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Mudbrick architecture

Mudbrick Architectures: From Soil to Vaulting Cultures
A contribution by Wesam Al Asali

Cultures of Mudbrick
Mudbrick is one of the most common materials in architecture. Despite the extensive use of cement for the past one hundred years, since its industrial reproduction at the beginning of the 20th century, nearly a third of the Earth's population still lives in mud structures.[1] This material, which has lived for many centuries, is considered one of the most direct expressions of building with local or nearby materials. Clay brick material does not need any chemically composed additives or processed materials on the one hand, nor advanced tools for production and construction on the other hand.[2]

Earth and stone wall construction, Al-Bidya Mosque, Fujairah, UAE.
Image by Raghad Al Ali.

Therefore, clay bricks were rather identified as a domestic activity than an industrial or commercial one because families can make their own bricks — a master brickmaker only being consulted in the preparation of materials and mixtures. Because of their size, measured by the builder's hands, clay bricks have become the most common earth material when compared to other similar techniques such as rammed earth or wattle and daub. Mudbrick architecture spreads over many geographies, but it is concentrated in arid and semi-arid regions where it is possible to obtain soil with a high percentage of clay, water for mixing, and plant fibres such as straw.[3] Therefore, today we find variations of mudbrick architecture extending from the Middle East to South America and from the Mediterranean to West and Southwest Asia.

In archaeology, remains of mud architecture are rare. This, however, does not denote lack of use throughout history. On the contrary, mud architecture can be considered the most widespread architecture in the areas of rivers valleys and clay soils. It is the fragility of the material and its ease of decomposition that prevents mudbrick architecture from reaching us compared to other materials such as stone and wood.[4] Archaeological studies reveal mudbrick architecture in the Middle East region as early as

Mud village near Aleppo, Syria, 2022.
©Wesam Al Asali.

the Pre-Pottery Neolithic era (around 10,000 BC) in the Southern Levant. Examples from early mudbrick architecture are also prevalent in the Nile Valley and Mesopotamia.

In the Emirates, excavations in the Hili area in Al Ain indicate a unique mudbrick architecture in the Iron Age, about 3,000 years ago.[5] In addition to mud ovens or pits for cooking (called tannour), the excavations showed groups of bricks with distinct finger marks (called frogs) made by their makers to increase the contact area between the mud surface and the mortar for a better interlocking between bricks. The Hili excavations revealed an architecture referred to by one of the earliest models of mud residential architecture in the Emirates, which, as we mentioned, are difficult to show in comparison with other forms of buildings such as fortifications or columned halls.[6] In the more recent architecture of the Emirates, brick construction is still widespread in the Al Ain region, where the brick walls are raised on stone bases, and the roofing between them is made of palm trunks and woven plants. This model of mud residential architecture abounds in the interior oasis areas of the Arabian Peninsula, where mud is more accessible than in mountainous and coastal regions in the Emirates, rich with coral or limestone.

Since the time of the houses in the Hili excavations until today, mudbricks have not changed much. The material maintains its three main components: soil, plant fibres (temper) and water. As for the soil, clay bricks are widely used in soils with a high clay content. The percentage of clay in brick mixes ranges from 60 to 85 per cent to obtain a grain with minimal diameters to ensure adhesion between them.[7] The water is added to the soil to form a slurry consistency before adding the plant fibres.

Earth wall construction, Al Hili Fort, Al Ain, UAE.
Image by Raghad Al Ali.

Mud preparation during the restoration of Gurna Village, Arch, 2019.
©Mohamed Tantawy.

The plant fibres' main task is to increase the brick's compressive and tensile strength. In other words, the fibres in clay bricks can be considered the reinforcing steel for modern cement. In addition to the structural properties, plant fibres help produce the bricks as they reduce cracking during the drying process, especially when damped bricks lose moisture quickly under the hot sun.

In the current revival of the vernacular for resourceful local architecture, architectural design and practice are witnessing a return to mud building methods in general.[8] The heritage of adobe making constitutes the first and last repository of knowledge of its future architecture in the region. However, this knowledge is undergoing continuous decay for several reasons, the most important of which is the decline in the tacit practices of mudbrick making — the craft of knowing its mixtures and properties. Another cause of this decay is limiting earth construction to restoration projects of existing monuments, while many earth houses are being neglected if not demolished.

Finally, even when earthen architecture is considered in contemporary projects, it is likely rough mudbricks will be the least-favoured option in comparison to other more regular techniques like rammed earth or compressed earth blocks. Mudbrick architecture can be considered the least fortunate among its counterparts. Their use is, therefore, limited to today's self-built houses in rural contexts in the Middle East, North Africa, and Latin America — usually stigmatized and associated with poverty and underdevelopment.

Soil , Straw , and Water

Methods of preparing mudbricks do not differ much from region to region. The process begins by mixing soil with water to obtain clay. Ground is chosen close to water sources such as rivers, lakes, and irrigation canals, rich in clay and organic matter. After that, plant fibres are added. Straw has been widely used in the Middle East since the beginning of the use of mudbricks. Straw lengths range from less than 1 to 10 cm. Rice or wheat husk can also be added to the mixture. The straw's proportion and size depend on the soil's nature. Studies indicate that the ratio of straw to soil ranges between 2 to 6 per cent, while some rules of thumb in Egypt show an estimate of up to 8 kg of chopped straw per cubic metre of clay.[9] After adding the clay, the mixture is prepared in a ditch and then kneaded using feet or animals. This is done for several days (about 4 or 5) before it is left for another few days to settle and ferment.

The clay mixed in this hole (which is then covered) forms the primary material for making bricks; even for weeks or months after mixing it, the builder kneads the mixture a little before pouring it into the moulds. Now that the mixture is prepared, a process called beating the bricks "Darb al Toub" takes place. The workers pour the mix into wooden moulds made for this purpose. The dimensions of the brick differ by local standards and uses.

Mudbrick after the making, Aleppo, 2022.
©Wesam Al Asali.

The bricks intended for walls are often large, in contrast to those intended for arches and vaults, which are smaller so that an individual builder can quickly build with them on a scaffold. Wooden structures are manufactured with many openings to make multiple bricks in each cast, some of which reach 16 bricks, to increase brick-making productivity. After pouring the bricks, the mould is taken out after 15-30 minutes, and the bricks are left under the sun on a bed of sand or straw to avoid sticking to the ground. The bricks' drying depends on the site's temperature and humidity. Roughly after a week, the bricks can be turned over to ensure they dry for another week. A week after, the bricks are stacked into piles, ready for construction or transportation.

From Walls to Vaults: Building with Mudbrick

When mudbricks are ready for construction, they are used for the two main structural elements: walls and ceilings. The mortar used with mudbricks differs from sandy mud to mixes of lime and plaster.

Mudbrick walls are built on stone foundations to avoid moisture rising from the ground, and their construction is subject to the regular methods of the brick construction of single, double, or one-and-a-half bricks. In many cases, clay block construction is mixed with wood. The use of wood ranges from minimal cases, as it is only found in door and window lintels, to cases where Mudbricks serve as infill of wooden frames, such as the mud and timber walls (called mukattaf)in central Syria and Southern Turkey.[10] Although we refer to mudbricks as dried blocks of a rectangular form, it is inevitable to remember another mud construction that uses wet cob balls called Madar or Laban. Workers throw the cob balls on the wall to extrude it, and the damp mud dries in after it is built. Cob ball construction is ubiquitous in Southern Arabia (particularly southern Asir and Yemen).[11]

Earth wall construction, Al Hili Fort, Al Ain,UAE.
Image by Raghad Al Ali.

But what distinguishes the mudbricks technique from other earth constructions is its ability to span arches in walls for opening and vaults between walls for ceilings. For a mudbrick structure to carry out this task, builders rely on the structure's geometry, so they bend the brick paths and coursing to form curved lines and surfaces that will safely transfer the loads from the top of the structure to its foundations. Thus, a very fragile material such as clay becomes capable of producing roofs without the need for reinforcement — they start to work predominantly in compression and not in tension. Therefore, builders of the region, who worked for millennia with this material, have developed unique models for vaults and domes that rely carefully on gravity and design forces. Today we know the essential physics behind vaulted and arched structure builders made centuries ago with their empirical knowledge and deduced into rules of thumb. For an arch to stand, a trace of an inverted hanging chain must be maintained in its section. In other words, what is formed by a structure subjected to compressive loads only is the opposite of a structure subjected to tensile loads- a standing arch or vault is the opposite of a hanging chain. This hanging chain curve is called the catenary curve.[12]

To design with the catenary curve, traditional builders adopted three approaches:
1- Material Approach: Builders ensure that this curve is contained in the thickness of the load-bearing walls on which the vault stand or by supporting them with buttresses, especially if semi-circular vaults are used.

2- Geometrical Approach: Builders designed the vault shape to be very similar to the catenary curve, thus reducing the use of redundant materials to support the vault. Therefore, some arch builders today hang a metal chain and adopt its curves to build after turning it over.

Adobe vault construction, detail, 2014.
©Wesam Al Asali.

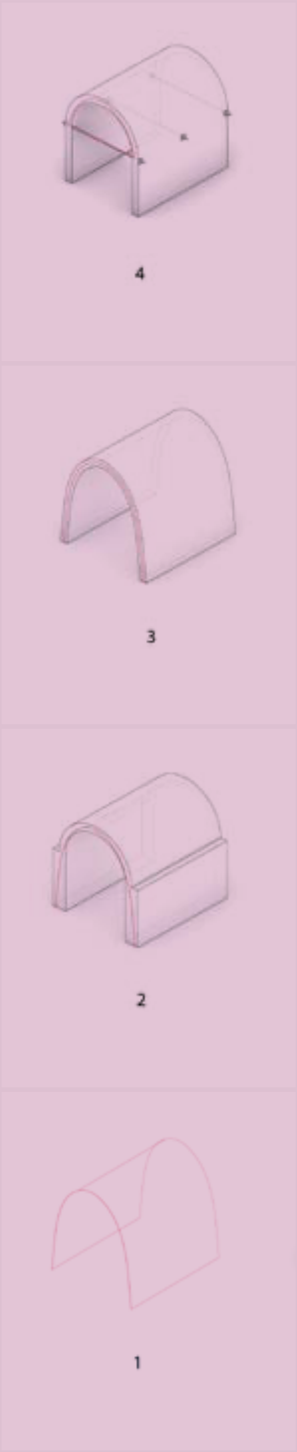
3- Engineering Approach: Builders found solutions to neutralize the horizontal thrust of the vault's forces using metal or wooden rods that tie the base of the vault. Today, builders use reinforced concrete ring beams as a base for their structures.

When these design preconditions are fulfilled, the question becomes which strategies build mudbrick vaults with the least temporary materials to support the construction. Unlike stone-cut vaulted structures, mudbrick vaults need minimum temporary support to be made. They usually rely on the inclination of the bricks to maximize the mortar's friction and eliminate any need for formwork. Domes are also very prevalent in mudbrick architecture, where corbelled (false) domes and spherical domes are built without formwork.

Through observing the mentioned constructional and structural properties of vaults, we notice the following ancient vaults and domes solutions that are suitable for mudbricks:

1- Pitched brick vaults: Barrel vaults in Mesopotamia and Ancient Egypt could be erected because of the inclination of the coursing towards a supporting wall. This vault's typology is called a Nubian vault in Egypt, referring to its origins in the Nuba's architecture in South Egypt and Sudan, where it is still practised for building mudbrick houses.[13]

2- Sail vaults: Like barrel vaults, sail vaults also rely on the inclination of the individual brick to eliminate the use of wooden formwork. However, instead of starting from a wall, a sail vault grows from the corners of the space it covers, forming squinches of subsequent arches. Originating in Mesopotamia and today's Iran, this vaulting technique became very prevalent in the Mediterranean region. It travelled with the Spanish colonization to Latin America, where it is currently called 'Ladrillo Recargado' in Mexico.[14]



Mudbrick Vaults: Structural Approaches:
1- Catenary Curve, 2- Material Approach, 3- Geometrical Approach, 4- Engineering Approach.
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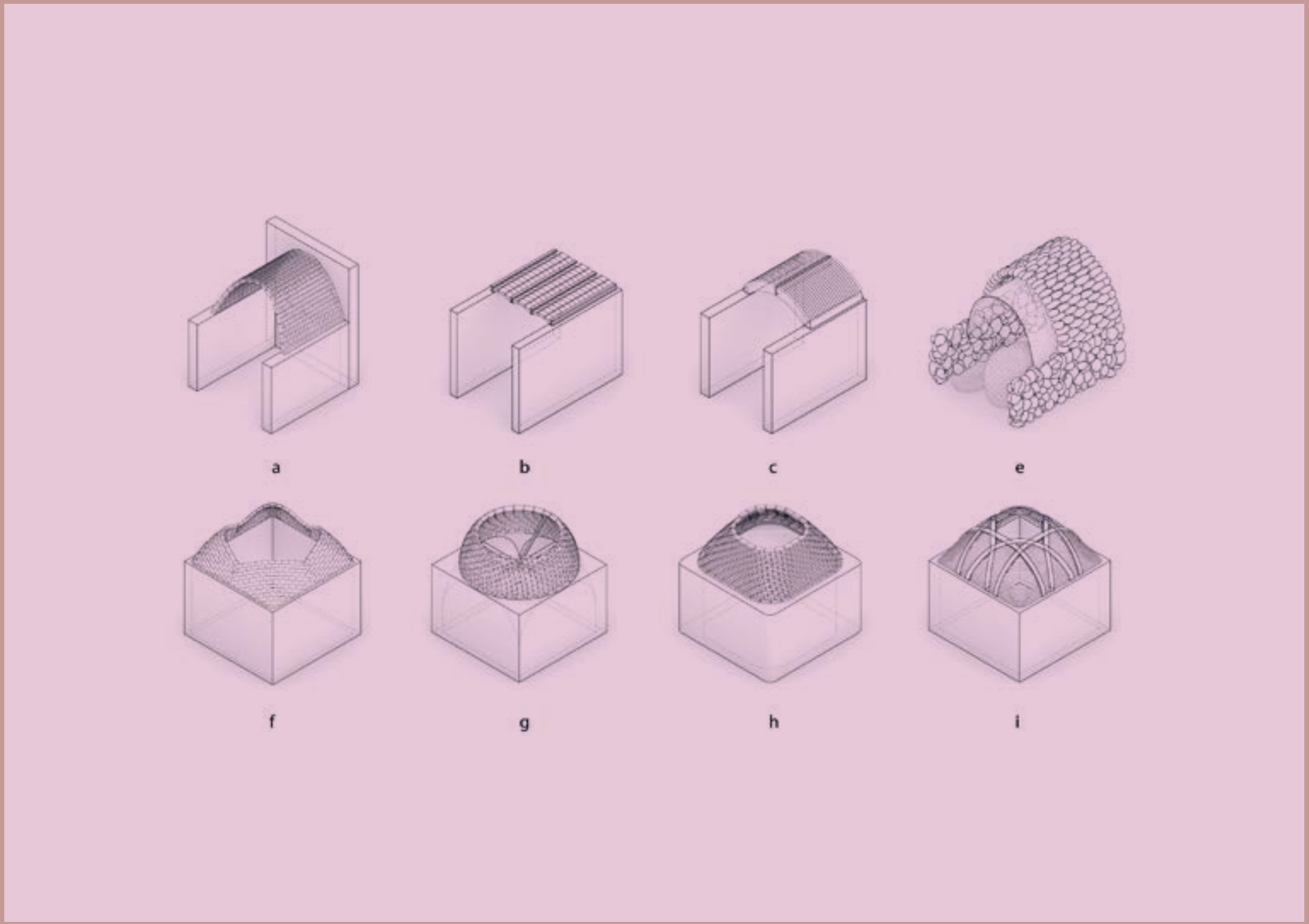
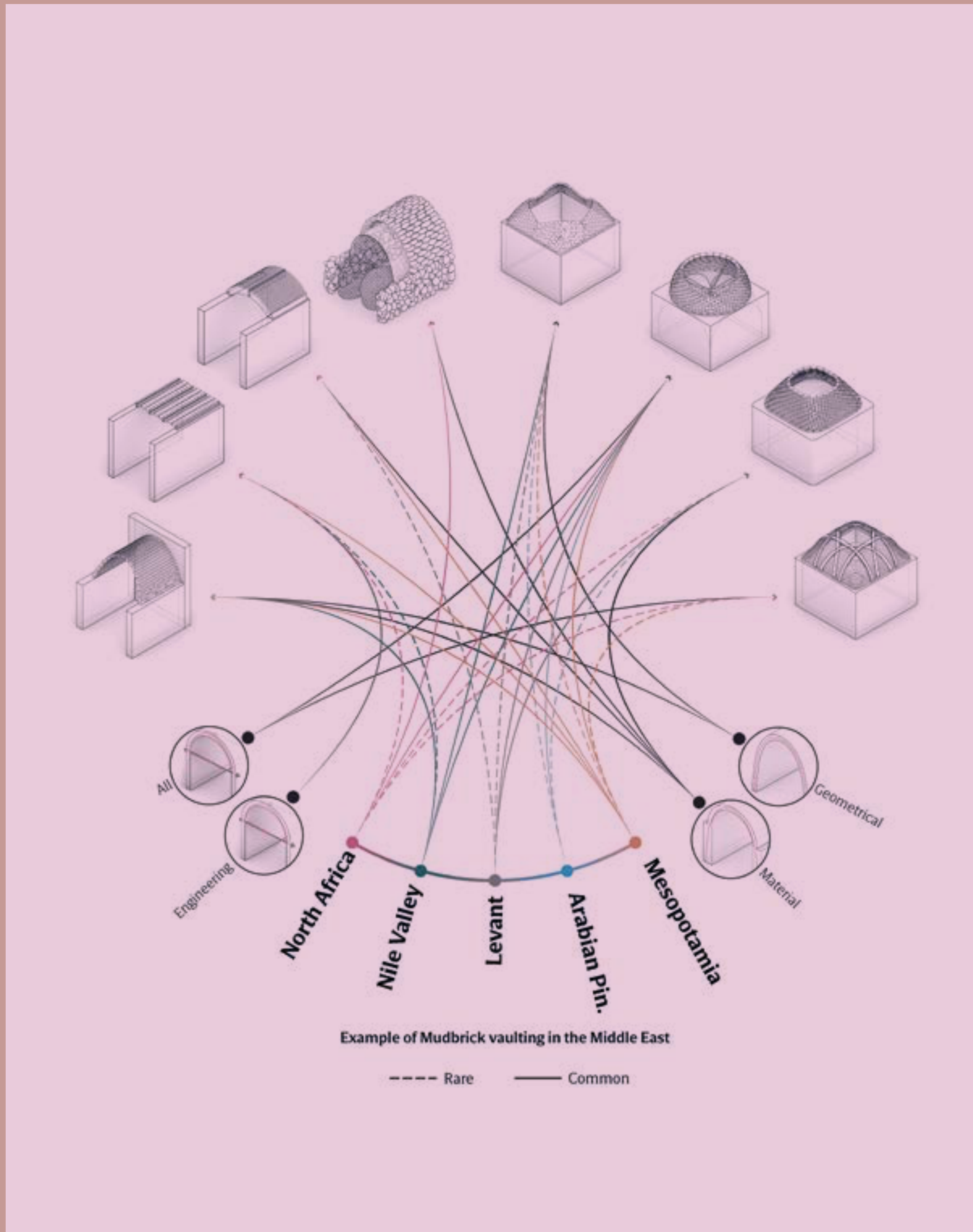
3- Barrel vaults on beams: This technique is a composed of wooden beams and flat barrel vaults. Because it gives a flat surface on the top, the technique is usually used as a floor system between two floors in a multi-storey building. The beams are laid on the top of the walls with spacing between them between 0.6 and 1.6 metres. Builders use fast-setting plaster mortar for shallow vaults that span the spaces between the beams. The vaults are covered with lime mortar. Today, a variation of this technique is still practised in Iraq (called Akkada) and Egypt. [15]

4- Vaults of mudbrick and stone: In cases where formwork is inevitable, builders used recyclable systems and materials as temporary support, such as piles of bricks covered with straw or bags of hay covered with woven mats. The latter was vastly used in the mud construction of Kasrs, grain storages, and halls in the Amazigh architecture in North Africa. [16]

5- Prefabricated bricks: In anticipation of vault construction, some of the adobe bricks were made specifically for this purpose. Large and curved bricks are made as halves of arches and joined together to form the vaults. This specific technique was used for small and long spaces such as corridors and storage vaults.



Mudbrick Vault and Domes: a- Pitched Bricks Barrel Vault, b- Shallow Vaults on Beams, c- Prefabricated Curved Brick, d- Groufah Vaults, f- Pitched Bricks Squinch Vault, g- Dome, h- Corbelled Dome, i- Rib Dome. ©Wesam Al Asali.



As a variation of this type of vaulting, builders in Basra made halves of arches on the ground using small bricks and fast-setting plaster of gypsum before they raised them on the wall and joined them with the crown brick.[17]

6- Spherical Domes: In this type of dome, bricks are inclined towards the centre of sphere-forming rings that close towards the top. Builders use a rotating pole called a compass that is usually fixed to the centre of the dome and describe the location and angle of every mudbrick. Spherical domes are found in almost all regions of Mudbrick architecture.[18]

7- Corbelled Domes: Unlike spherical domes, these conical structures are built with horizontal bricks in a spiral fashion. Corbelled domes are found in what is named as the beehive villages in the Levant and can also be traced in mud mosques architecture in Libya. Al-Bidya Mosque in Fujairah, with its four spiral domes, is reminiscent of the architecture of corbelled domes.[19]

8- Rib Domes: Gypsum plaster allowed the builders to use it as a stay-in-place formwork. In many mudbrick domes, moulded arches segment the spaces forming stay-in-place ribs. Bricks infill between or above these ribs without needing support. The rib vaults have been used across many cultures in Islamic architecture, from the South and Central Asia to the Iberian Peninsula.[2]

Restoration: From Buildings to Cultures

Mudbrick architecture presents today one of the most pressing paradoxes in the contemporary practice of architecture. While mudbrick buildings are massively present in historical city centres and village spaces, we find it difficult to reproduce them in contemporary practices.

Cultures of Mudbrick Vaulted Architecture
in the Middle East and North Africa. ©Wesam Al Asali.

Mudbrick architecture (and other vernacular construction methods) are generally excluded from building codes and construction regulations as they are tough to map and systemize. Only in times of scarcity and crisis does architectural thinking shift back to using local materials. For example, one of the earliest attempts to make earth-building regulations occurred in post-war Germany in the 1940s and 1950s. Because of the need to build in economic hardship, codes and standards were set for earthen architecture to be used. This experience played an excellent role in reproducing these codes at the beginning of the 21st century in Germany and Europe.[21]

Today, and considering the recognition of rethinking design practices under the environmental crisis, the concepts of codes in general and their relationships with local architecture are being challenged. In the Middle East, there are countless encyclopaedias before our eyes in the form of historic mud architecture that await investigation. However, the problem of approaching mud architecture in the region is double-sided. The first side is technical and represented by the adoption of imported codes that alienated localized building techniques and knowledge; materials were lab subjects only, not cultural subjects. The second side is ideologic, representing the nostalgic approach to associating vernacular buildings with a static historical identity.

Such an approach equally alienates local materials by denying their right to progress with the advancement of construction techniques and the increased urbanization of the world. The solution to this alienation should be both playful and systemized, risk-taking, and cautious.

In this short study, we find that clay bricks cannot be understood as a mere building material but as both cultural and technical systems that differ in size, use, and property. Today, this architecture needs comprehensive tasks that combine history, ethnographic studies, architecture, and material science. These tasks cannot be undertaken in isolation from each other. The laboratory is the building, and the material is the builder.

Exposed mudbrick domes during the restoration of Gurna Village, Arch, 2019.
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Desertscape, Abu Dhabi, UAE.
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Earth wall construction, Al Hili Fort, a fort in Al Ain,UAE.
Image by Raghad Al Ali.

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