CHAPTER 1

# Examining the Materials Available in Ancient Egypt

The most fundamental constraint in any manufacturing process is the availability of materials. Even in modern industry, no product can be made unless the necessary materials and components can be obtained. The next essential factor is the method of fabrication: without a workable method, production cannot proceed. Because this book concerns the construction of pyramids, the physical materials and the techniques used to manipulate them form the foundation of the entire discussion. Like modern engineers, the ancient Egyptians began by securing the materials on which their construction processes would depend.

Let us therefore examine the materials required for pyramid construction.

## 1. Stone

Stone was by far the most extensively used material in pyramid building, and understanding its properties is essential to understanding the construction process as a whole.

It is generally thought that one of the principal reasons Giza was selected as the site for pyramid construction was that the core masonry—used in the greatest quantities—could be quarried locally. South of Khufu's pyramid, the depression known as the Central Quarry remains as evidence of this activity, and the Sphinx itself is believed to have been carved by reshaping the remnants of another quarry.

The fine limestone used for the outer casing stones—second only to core blocks in total volume—was quarried at Tura, located approximately

*Table 1-1. Principal Stones and Their Uses in Pyramid Construction*

| Rock Type | Primary Use | Main Source | Distance from Giza |
|---|---|---|---|
| Limestone | Core masonry | Giza Plateau | 0–2 km (local) |
| Fine Limestone (Tura) | Casing stones | Tura, east bank of the Nile | 10–15 km southeast of Giza |
| Granite | Burial chamber and special spaces | Aswan | 1,000 km upriver (following Nile bends) |
| Diorite | Tools | North of Fayum | 50–100 km southwest |

10–15 km upstream on the opposite bank of the Nile. Tura remains an active limestone quarry even today and hosts cement factories that use its limestone as raw material.

Other essential materials included gypsum, used as the primary ingredient in mortar, sourced from the northern Fayum region about 40 km southwest of Giza. Quartz sand for polishing could be collected in Giza.

### 2. Metals

In the Old Kingdom, the Egyptians relied almost exclusively on copper for tools, weapons, and construction equipment. Iron smelting was not yet known, and Egypt produced virtually no tin, making bronze production impossible. Without iron, brass was also unknown.

Egyptian copper ore naturally contained arsenic, producing an arsenical copper that was somewhat harder than modern pure copper, though still limited in strength. By the Old Kingdom, copper mining was well developed, and copper was not a rare metal. However, it was seldom used structurally; its primary role was in tools.

*Table 1-2. Comparison of Copper Use in Ancient Civilizations*

| Region | Copper Ore | Tin | Fuel | Bronze Production |
|---|---|---|---|---|
| Egypt | Copper + arsenic | None | Scarce timber | Impossible |
| China | Copper naturally mixed with tin | Available | Abundant forests | Bronze produced |
| Mesopotamia | High-purity copper | Tin nearby | Forests available | Deliberate alloying |

Copper tools were adequate for cutting limestone but insufficient for working granite. As a result, granite had to be shaped using alternative methods such as pounding and sand abrasion. The absence of bronze and iron also imposed practical limitations: nails, levers, and other metal fittings common in later civilizations were unavailable.

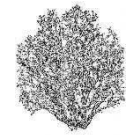
### 3. Wood

Because most of Egypt's territory is desert except for the banks of the Nile and the Mediterranean coast, the country was never rich in timber resources. The arid climate prevented coniferous trees from growing, and large straight trunks—essential for structural use—had to be imported, most notably the cedar of Lebanon.

The Nile Valley was the principal source of native Egyptian wood, but trees could not grow in the floodplain itself because annual inundations repeatedly destroyed vegetation. As a result, native trees were limited to the narrow areas of river terraces and other elevated ground.

Among Egypt's native species, acacia was the most important hard and durable wood. However, unlike conifers, acacia does not grow into tall, straight trunks, and its use was therefore restricted to small components.

*Table 1-3. Principal Woods Used in Ancient Egypt*

| Cedar of Lebanon | Acacia | Sycamore fig | Tamarisk | Date palm |
|---|---|---|---|---|
|  |  |  |  |  |
| Long, light, strong, easy to work | Hard, durable | Soft, workable, wide boards | Dense, fine-grained | Poor for carpentry |
| Ships, beams, high-quality construction | Small boats, furniture, coffins | Furniture, coffins, construction | Beams, coffins, tool handles | Low-grade uses |
| Imported, valuable | Does not grow large | Fruit edible | Short lengths | Abundant, fruit edible |

Sycamore fig, a species of Ficus, was widely cultivated both for its edible fruit and for timber. It grows rapidly and, unusually for native Egyptian wood, can yield planks 30–50 cm wide, with exceptional pieces reaching about 60 cm. For this reason, it was extensively used for furniture, coffins, and the bottom planks of boats. Its wood, however, is relatively soft and therefore unsuitable for structural applications.

By contrast, the date palm—abundant in Egypt both as a wild species and as a cultivated crop for dates—grows into tall trees. Yet its internal fiber structure differs fundamentally from that of typical hardwoods and softwoods, making it impossible to plane or cut with precision. As a result, it was considered a poor-quality timber with limited applications. Nevertheless, because date palm wood is strong in compression, it may have been suitable for use as rollers in stone transport.

Importantly, Egypt had no large bamboo, unlike Asia. Thus, the



*Fig. 1-1. Papyrus (photographed in the front courtyard of the Cairo Museum, 2008. Unless otherwise noted, all photos in this book were taken by the author.)*

bamboo scaffolding common in Hong Kong or Southeast Asia would have been impossible in ancient Egypt.

Although not a wood, papyrus was an important plant material. A perennial reed, it grew rapidly during the Nile's inundation, reaching heights of 3–4 meters. The pith was used to make papyrus sheets, while the outer rind was used for rope and sandals. Because the pith contains air, papyrus bundles had high buoyancy and were used to make boats. However, papyrus boats deteriorated quickly when left in water, and their usable lifespan appears to have been short—likely on the order of several months.

### 4. Ropes

Ropes were not primary building materials, but they played a crucial supporting role in construction—particularly in transporting heavy stones, securing scaffolding, and performing lifting operations. In tasks

that required pulling or raising massive blocks, ropes were indispensable.

In ancient Egypt, ropes were made from papyrus, flax, and fibers extracted from the cores of date palms. By contrast, ancient China relied on hemp, which produced exceptionally strong ropes, while Mesopotamia used wool, goat hair, and palm fibers. Each civilization developed rope-making traditions shaped by the materials available in its environment.

Egypt, however, had little access to hemp. As a result, Egyptian ropes were made from relatively short fibers, giving them low tensile strength, high elasticity, and a tendency to fray or break. Their durability was also limited. From an engineering standpoint, Egyptian ropes were weak materials—far inferior to the hemp-based ropes familiar in other ancient cultures.

Modern readers often imagine rope as a strong and reliable material because Manila hemp rope—long-fibered and extremely durable—was widely used until recently, including for mooring large ships. This modern image can be misleading. Egyptian ropes were fundamentally different in both quality and performance.

Tensile strength is typically expressed in daN (decanewtons), where 1 daN corresponds to roughly 1 kg of vertical load. Modern Manila hemp rope with a diameter of 10 mm has a breaking strength of 670–800 daN, and because strength increases with the square of the diameter, a 20 mm Manila rope reaches 2,600–3,250 daN.

These values correspond to typical manufacturer specifications and internationally recognized rope standards, which consistently report similar strength ranges for natural-fiber ropes.

Other natural fibers are weaker. Jute rope of 10 mm diameter has a breaking strength of 300–600 daN, and cotton rope 300–500 daN—roughly half that of Manila hemp.

Given the short fibers of papyrus and flax, and the low tensile strength of date-palm fibers, Egyptian ropes likely performed at the lowest end of the jute/cotton range: approximately 300 daN for 10 mm and 1,200 daN for 20 mm.

However, rope must be evaluated not only by breaking strength but also by safety factor. Even in modern industrial standards, rope is rated by both its ultimate strength and the safety factor required for practical use. Manila hemp, with its long, strong fibers, typically uses a safety factor of 1/7 to 1/5. Jute and cotton may require 1/10.

For ancient Egyptian ropes—made from short, inconsistent fibers and produced without strict quality control—a conservative safety factor of 1/15 is appropriate.

Under this assumption, a 20 mm Egyptian rope would have a working load of only 80 daN. Even if one were willing to accept a risky safety factor, the working load would be no more than 200 daN. In practical terms, this means that even with a 20 mm rope, pulling a 200 kg stone would already be approaching the limit of safety.

For comparison, a modern 20 mm nylon rope has a breaking strength of 7,200 daN and a working load of about 1,200 daN. Comparing working loads, the Egyptian rope's 80 daN was therefore only about 6.7% of that of modern nylon rope.

Given that even relatively small casing stones weigh over one ton, and core blocks can reach six tons, it becomes clear that hauling large stones

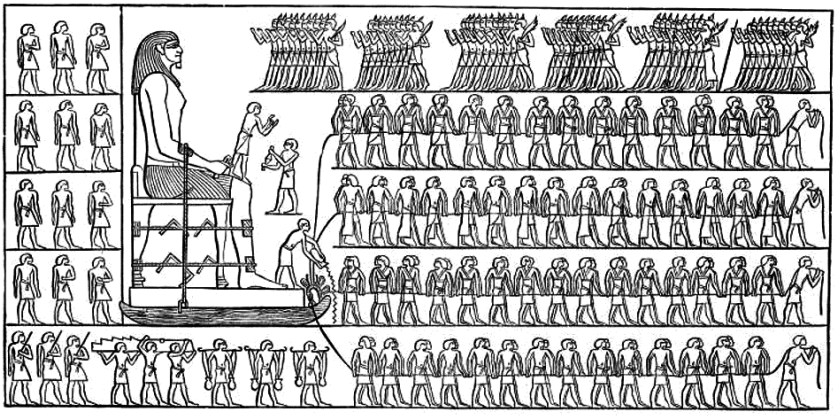


*Fig. 1-2. "Transport of a colossus, from a tomb at El Bersheh" The Miriam and Ira D. Wallach Division of Art, Prints and Photographs: Picture Collection, The New York Public Library. The New York Public Library Digital Collections. 1881-1882.*

up steep ramps using long, thick ropes—like a giant tug-of-war—would have been highly impractical. Likewise, lifting stones with pulley systems would have been extremely limited, not only because of weak ropes but also because Egypt lacked strong, long timber suitable for constructing robust scaffolding.

A frequently cited counterexample is the famous relief from the tomb of Tehutihetep at el-Bersheh, which shows a colossal statue being hauled on a sledge by a large number of men. This image is so striking that it has shaped the modern imagination of how the Egyptians transported heavy objects.

However, the relief invites a more nuanced interpretation.

The scene shows four ropes, each pulled by a separate row of workers. The number of workers appears exaggerated, but the arrangement raises an important question: why four rows?

Rather than imagining a stop-and-start motion—pulling, stopping, pulling again—it is plausible that the workers used a synchronized, alternating pulling technique.

Static friction requires the greatest force to overcome. Once an object is moving, kinetic friction is lower, and maintaining motion requires less force. If two rows pulled while the other two prepared, and then they alternated without allowing the sledge to stop, the workers could keep the statue moving using only kinetic friction.

This method would compensate for the weakness of Egyptian ropes.

Another notable feature of the relief is that none of the workers adopt a "tug-of-war" posture. No one is leaning back or bracing with body weight. Instead, they appear calm, pulling steadily and uniformly. This supports the idea that they were maintaining a constant, moderate speed—consistent with a technique designed to avoid static friction.

### 5. Mudbrick

Mudbrick is one of the most common materials encountered at Egyptian archaeological sites—arguably even more ubiquitous than stone.



*Fig. 1-3. Mudbricks stacked in a retaining wall along a passageway (photographed in Luxor, 2008)*

In domestic architecture, walls built of stone or timber were rare; most ordinary houses were constructed almost entirely of mudbrick. In ancient Egypt, mudbrick was the most basic and most versatile building material.

The raw material for mudbrick was the alluvial silt deposited annually by the Nile. After the inundation receded, a thick layer of fresh silt covered the floodplain between the Nile and the Giza Plateau. Over centuries, these deposits accumulated into deep, abundant layers, providing an effectively inexhaustible supply of material for brickmaking.

Mudbricks were not fired. They were made by mixing Nile silt with chopped straw, packing the mixture into wooden molds, removing the bricks from the molds, and leaving them to dry in the sun. Straw served two important functions: it prevented shrinkage cracks during drying by binding the clay matrix, and it helped the brick retain its shape even if minor cracking occurred.

Brickmaking took place on the flat ground exposed after the floodwaters receded. Because rainfall was extremely rare, bricks could be produced almost continuously for the seven months until the next

inundation.

Assuming a standard brick size of 30 × 15 × 10 cm, each brick has a volume of 0.0045 $m^3$. The production process was simple, and a single worker could easily make 100 bricks per day. Because the work required little skill and was not excessively strenuous, people of all ages and genders could participate. With 1,000 workers, daily output would reach 100,000 bricks, and over seven months, 21 million bricks—a total volume of 94,500 $m^3$.

For comparison, the volume of Menkaure's pyramid at Giza is estimated at 235,000 $m^3$. (This estimate follows the value given by Mark Lehner in The Complete Pyramids, 1997.) Thus, in a single year, the volume of mudbrick produced could reach roughly 40% of the volume of a major pyramid.

Although unfired mudbrick is brittle under impact and easily broken, it has high compressive strength and is fully adequate for pavements and walls. The large mounds of surviving mudbrick debris at many sites demonstrate that, in Egypt's arid climate, mudbrick structures could endure for millennia. However, mudbrick deteriorates rapidly when exposed to rain or water, returning quickly to mud. It was therefore a material uniquely suited to Egypt's dry environment.

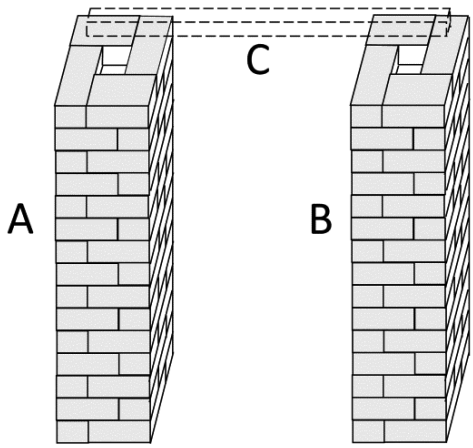



*Fig. 1-4. Scaffold constructed by stacking mudbricks in a looped arrangement.*

In modern construction, scaffolding is typically made from steel pipes or timber. In ancient Egypt, however, long, high-quality timber was scarce. For this reason, I believe that mudbrick was frequently used to build robust temporary scaffolding. A small team of workers could easily stack bricks into walls several meters high. Mudbrick walls are strong under vertical load but weak against lateral impact, which means they could be dismantled quickly when no longer needed.

For example, Fig. 1-4 illustrates a simple scaffold built by arranging four mudbricks in a loop to form one course, then stacking 15 courses to create a square pillar 1.5 meters high. A wooden beam (C) could be placed across the top. Each pillar (A and B) would require 60 bricks. For temporary use, mortar was unnecessary; the bricks could simply be stacked. A small crew could construct such a scaffold in half a day.

Attempting to build scaffolding from timber would have been far more difficult. Without pipe joints or clamps, wooden scaffolds would require complex joinery, diagonal bracing, and rope lashings. Compared with this, mudbrick offered a faster, simpler, and more stable solution.

In ancient Egypt, therefore, mudbrick was not only a fundamental building material but also an exceptionally practical material for temporary scaffolding.

For reference, I include here a wall painting from the New Kingdom, found in the tomb of Rekhmire at Luxor, which depicts the manufacture of sun-dried mudbricks. The sequence shows workers collecting mud

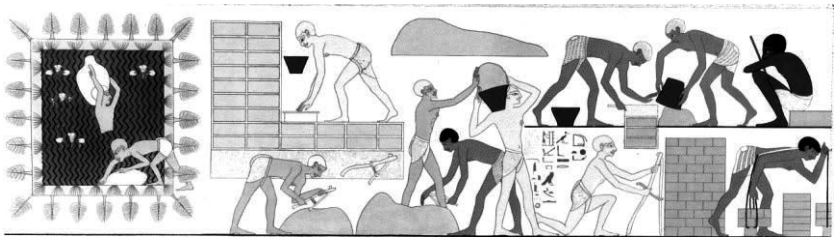


*Fig. 1-5. A mural depicting the manufacturing process of sun-dried bricks. (Karl Richard Lepsius, Denkmäler aus Aegypten und Aethiopien, 1849–1859, Abth. III, Bl. 40. Public Domain Mark 1.0 via Internet Archive.)*

from a pool, kneading it, placing it into molds, leaving the bricks to dry, and finally transporting the finished products. One particularly interesting feature of this scene is the dark-skinned figure seated at the far right, observing the work. This figure is generally interpreted as a Nubian overseer. However, such Nubian overseers would not have been common in the Old Kingdom.

I also find myself questioning whether the scene of workers scooping mud directly from a pool reflects actual practice. It seems possible that the painter was not reproducing a literal landscape but rather depicting an imagined or conventionalized setting.