaling or spalling of the surface of the brickwork, distortion as the bricks dried leading to cracking, and shear cracking especially in the case of a foundation platform which is going to bear the load of building above (e.g. Clarke and Engelbach 1930: 210–11; Petrie 1938: 10–12). Chevrier (1964) has provided mathematical support and experimental verification, and powerful witnesses are the tall Roman houses at Karanis built in this way, which continued to stand to considerable heights after the town had been abandoned yet remained free from cracking until buried in drift sand (Husselman 1979).

The building of large temple enclosure walls was included amongst the pious acts of kings and formally commemorated as such, at least from the Eighteenth Dynasty onwards (Traunecker 1975). Often made to look like the walls of a fortress (Kemp 1972; Golvin and Hegazy 1993), they were seen symbolically as providing essential protection against the forces of disorder. It is conceivable, therefore, that their design drew upon mythology, although this does not preclude the possibility that symbolic interpreta-
tion was secondary to a design which arose from practical utility. One explanation of this kind (Barguet 1962: 31-2; also Spencer 1979a: 114–5) looks to an element of temple mythology, in which each temple was thought to stand upon the primordial mound of creation, newly emerged from the waters of Nun. The undulations of the wall convey the watery environment. An example at Deir el-Medina preserves battlements and a walkway along the top, and these actually retain the undulations of the bedding-planes of the individual sections of the wall and so emphasise that they were integral to its appearance (Golvin and Hegazy 1993). On the other hand, the employment of concave bedding at Medinet Habu, because it ran at right-angles to the face, was invisible from the outside.

Whatever the original thought behind it was (and I would support those who see it as essentially a technological improvement) we seem to be dealing with an important and distinctive development in architectural aesthetic, the substitution of curving for straight lines. It appears in large buildings where, in contrast to stone-built temples, the outlines were not so strictly dictated by specific design models, and their general visibility would have been a startling contribution to the built environment.

Soil for mortar, plaster, and flooring

Soil provided the mortar used for laying bricks, its compositional relationship to the bricks depending to a large extent on whether the bricks were made on site, and thus from the same earth, or were imported. In the latter case bricks and mortar could be significantly different, as with the whitish mortar of desert clay mixed with straw used with alluvial mud bricks in the Eleventh-Dynasty temple at Deir el-Bahari (Arnold 1979: 6, 16, 25). Coarse filler such as chopped straw was, however, often not used. Cases have been noted where gypsum appears to have been used as mortar when adjacent to stonework (Martin 1989: 9, 12). It is important to be sure that this was a deliberate choice and not the accidental consequence of gypsum used for the bedding of stones spreading into the normally open vertical joints of adjacent brickwork (Mallinson 1995: figs 3.6, 5.9).

Mortar normally formed a bed beneath each course. It was often (at least in the New Kingdom) laid down as separate little piles which the weight of the new brick would spread out into circular mats (two per brick, Fig. 3.4a). Vertical joints tended to be very close and with little or no mortar within them. Moreover, where brickwork had considerable depth, as in pylons, enclosure walls, and pyramids, the internal brickwork could be laid without mortar at all (e.g. Golvin and Hegazy 1993: 149, pl. IIa; Hölsher 1951: 3). The plastering of wall surfaces above ground, inside and out, made ‘pointing’ (when the bricklayer smooths and presses mortar into all joints) unnecessary. Nevertheless, the practice was known and occurs on the foundation courses of some good quality buildings (at Amarna, at least), thus below the level of the plastering. Whether or not it was the intention, it would presumably have provided a barrier against the fauna that likes to live in wall cavities.

It is important to distinguish mortar from plaster. They do different things and this is reflected in composition. Plaster not only improves the appearance of a wall and helps to protect it against weathering, it also adds to its mechanical strength (Petrie 1938: 6–7). In composition what normally distinguishes plaster from mortar is the high concentration of straw, the inclusion of which reduces cracking. Subsequent loss of straw from insect attack leaves it very friable and, since it was also the normal medium on which painting was done, wall paintings from domestic or religious buildings of mud brick only survive in exceptional circumstances. An unusual mix of a silt-lime plaster with straw chaff has been identified in the Fourth-Dynasty mastaba of Nefermaat and Atet at Meidum (No. 16) (Borkowski and Majcher 1991: 28–9).

Floors are an aspect of soil architecture which tend to receive less attention than walls, yet are, at the same time, often less straightforward to deal with, the reason being that it is not always clear how deliberate their creation has been. Floors can be deliberate layers of mud plaster over a base of mud bricks, which were sometimes made specifically for flooring and have sets of dimensions of their own, often exactly or approximating a square, of between 30 and 43 cm (Spencer 1979a: 119; see also above for fired brick tiles used to create floors). In the case of compact muddy surfaces over open areas, however, the possibility exists that they came into existence through the combined action of trampling and of wetting the ground, a puddling process in itself. Such by-products of human behaviour can recur over the same area to produce a laminated effect. Deliberately made mud floor plaster probably benefits in the same way that wall plaster does in being given a relatively high organic content, usually derived from chopped straw, and being applied in a fairly plastic state, thus without the addition of too much water. Another form of external mud rendering, midway between the plaster of walls and floors, was the surfacing of sloping revetments, such as the glacis of a fortress (e.g. at Mirgissa: Reiser et al. 1967: 151).

The detailed study of the composition of floors leads one into a vital aspect of archaeological interpretation, for floors can contain a record not only of how they were made but also, from material that subsequently becomes incorporated into them, of what activities were carried out on them (a clear example is Becker 1986). The evidence is often microscopic, but a technique has been developed for taking and studying large thin-sections of archaeological deposits which include floors (Matthews and Postgate 1994). Specialist skill and access to an appropriate laboratory are required, but first results (not from Egyptian sites) are so promising as to imply that the technique could play an important part in interpreting the results of excavation on settlement sites in Egypt, whether in the desert or on the floodplain.
One specialised use of spread soil took advantage of its lubricant property when wet. Used in conjunction with reinforcing timbers to take the weight, a layer of mud was the basis for prepared roads over which heavy loads were dragged. The best-preserved example is a slipway near the Middle-Kingdom fortress of Mirgissa in Nubia which had enabled boats [presumably loaded on sledges] to be hauled past a particularly difficult stretch of the river (Fig. 3.8a; Percouther 1970: 204–14). The remains of similar examples have been found at a quarry at Lahun and beside one of the pyramids at Lisht (Arnold 1991: 86–92). These examples need to be interpreted in the light of the well-known scene of the transport of a colossal statue in the tomb of Thuthotep at Deir el-Bersa (Newberry [1895]: 16–26, pls. XII–XIX; Arnold 1991: 277–8) and a similar one in the tomb of Ty at Saqqara. As it is dragged on its sledge a man pours water, presumably to ease the gliding, an effect which modern experiments have replicated (Chevrier 1970: 20–5).

Roofing

An important sub-section of the topic of soil architecture is roofing, which took two forms: flat roofs of mud laid over wooden beams, and vaults and domes of brick. Occasionally actual roofs of ancient buildings have survived but mostly the roofs of above-ground structures will have collapsed. Even then, at least on desert sites, evidence for roofing can still be found amongst the fragments of rubble. In the past this has often been ignored by archaeologists. As a result there is insufficient evidence for judging the relative frequency of the two kinds, both by historical period and by type of building. The plan of a building might sometimes point to the answer; for example, vaults need a certain thickness to accommodate both the springing and, if not balanced by a parallel vault, the lateral force that a vault creates. On the other hand the presence of columns might be thought to indicate a flat roof, although the throne room in the palace at Medinet Habu possessed long vaults above the columns (Hölscher 1941: 38–9, pl. 26; 1951: 29).

Flat roofs require a rigid framework of beams to take weight, and a covering surface laid on top of them to provide a ceiling or roof. The evidence for ancient practice shows that the covering surface could consist of a layer of bricks (e.g. Emery 1949: 74, fig. 36; 1961: 184–5, fig. 108) or (probably more commonly) of a layer of plant material (thin poles, the central ribs of palm leaves – gereed – coarse grass, or woven matting) covered by a thick layer of mud (Fig. 3.8b; Petrie 1890: 23; 1891: 8; Peet and Woolley 1923: 57–8, fig. 6; Frankfort and Pendlebury 1933: 5, 9–11; Lacovara 1990, 8, fig. 2.11; Kemp, 1958: 8–11; Tuveson 1903: 13, are aware but are the reconstructions reliable). The width of spans would depend on the thickness of the timber cross beams which could be given intermediate support from columns. At Amarna flat roofs were usually not more than about 3.5 metres across. For aesthetic reasons the underside, including that of the protruding beams, could also be plastered with straw-rich mud plaster, which could then be painted. When ceilings and roofs of this kind collapse, the mud coverings break into pieces which will continue to retain the impressions of beams and other supporting material (which will normally eventually decay). Such roofing-fragments are important structural evidence and should be looked for and recorded during excavation.

Vaulted roofs are better documented, partly because of their use in tombs where they have had better chances of survival. The earliest examples recorded come from the First-Dynasty necropolis at Saqqara (Fig. 3.9a = Tomb 3500: Emery 1958: 102, pls. 116, 120; 1961: 185, fig. 90); domes have been recorded in Fourth-Dynasty tombs at Giza (Fig. 3.9d; Junker 1941: 25, 30–3, Taf. III; Larsen 1956: Abu-Bakr 1953: 129–43; for later examples see Spencer 1979a: 48, 123–6). Vaults are known to have covered spans of around five metres (Martin 1989: 55–6; Hölscher 1951: 29) and more, one in the mortuary temple of Amenhotep son of Hapu reaching 7.70 metres (Robichon and Varille 1936: pl. XI; Spencer 1979a: 87, following Hölscher, cites a possible case of a span of 8.60 metres at Medinet Habu). In order to create a flat surface above adjacent vaults, either for a roof or for the floor of an upper storey, the intervening spaces had to be filled. Bricks or rubble were used in the only surviving examples (Fig. 3.9b; Emery and Kirwan 1935: 34, 37, fig. 13, pls. 6 and 9; Ghazouli 1964: 143, pl. XVIA; Thorel 1976: 34, 41–2, 47) but by Coptic times smaller relieving vaults were being built into these spaces instead (e.g. at St Simeon’s Monastery at Aswan). A further use of vaulting was to create relieving arches to protect doorways or chambers which lay within large masses of masonry (e.g. Minault-Gout and Deleuze 1992: pls. 11–19).

Most ancient vaults seem to have been of the pitched type in which each arc of bricks was laid at a slight angle to the vertical, so that the weight of each new one was borne by those already in place (Fig. 3.9; Van Beek 1987: 81). It has remained a living tradition especially in Nubia (e.g. Mileham 1910: 8–10; also Fathy 1969: 16–18, pls. 7–18). Its attraction is that it enables vaults to be constructed without the use of temporary supports. Although ordinary bricks can serve for this type of vault, special bricks were sometimes made. Normally they have two distinguishing characteristics. They were thinner, resembling tiles (Fig. 3.10), and did not need the standard 1:2 length:width ratio. Specimen dimensions are 41 × 23 × 3 cm (Martin 1989: 55–6); 60 × 22 × 7.5 cm (Ghazouli 1964: 144); 40 × 19 × 37 × 6 cm (Robichon and Varille 1936: 38); 40 × 20 × 40 × 7 cm (Frankfort 1933: 143), the last two with a slightly wedge-shaped design, which in other cases was accompanied by a slight curvature of the edges (Spencer 1979a: 142, fig. 90). The other characteristic was a scoring of one face (to be the underside), or even of both faces, by dragging the fingers down its length during
Figure 3.8 Uses of spread mud layers. (a) In a boat slipway at Mirgissa, Nubia (after Vercoyter 1973); (b) As a roof covering in a reconstruction of roof design at Amenhotep III’s palace at Malkata, site E, square sf21 (1973 excavations of the University Museum of Pennsylvania).
Figure 3.9  Brick vaults and domes. (a) The earliest example, which covers a subsidiary burial at Saqqara tomb 3500, First Dynasty (after Emery 1938); (b) Brick vaulting at the Ramesseum with alternate pitching for double or multiple vault layers (after Thord 1975); (c) A detail of the same, showing the grooved surfaces of the vaulting bricks; (d) Domed brick chapel at the Fourth-Dynasty tomb of Seneb at Giza (after Junker 1941).
roofing tiles if found loose in rubble during excavation.

In some examples of pitched vaults the tiles or bricks were laid in two (and even up to four) layers, often with alternating angles of tilt (Fig. 3.9b, 3.9c; Emery and Kirwan 1935: 37, fig. 13, 43, fig. 22, pls. 6 and 9; Martin 1959: 51, pls. 46 and 157; Ghazouli 1964: pl. X11B; Frankfort 1933: 14, pl. XI.4; Van Beek 1967: 79, 81). In a well-preserved cellar vault at Amarna pairs of reeds were inserted between the rings of the vault (Frankfort and Pendlebury 1933: 52–3, fig. 6).

To what extent vaults were built using vertical arcs of brick is not clear. A Sixth-Dynasty chapel at Giza is one example, built with specially shaped bricks with interlocking zig-zag edges (Fig. 3.11a = Fisher 1924: 114–7, pl. 13.2, 17–19). The vertical placing of the arcs was necessary to the creation of an effect of rounded ribs on the underside, which was part of the moulding (see the section on special shapes). True vaults are more likely to require wooden formwork which will temporarily support the arcs. Sets of square holes for the ends of wooden beams in arc-patterns preserved in stone walls at Medinet Habu probably derive from such a building system, but the appearance of the roof and ceiling (was it also ribbed?) is now lost (Hölscher 1941: 38–9, pl. 26, 1951: 29; Spencer 1979a: 87). One should not rule out the possibility that, for large building projects, professional (or at least specialised) vault-builders were employed, who came with their own equipment. Support would also have been needed for arches, commonly built over doorways, but this could have been achieved very simply, through the use of lengths of bent palm-leaf rib or more substantial pieces of curved wood.

Many examples, mainly from tombs, are also known of corbel vaults of brick, in which the space was gradually closed by slightly projecting each course of bricks beyond the one beneath until the bricks of both sides met in the middle (Spencer 1979a: 126–7).

**Figure 3.10** Brick vaulting at the magazines beside the temple of Seti I at Abydos. (a) Junction of pitched vaulting with wall; (b) Vault end, showing the use of roofing bricks turned at right-angles to fill the space left by the vault pitch.

The manufacture to create ‘frogging’ (Fig. 3.9c). This keyed the dried mortar on to the otherwise smooth surface of the brick and so helped to prevent shear loads from above splitting it away, and also perhaps augmented the suction of the wet mortar by allowing it to act on a greater surface area (Martin 1959: 51). It is important to identify fragments of such

**Soil as filling material**

Large building (and perhaps demolition) projects in ancient Egypt required the use of extensive ramps for the movement of building materials between different levels. In one method of construction parallel walls or a network of chambers were built of brick and then filled with soil (desert or alluvial) (Badawy 1937: 64–5; Arnold 1991: 86–98; Petrie 1912: 55, pl. XXXI). A comparable practice was also employed for foundation platforms of large buildings (e.g. Janosi 1956) and occasionally 8th thick walls (e.g. Ziermann 1939). The most notable examples come from the Late Period, when civil and religious buildings were often set upon massive cellular pedestals filled with soil (e.g. Fig. 3.14; Kemp 1977; Petrie 1888: 52–61, pl. XLIII, XLIV; Holladay 1982: 31–4, pl. 42). These examples notwithstanding, Egyptian builders often display a preference for creating required mass (e.g. in thick enclosure walls and temple pylons) through solid brickwork.
Figure 3.11 Architectural mouldings in mud. (a) Ribbed vaulted roof in a Fourth-Dynasty chapel at Giza which used specially moulded bricks (after Fisher 1924); (b) Moulded mud panels fixed to a Third-Dynasty tomb façade (no. 3070) at Saqqara by wooden pins (after Emery 1905); (c) Archers' loopholes in the fortress wall at Bubastis, Twelfth-Dynasty (after Emery et al. 1979); (d) Composite column from building R413 at Amarna; (e) Parapet moulding for an ornamental pool at Maru-Aten, Amarna (after Peet and Woolley 1923: 119, fig. 29, pl. XXXVII); (f) and (g) Composite mouldings from Deir el-Medina (after Bruyère 1926).
Some of the evidence for the use of loose soil also comes from building texts, although vocabulary difficulties still hinder translation (Simpson 1963: 73–5, 78). In the best known (P. Anastasi I) the soil is sand, and the interpretation seems to be that the removal of the free-flowing sand allowed a heavy mass, a colossal statue in this case, to be set up vertically on its pedestal (Arnold 1991: 70).

The claim has been made by Badawy (1957: 59–60) that the Egyptians used the rammed-earth method of construction, citing examples ‘platforms replacing pavement in archaic huts, enclosure walls constructed of two facings filled in, constructional ramps consisting of a network of coffers in brick filled in with earth’. If, as I suspect, these examples involved the filling of spaces defined by permanent walls then the term ‘rammed earth’ is not appropriate.

It is better kept for the technique in which earth is rammed by compression between temporary formwork (usually of wood) which, when removed, leaves a solid construction behind. The key to success is to use an almost, but not quite, dry mix of soil in which the action of ramming is not impeded by the need to expel a lot of water. A large amount of strong wooden planking is required and the means of fixing it securely as the mud is compressed. The result can be more solid than that achieved by building in bricks made by the traditional method. I know of no examples of true rammed earth construction in ancient Egypt, but, especially on damp floodplain sites, they might be difficult to identify.

A Fourth-Dynasty mastaba at Meidum (no. 16, of Nefermaat) had been filled with ‘layers of Nile mud, poured in and left to harden before a fresher mass was applied’ (Petrie 1892, 1938: 8), but nor is this a true example of the practice; nor the brick quarry ramp at Qau el-Kebir, made from parallel brick walls filled with loose mud (Petrie 1930b: 16, pl. XXII.4; Arnold 1991: 93).

Special shapes and vernacular style

The Egyptian architectural style took its inspiration from wood and plant forms. We are most familiar with the formalised shapes as they were rendered in stone, starting with the Step-Pyramid enclosure. Sporadic examples show, however, that the same or related forms could be reproduced in mud as well, sometimes through the use of specially shaped moulds. Examples are vaults from Old-Kingdom chapels at Giza, sometimes painted red, shaped to represent curved ceilings of reed bundles (Fig. 3.11a – Fisher 1924: 14–7, pls. 13.2, 17–19; Abu Bakr 1953: 129–43; Spencer 1979a: 23, 142; Kuhlmann 1966); cavetto cornices and torus mouldings at Deir el-Medina and Amarna (Fig. 3.11e, f, g; Spencer 1979a: 142; Frankfort and Pendlebury 1933: 6–7; Pendlebury 1951: 141, fig. 20; Kemp 1985: figs 1.4, 1.5, 2.3); and, again at Amarna, columns of rounded mud bricks built around a central wooden post and faced with fluted mud mouldings (Fig. 3.11d = Pendlebury 1951: 22, 109). Curved bricks made in curved moulds were used at Amarna for column bases (Clarke and Engelbach 1930: 215; Pendlebury 1951: 132) and for circular grain silos (personal observation, house Q44.1). They are also attested in vault construction (Deleuze 1958; Minault-Gout and Deleuze 1992: 72).

The substitution of mud and mud bricks for stone could extend to moulded lotus-clump columns with screen walls (Pendlebury 1951: 139, pl. IV.4) and to statues, although surviving examples are extremely rare: the bull’s heads moulded in clay, into which real horns were inserted, laid out along the base of some First-Dynasty tombs at Saqqara (Emery 1954: 8–9, pl. VII; 1958: 6–8, 75; 1961: 71, pls. 8, 9); statue groups of plastered brick added to some of the corridors of the Ramessid temple in the Third Intermediate Period (El-Achirie and Fouquernie 1976: 11–13, pls. XXXIV–XL1a–b; Schumann Antelme 1976: 71–6, 172–4); figures of Bes moulded in high relief in a Ptolemaic shrine at Saqqara (Quibell 1907: 12–14, pls. XXVI–XXIX).

The First Dynasty had also seen, however, the introduction of a style of ornamental brickwork used for palace façades and the tombs of the elite which might well have been independently inspired by the brick architecture of Mesopotamia. Panelling and imitation doorways formed the basis of the lower parts of walls (Figs. 3.6 and 3.7). (In one case the panelled effect itself was achieved by means of pre-cast mud slabs fastened to the façade by long wooden pegs, an early form of architectural cladding. Fig. 3.11b – Emery 1968). The upper parts bore complex patterns which are known mainly from artistic representations, and these, according to one excavator, were sometimes moulded in mud (Emery 1954: 139; 1961: 181; but without illustrations). The same was true of decorative elements in

Figure 3.12 Part of the lower ramparts of the Twelfth-Dynasty fortress at Mirgissa, Nubia. Note the angled bedding planes to take the brickwork uphill.
Figure 3.13  New Kingdom and Late Period ramparts. (a) Section through the enclosure wall at Medinet Habu (after Hölscher 1951); (b) Sketch of preserved brick crenellations at the Late-Period fortress on Dervianti Island, Nubia (after Knudstad 1966: pl. XXIVa); (c) Plan of one course of bricks and timber beams in the enclosure wall of the Montu temple at Karnak (after Christophe 1955: pl. VI); (d) Plan of the foundation brickwork at the north corner of the Montu temple at Karnak, built over earlier constructions (after Christophe 1955: pls. XVI, XVII); (e) Reconstruction of the centre of the east side of the Thirtieth-Dynasty enclosure wall at the Amun temple at Karnak (after Golvin and Hegazy 1993).
Amarna houses (Frankfort 1929: 55, 57). Fortifications in mud brick, which used curved walls, elaborate systems of loopholes, and crenellated battlements (Figs. 3.11c, 3.12, 3.13b; for two surviving examples see Knudstad 1966: 185, pl. XXIVa; Golvin and Hegazy 1993) provided builders with yet a further set of models.

The lack of tensile strength in mud can make fancy shapes difficult to achieve without reinforcement. Occasional finds of reinforcement in the form of wood or rope which will normally have survived only as impressions in the mud show that simple means to overcome this were understood, as in the case of window grilles, roughly square in section, moulded from mud around wooden cores at Amarna (Frankfort 1929: 57; Frankfort and Pendlebury 1933: 10; also Fig. 3.11d). Linen can also be useful. It has been noted at Amarna laid over mud columns, to which paint was applied (Pendlebury 1951: 139), and Emery (1954: 139; 1961: 182) cites architectural elements from Early Dynastic tombs at Saqqara which were 'of extraordinary strength and weight, obtained apparently by reinforcing the mud with small strips of flax linen and drying it when under great pressure'. One product was a lintel measuring, in its broken state, $63 \times 18 \times 10$ cm.

The total evidence for architectural detailing in mud is not great, but, in view of its vulnerability to decay and of the fact that ancient buildings frequently survive only as foundations, this is not really surprising. The evidence certainly points to an awareness by builders of the potential of soil architecture for producing both decorative and utilitarian shapes, but whether they employed it to bring into existence a class of vernacular architecture, primarily domestic, is impossible to tell in the present state of knowledge. Since the forms of brick buildings would have contributed significantly to how ancient Egypt really looked, this is an important field of research.

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