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IMPROVING ADOBE BUILDING CONSTRUCTION IN TANZANIA

IGNAS A. RUBARATUKA
Department of Structural and Construction Engineering University of Dar es Salaam, P. O. Box 35131, Dar es Salaam, Tanzania, (E-mail: rignas1@uccmail.co.tz)

ABSTRACT: *Adobe in the form of sun dried bricks and clay mortar is still one of the primary building construction material in Tanzania especially in rural areas due to its low cost, availability and affordability. Investigations carried out in some regions of Tanzania revealed that, despite this extensive use, adobe constructed buildings have some major shortcomings, which include its heavy weight, low material strength, cracking and lack of proper connections between the main load – carrying elements of the buildings. Therefore, in order to improve the performance of adobe building constructions, there is a need to provide an overall binding system in the form of wood acting as ring beams supported by vertical elements, that would prevent walls from falling out of their planes, plaster the walls externally to minimize the action of rainwater, provide strong foundations such as stone made foundations with damp proofing material applied between it and the walls and avoid adobe made flat roofs.*

1. INTRODUCTION

Adobe is a natural building material mixed from sand, clay, and sometimes with straw, dung or other fibrous materials, which is shaped into bricks and dried in the sun as shown in Figure 1. Adobe mud sun-dried bricks are one of the oldest and most common used building materials. Use of these sun – dried bricks for structures dates back to 8000 B. C. (Houben, et al 1994) and account for the oldest buildings on the planet.

Adobe constructions are very common in some of the world's most hazard– prone areas across Africa, Latin America and parts of Asia (Blondet, *et al* 2003). About 30% of the world's population lives in earth-made construction. Approximately 50% of the population in developing countries, including the majority of the rural population and at least 20% of the urban population, live in earthen dwellings (Houben, *et al* 1994).

By and large, this type of construction has been used and will continue to be used mainly by low income rural population due to its low – cost, readily



Figure 1: Adobe Sun – Dried Bricks

available construction material manufactured mostly by local communities. Adobe buildings are generally self-made because the construction practice is simple and does not require additional energy consumption. In this paper, construction practices and problems of adobe buildings in Tanzania are presented, and measures to improve their performance ar also outlined.

2. CONSTRUCTION OF ADOBE BUILDINGS IN TANZANIA

In Tanzania, adobe constructed buildings are very common mainly in rural areas. These buildings differ in size/dimensions and have different features depending on traditions and weather conditions in the regions where they are constructed. For example, most of adobe buildings found in Dodoma, Singida, Tabora, Shinyanga and Arusha have adobe flat roofs in addition to adobe walls. In Figure 2, an adobe constructed building in Dodoma region which is typical for most rural areas in Tanzania is shown. The walls are made of sun dried adobe bricks joined with mud mortar and mud plaster. In many regions, most of the roofs are constructed using adobe, except in Shinyanga and Mwanza regions where most of the roofs are made of thatched grass material.

For a building shown in Figure 2, timber poles have been added to assist the load bearing walls to support the heavy adobe roof. For example, adobe roofs in Dodoma are flat and are constructed such that the thickness at the centre of the roof is about 40



Figure 2: Adobe Constructed Building in Dodoma, Tanzania

cm and decreases outward hence creating a slope. To improve the roof durability, cow dung is mixed with soil from ant hills in a ratio of about 1:2 hence produce the adobe material for the roof. After some time grass is allowed to grow on top of the roof hence reducing erosion/wearing of the roof. The average height of these buildings is slightly less than 2.0m.

Of recent adobe constructed roofs are being replaced by corrugated iron roofing sheets which are kept in position by placing stones or other heavy objects on top as shown in Figure 3. The placing of stones on top is necessitated by the fact that most of the adobe constructed buildings in rural areas lack strong roof structure to hold in place roofing sheets especially against wind loads. Most of adobe constructed buildings are rectangular in plan with a single door (see Figure 2) of about 0.6m x 1.2m and small windows as shown in Figure 4. To reduce the effects of sun heat , the orientation of the buildings is normally to have the front side, which is a longer side to be facing North or South and the narrower sides to face East or West.

In order to increase the headroom, floor levels for some of these houses are below the external ground level by about 0.3m. This is achieved by excavating the inner part of the houses. Most of adobe buildings investigated in Dodoma region had shallow foundations about 160mm below ground level and were constructed by adobe bricks with adobe mortar and adobe flat roofs.



Figure 3 Adobe Constructed Building Roofed with Corrugated Iron Sheets

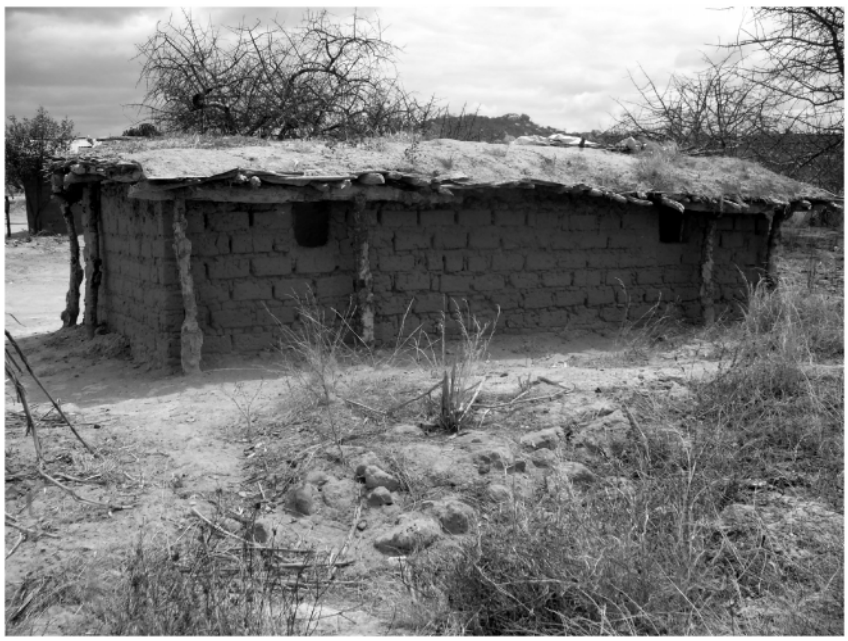


Figure 4: Typical Windows in Adobe Buildings

3. PROBLEMS OF ADOBE BUILDINGS IN TANZANIA

Investigations caaried out in Tanzania have revealed that despite their advantages such as low cost, simple construction, excellent thermal and acoustic properties, adobe buildings experience many problems, the main ones being those related to structural damages and water effects. Other problems are due to vegetation, insects/termites, lack of proper foundations and material incompatibilities.

3.1. Structural Damage Problems

Many of the structural problems originate from improper design or construction, insufficient foundations, weak or inadequate materials, effects of external forces such as wind, earthquakes, etc. The most common structural problems are cracks in walls, foundations and adobe made roofs. In adobe buildings, cracks are generally quite visible, but their causes may be difficult to diagnose. Some cracking is normal, such as the short hairline cracks that are caused as the adobe shrinks and continues to dry out. However, extensive cracking usually indicates serious structural problems. Lack of ring beams on top of the walls is one of the causes of vertical cracks in adobe building as shown in Figure 5.

Adobe buildings are not safe in seismic areas because their walls are heavy and they have low strength and brittle behaviour. During strong earthquakes, due to their large mass, these structures develop high levels of seismic forces, which they are



Figure 5: A Vertical Crack in a Wall of an Adobe Building

unable to resist, and therefore, they fail abruptly. Typical modes of failure during earthquakes are adobe bricks are not fired, they do not permanently harden, but remain unstable as they shrink and swell constantly with their changing water content. Their strength fluctuates with their water content: the higher the water content, the lower the strength. Adobe severe cracking and disintegration of walls, separation of walls at the corners, and separation of roofs from the walls, which sometimes lead to collapse.

Wind blown sand has often been cited as a factor in adobe erosion. Furrowing caused by wind is usually more obvious at the upper half of the wall and at the corners, while coving from rain splash and ground water is usually at the lower third of the wall.

3.2. Water Related Problems

Adobe buildings generally deteriorate because of moisture, either excessive ground water or rain water. The erosive action of rain water and the subsequent drying out of adobe roofs, parapet walls and wall surfaces cause furrows, cracks, deep fissures and pitted surfaces to form. Rain saturated adobe loses its cohesive strength and sloughs off forming rounded corners and parapets. Rain water damage, if left unattended, can eventually destroy adobe walls and roofs, causing their continued deterioration and ultimate collapse.

Standing rain water that accumulates at foundation level and rain splash cause the hollowing out of the wall just above grade level as shown in Figure 3 of a building in Dodoma.

In Dodoma and the neighbouring regions, most of the land terrain is flat and it has been observed that there are no proper drainage systems provided around the houses for storm water. During the rainy seasons, there is water ponding around the building which eventually affect the foundations of the houses. Further, it was established that the roof overhang is not adequate to protect adobe walls against driving rains.

3.3. Vegetation Related Problems

Vegetation and pests are natural phenomena that sometimes accelerate adobe deterioration. Seeds deposited by the wind or by animals may germinate in adobe walls or roofs (see Figures 2 and 5) and their roots may damage adobe bricks or cause moisture retention which will harm the building.

Insects often live in adobe structures burrowing in walls or foundations. These insects undermine and destroy the structural soundness of the adobe building. In some buildings vegetation was observed especially on roofs.

4.. IMPROVED ADOBE BUILDING CONSTRUCTIONS IN TANZANIA

Due to its low cost, adobe construction will continue to be used in many areas of the world particularly in developing countries. Therefore, development of cost effective

building technologies leading to improved performance of adobe construction is of utmost importance. The aim of improving adobe constructed buildings is to increase durability, comfort, and aesthetics while ensuring that they are affordable and socially acceptable. Based on the state of the art research studies and field applications, the key factors for the improved adobe construction are as follows: (i) Adobe brick composition and quality of construction; (ii) Improved building technologies; (iii) Elimination of moisture destructive effect, and (iv) Layout of buildings.

4.1. Adobe Brick Composition and Quality of Construction

In order to increase the strength of adobe masonry, the clay component which also causes drying shrinkage of the soil must be adequate (Blondet *et al* 2003). A composition of 30% clay and 70% sand/gravel make a perfect brick. Also as little as 10% of clay could make a good brick. Additives such as straw, and, to a lesser extent, coarse sand control micro cracking of the adobe due to drying shrinkage, and therefore improve the strength of adobe masonry have to be added. In Dodoma region, an analysis of soil used to manufacture adobe bricks was carried out and the composition was 26% clay, 17% silt, 36% sand, 21% gravel and the density was 2610 kg/m^3 which is suitable for adobe bricks.

The workmanship for most of the buildings is satisfactory. However, it has been established that some of the good practices for construction of adobe buildings are not adhered to. For example, mud is not stored for one or two days before the fabrication of adobe bricks or mortar so as to allow for a better integration and distribution of water with the clay particles, thus activating their cohesive properties, not always wetting of all faces of the adobe brick that are to be in contact with mortar is carried out before laying, not all foreign matters from the soil are removed before manufacturing of bricks.

4.1.1. Soil Stabilization with Lime

Soil stabilization with lime was carried out for soil samples obtained in Dodoma region. A slab was prepared cured and left to dry in the sun for 48 days and water absorption and pitting/erosion determined. The results are shown in Table 1 below.

Table 1
Pitting and Water Absorption Results

	Pitting				*Water absorption*			
Amount of lime (%)	*Height before (mm)*	*Height after Spraying (mm)*	*Pit Developed (mm*	*%*	*Weight of Dry Ample (kg)*	*Weight of of wet Sample(kg)*	*Change In weight (kg)*	*%*
0	85.0	68.6	16.4		5.242	5.542	0.300	5.72
6	87.0	77.3	9.7		4.953	5.183	0.230	4.64
9	83.7	75.9	7.8		5.194	5.394	0.200	3.85
12	87.0	78.0	8.1		4.566	4.746	0.180	3.81

From the results in Table 1, it has been observed that as the percentage of lime is increased to about 9%, the pitting and water absorption decreases.

4.2. Improved Building Technologies

To improve the performance of adobe constructions, it is recommended to reinforce them horizontally and vertically using any ductile material such as bamboo, cane sticks (of diameter 20mm), rope, vines, timber, barbed wire, chicken wire, or steel bars. Horizontal reinforcement will help to transmit the bending and inertia forces in transverse walls to the supporting shear walls, as well as restraining the shear stresses between adjoining walls and minimizing vertical crack propagation. Vertical reinforcement will tie the walls to the foundation and to the ring beam and restrains out–of–plane bending and in – plane shear. Both vertical and horizontal reinforcement should be tied together and to the other structural components such as foundations, ring beam, roof by means of materials such as nylon string hence resulting in a stable matrix, which is inherently stronger than the individual components. However, placement of reinforcement must be carefully planned and bricks made with special provisions (Coburn, *et al* 1995).

To ensure good performance of adobe buildings, a strong, continuous and well tied ring beam made of either timber or other similar materials need to be provided like a loop or a belt so as to receive and support the roof. When constructing an adobe building, the ground should be compressed because the weight of adobe bricks is significantly greater than a frame house and may cause cracking in the wall in case of a weak foundation base. The footing must be dug and compressed once again. The footing depth will depend on the region of site and the water table.

Adobe bricks must be laid by course where each course has to be laid the whole length of the wall, overlapping at the corners on a layer of adobe mortar. When putting in door and window openings, a lintel from wood or other materials has to be placed on top of the opening to support the bricks above. Within the last courses of brick, bond beams must be laid across the top of the bricks to provide a horizontal bearing plate for the roof to distribute the weight more evenly along the wall.

Roofs to be provided should be ideally light as possible in order to reduce the loads on the walls as well as the lateral seismic loads in earthquake prone areas. In all types of roofs, the structure should not transfer thrust onto walls except vertical reactions to supports. For protection, adobe walls should be plastered with permeable soft plaster, hydraulic lime or mud – lime based plasters. It has been observed that wall erosion due to rains and moisture is minimized by plastering walls with lime based plasters as shown in Figure 6. Impermeable (water tight) materials like Portland cement should not be used for plaster since adobe wall should be able to breathe.



Figure 6: Adobe Constructed Building with Lime Based Plaster

4.3. Eliminate/Minimize Moisture Destructive Effect

To protect external and internal walls from the effect of moisture and water, finishes such as mud plaster or white wash or other non traditional plasters that can provide longer protection have to be applied. Some ancient cultures used lime based cement for the plaster to protect walls against rain damage.

If the foundation is made of stone, then a damp proofing material must be placed between the foundation and the wall or adobe bricks which are water proof have to be constructed between the foundation and upper wall to prevent ground water from rising through capillary action into the wall and hence causing the adobe to erode, bulge and cove. In order, to minimize ground water, proper drainage systems must be provided around the building. The effect of rain water on the walls and foundations is minimized by providing roof overhangs of ranging between 200 mm to 500mm. Further, it is recommended to use roofing sheets such as iron sheets or grass thatched roofs with adequate slope which easily drain water away from the roof.

4.4. Layout of Buildings

One of the essential principles for improving the performance of adobe buildings is to adopt a compact, box – type layout. The following are recommended for construction of adobe buildings: (i) Construct a strong and firm foundation; (ii) Arrange the wall layout to provide mutual support by means of cross walls and intersecting walls at regular intervals in both directions; (iii) Keep the openings in the walls small and

well – spaced; (iv) Build only one storey houses; (v) Use an insulated lightweight roof instead of a heavy roof such as compacted earth or clay tiles.

Since walls are the main load – bearing elements in an adobe building, the following recommendations are made in order to improve the performance of adobe buildings (Blondet and Gladys, 2003): (a) The wall height should not exceed eight times the wall thickness at its base, and in any case should not be greater than 3.5 m; (b) The unsupported length of a wall between cross walls should not exceed ten times the wall thickness, with a maximum of seven metres, When a longer wall is required, it should be strengthened by an intermediate vertical buttress; (c) Provide buttresses at all corners and junctions of walls; (d) Wall openings should not exceed one – third of the total wall length or should not be wider than 1.2 m; (e) Provide piers of at least 1.2 m width between openings; (f) Roughly squared rooms; (g) Provide at least four courses of plinth masonry above foundations; (h) The distance between an outside corner and the opening should not be less than 1.2 m; (i) The sum of the widths of openings in a wall should not exceed 1/3 of the total wall length; (j) The bearing length (embedment) of lintels on each side of an opening should not be less than 0.5 m.

5. CONCLUSIONS

Although traditionally adobe buildings have been considered not to be durable and stronger, practical experience and research findings have revealed that, if strengthened and stabilized, the performance of adobe constructed buildings can be improved significantly. Adobe constructed buildings may last longer as any other building made of durable materials if they have a good foundation, a durable roof with adequate roof overhang and the exterior and interior surfaces of adobe walls are protected by surface coatings such as mud plaster, lime plaster, white wash, etc. which retard the surface deterioration by offering a renewable surface to the adobe wall.

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