Earth – as a building material

History and techniques
"Archaeological evidence can date entire cities constructed of earth back over 10,000 years. All of the great civilizations of the Middle East were constructed with mud brick and rammed earth - Assyria, Babylon, Persia, and Sumeria.

Rammed earth construction was used to construct countless monuments, temples, ziggurats, churches, and mosques. Many of these structures (the Great Wall of China being one) have stood the test of time and are still standing today.."

The earthquake that virtually leveled the historic city of Bam, a cultural heritage boasting a 2000 year old citadel that was the largest mud brick structure in the world
IN YEMEN – A HERITAGE CITY IN EARTH
RURAL COMMUNITIES IN AFRICA AND THE AMERICAS BUILT WITH EARTH
The Casa Grande Ruins were constructed in somewhere between AD 1200-1450 by the Hohokam Phoenix, Arizona. Restoration efforts was made in 1903 when a cover with a large galvanized, corrugated iron roof with a six foot overhang supported by 10”X10” redwood posts embedded into the ground (middle image) was made.

In 1932 Congress appropriated funds to construct a new shelter over the ruins to protect them. Completed on December 12, 1932, the structure stands forty-six feet from the ground to the eaves and was painted sage green to harmonize with the mountains and vegetation as well as provide contrast to the ruin.
One half of the earth population, approximately 3 billion people on six continents live or work out of buildings constructed with earth.

In most countries of the world, it is possible to mould earth with sophisticated or primitive tools to construct buildings. The range of the technical, constructional and architectural possibilities of earth is extremely wide. This wide constructional potential has enabled the construction of modest shelters, village houses, urban blocks and religious edifices, as well as palaces and entire cities.
• In countries with limited industrialized means, earth remains the main building material.

• Processed materials are costly both in foreign currencies and imported energy.

• Communities remain dependent on the use of locally available solutions, materials and knowledge.

• These materials and techniques if well used, can ensure true architectural quality which makes the most of the human and material resources available.
• Buildings of un-stabilized earth, face the risk of erosion unless special design precautions are taken to reduce exposure to rain and moisture.
• For durability, un-stabilized earth should only be used where it is not prone to water or damp.

• Optimum designs will depend a lot on the environment, such as the natural drainage and water table; the climate, for example, rainfall (quantity and intensity) and winds during rains; and on the maintenance practices of the users.

• Stabilizers and other additives or methods such as good compaction and grain size optimization can reduce swelling, shrinkage and cracking, increasing strength and water resistance.
• Most soils consist of clay together with proportions of silt, sand and gravel. The larger particles give structure to a soil, while the clay holds it together and to a great extent provides the cohesion.

• To obtain a good building material which is strong and easy to use, the proportion of clay in a soil should be about 15 per cent on average. The sand should be 40 to 80 per cent, the gravel 0 to 40 per cent and the silt 10 to 25 per cent. If the clay content in a soil is too high, some minerals, such as, sand and gravels, or fibers, such as, straw or hair, can be added.

• Earth is a ready building material which requires little further processing. Generally, a fairly wet mix with higher proportions of clay is used in moldings and spreading applications, while a mix with less clay is best suited to compaction in a moist or damp state.
Environmental Advantages

• earth does not contribute to the deforestation which follows the use of organic resources for firing baked earth materials.

• One can limit the use of non-renewable energy, for example, oil and gas, at source for the processing and production of materials and reduce the use of cements, lime and other conventional binding materials.

• By exploiting strata on construction sites, it allows a considerable saving in energy for the transportation of materials.

• It does not contribute to the degradation of the landscape as does the extraction of minerals and ores which hollows out hillsides and open cast sites. A great deal of the earth excavated in the course of large public facilities work, for example, roads, can be recycled and used in building (allowing very easy decentralized distribution).
• It does not contribute to the diminishing of resources of aggregates, such as gravel and sand, excavated either from quarries or from water courses, in insular sites or lagoons, putting into peril the ecological balance of these natural environments.

• It uses very little water, essential for the life of the people.

• It produces no industrial or chemical waste and moreover has the additional advantage of being almost entirely recyclable.

• Unbaked earth is not only non-polluting in its use, it also guarantees the absence of harmful effects in the context of daily life such as the absence of gaseous emissions or other toxic chemical components, radioactive emission etc.

• The surface texture, color, form and luminosity of unbaked earth makes it an attractive material for buildings without ruining the natural environment.
Economical Advantages

• Unbaked earth is often comparable in cost with, or indeed more economical than, competing technologies. It requires no major financial transport costs because its generally light production infrastructure.

• Unbaked earth requires only simple production and application tools (moulds, presses, light shuttering and masonry tools etc.) which are accessible to a wide population of masons and self-help builders.

• Unbaked earth follows on in the heritage of the traditional architecture of numerous countries using local materials. It allows local populations to take charge of the production of their built environment and thus control their living environment.
TYPES OF EARTH CONSTRUCTION:

1. ADOBE
2. RAMMED EARTH
3. STRAW - CLAY
4. COB
5. COMPRESSED EARTH BLOCKS
6. WATTLE AND DAUB
7. DIRECT SHAPING
1. Adobe

Definition: Adobe is a term widely used in the southwestern United States and Spanish speaking countries. Although the word is often used to describe an architectural style, adobe is actually a building material.

Adobe "bricks" are usually made with tightly compacted earth, clay, and straw. However, construction methods and the composition of the adobe will vary according to climate and local customs.
Sometimes asphalt emulsions are added to help waterproof the adobe bricks. A mixture of Portland cement and lime may also be added, but these materials will add to the cost. In parts of Latin America, fermented cactus juice is used for waterproofing.

In Kerala-India where torrential monsoons last for 4 months a year, the secretion of a eel like fish is used for stabilization of adobe walls.
2. RAMMED EARTH

Rammed earth construction resembles adobe construction. Both use soil mixed with waterproofing additives. However, even with the waterproofing additives, adobe requires dry weather so that the bricks can harden enough to build walls.

In rainy parts of the world, builders developed "rammed earth" construction. A mixture of soil and cement are compacted into forms. Later, the forms are removed and solid earth walls remain.

This technique is also known as *Pisé*, *Jacal*, and *Barjareque* to describe forms of earth construction similar to rammed earth.
The Chapel of Reconciliation is both Germany's first public rammed earth building in over 150 years as well as the first rammed earth German church. The building was built on the site of the former Church of Reconciliation, which was built in 1894 and was later destroyed, as it was surrounded by the wall dividing east and west Germany. The rammed earth walls in the new church are made using clay mixed with the ground up remains of the former church.
3. STRAW – CLAY

Definition: clayey soil is mixed in water to form a greasy slip which then added to straw.

The role of the earth is to bind the straw together. Straw clay is easily adaptable for prefabrication – wall panels, flooring and large wall bricks.

Straw clay allows for lightweight construction with good thermal properties.
4. COB

Definition: In Old English, *cob* was a root word that meant *lump or rounded mass*. Cob houses are made of clay-like lumps of soil, sand, and straw. Unlike adobe and straw bale construction, cob does not use bricks or blocks. Instead, wall surfaces can be sculpted into smooth, sinuous forms. A cob home may have sloping walls, arches and lots of wall niches. Cob homes are one of the most durable types of earth architecture. Because the mud mixture is porous, cob can withstand long periods of rain without weakening. A plaster made of lime and sand may be used to windproof the exterior walls from wind damage. Cob houses are suitable for the desert or for very cold climates.
5. COMPRESSED EARTH BLOCKS

nowadays, the process of compressing earth blocks has been mechanized and manual or hydraulic presses, or completely integrated plants can be used.

Products range from accurately solid shape, cellular and hollow bricks, to flooring and paving elements.
6. WATTLE AND DAUB

A supporting frame which is usually wooden, is filled with a daubed lattice or netting woven from vegetable matter. A very clayey earth is used which is mixed with a straw or other vegetable fiber to prevent shrinkage upon drying.

7. DIRECT SHAPING

An ancient technique of using plastic earth to model forms directly without using any mould or formwork. Skill of the builder is the only tool.
Adobe, rammed earth and compressed earth blocks are the most widespread earth construction techniques used today. They have reached extremely high scientific and technological levels, and permit the construction of a wide variety of components and construction systems - for example, foundations, floors, pitched and flat roofs, arches, tiles, chimneys, canals, roads, dams and bridges etc.
TYPES OF SOIL

1. Laterites - wet climates, tropics and sub-tropics
   • Highly weather soils containing large proportion of iron oxides and aluminum
   • compact concretion to crumbly soil
   • Red, ochre, brown and black
   • bulk density 2500-3600 kgs / m³

2. Black cotton soil – wet tropical area
   • Soils rich in calcium carbonate occurring over volcanic rocks
   • swell with moisture and severe shrinkage with dry conditions
   • dark brown, grey and black
   • bulk density 4000-4500 kgs / m³

3. Loess – wind deposit
   • fine, homogeneous with silty texture 10-20% calcium carbonate
   • dusty or fine powdery soil that is compact under the surface
   • Grey, ochre and white
   • bulk density 2000-3400 kgs /m³

4. Clayey rocks – desert and temperate areas
   • sedimentary conditions with phylosilicate
   • could be as hard as rocks to difficult to dissolve – chalk

5. Saline soils – semi deserts, steppe and tropical dry areas
   • rich in sodium chloride and sodium sulphate
   • crumbly to hard

6. Alluvial – along streams, rivers and lakes
   • rich in minerals
   • fine with sedimentation in depths
Soil identification

1. **Visual examination** – size of the different particles to the naked eye, after removal of stones, gravel and coarse sand.
2. **Smell test** – do be done immediately after excavation. Musty = organic content
3. **Nibble test** – sandy if it grinds between the teeth, silty if the grinding is not perceptible and clayey if it has a floury or pasty feeling on the tongue
4. **Touch test** – crumble the soil by rubbing in the palm with fingers. sandy = rough when dry and has no cohesion when wet, silty = slightly rough when dry and moderately cohesive when wet and clayey = lumpy when dry and sticky/plastic when wet.
5. **Washing test** – wash the soil in the palm of the hand and then rinse. Clean = sandy, clean with some amount of rinsing = silty and rinsing off with difficulty = clayey.
6. **Luster test** – cut a moist ball of earth with a knife, dull side = silty and shiny = clayey
7. **Adhesion test** – moist ball of earth that is sticky.....plunge a knife in it. Deep penetration = sandy, moderate penetration = silty and difficult penetration = clayey
9. **Shrinkage test** – long narrow box with greased inside (proportion of 1:8 min) fill with moist soil tightly using spatula. Dry in the sun for 3 days and then check the gap between the box and the hardened soil.
EARTH BLOCK MAKING

Excavation and sieving

• Soil excavated on site if possible, at the lowest point for using the depression for rain water harvesting

• Sieving to be done in the excavation site to reduce on movement of soil.

• Dry soil to stored away from tree cover to prevent contamination with organic matter

• Better to use the soil immediately after sieving
Mixing with stabilizers

• add sand if the soil has less than 40% sand content
• Dry mix the soil, sand and stabilizer.
• Humidify it with water while mixing only till it is moist.
• Moisture test – roll the earth in a ball with the hand and drop the ball from shoulder height: shatters - not enough water, lumpy or medium size pieces – right water content and keeps ball form - too much water
• Use the moist mix within 20 minutes if using cement based stabilizers
Organize the mixes for continuity of block production

• Three piles of mixes ready, 2 dry mix and the humid mix being used for block production
Production, stacking and curing:

• Load the machine with fixed volume (use a hopper or measure box made according to soil density-compression compartment size) to ensure uniform density of blocks.

• Stack the ready blocks close together to contain the inherent moisture that is already in the block.

• Cover the daily production of blocks with plastic sheets that are well tucked to prevent block drying for 3 days.

• Move and restack the blocks in the stock yard after 3 days.

• Cure the blocks with water from day 3-day 27 to keep them under moist condition to enable proper curing.

• Blocks ready for use after this.
RAMMED EARTH IN FOUNDATIONS
Block in walling

• Use the blocks as a module for the wall sizing to prevent cutting of blocks on site
• Teach the masons bonding for various situation (X, T, L, I and V) and provide a bonding book for aid.
• Integrate the block size to the opening size, heights and pillars
• Use stabilized earth mortar that has a similar stabilization proportion as the blocks
When using arches and corbelling for openings, design using the block module. Ensure that the mortar joints are nil or minimal at the intrados and the extrados is filled with gravel to prevent shrinkage.
Plaster at the base of walls on the outside to prevent erosion due to splashing of rain water.

Good overhang for shading from sun and rain.

Coping on all parapet walls to prevent rain water running down the wall. Also copings help to prevent cracks due to thermal expansions that allow water penetration.
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