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Housing materials and methods for tropical Africa



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How traditional, and some new, resources are used and might economically be used in future — as seen from the National Housing and Building Research Unit in Tanzania.

In tropical Africa the main problem in the provision of adequate housing is similar to that elsewhere: a shortage of resources in relation to human needs. However, tropical Africa is in some ways more fortunate than the other developing regions in that the vast majority of its population still live in rural areas, where housing requirements are more easily satisfied than is possible in urban areas. Nevertheless, the urban population is expanding at a very rapid rate, and many of its main cities have yearly increases of over 10 per cent (ref 1). Any discussion on housing provision in this region must therefore consider both shelter in the rural areas, where the vast majority of the population live, and the special problems the urban areas experience because of their rapid growth and their short supply of traditional housing materials.

The problems have been well documented in various UN publications (refs 2, 3). In general, neither the citizens nor their governments can afford the new materials. Therefore, it is here assumed that the traditional materials will still find major use in the foreseeable future. Housing improvements for the majority of tropical Africa's people must thus mean improving the traditional materials and construction techniques to enhance their standards of durability, hygiene and comfort. Furthermore, the local materials are often better suited to the climate than the newer ones.



Figure 1 House with traditional thatch roof and mud and pole walls

Roof structure

The traditional thatched roof is still the most common in rural tropical Africa (fig 1). It has the undoubted advantages of low cost and good heat insulation, as well as being a familiar and readily available construction material. Its chief disadvantages are its low durability, (generally 3 to 7 years), and its flammability, which is a more acute problem in urban areas. Also, in the inner urban areas, thatching material must come from the surrounding countryside, and may need hired labour to fix it. Preservation and fire-proofing would thus appear to make more sense in those urban areas where both material and placement costs are incurred, as renewal of thatching then entails extra material and labour costs. However, present costs for chemically treating thatch (and poles) to overcome problems of low-durability and fire-risk are very high (ref 4), and extensive use of thatching in urban areas must await further research. Similar provisions apply to the use of wood shingles.

Partly to overcome the problems with thatching, corrugated iron sheet roofs are very widely used, especially in the urban areas. They have the advantages of high durability and biological resistance. They are light-weight and breakage-resistant, and thus cheap to transport. Further, because of this lightness and flexibility, they require only a light roofing frame which can be easily constructed from bush poles (fig 2). Their disadvantages include climatic unsuitability in hot humid areas, since they are not porous to air, and also in hot arid regions, because of their high thermal conductivity without heat storage. More important, they are expensive, partly because they are imported. Aluminium sheet roofing has much the same advantages and disadvantages as corrugated iron sheets.

One method of reducing roofing costs when corrugated iron or aluminium sheets are used is to lower the roof slope. At present the roof slope used is often the same as that for thatched roofs. Steep slopes are needed for thatch roofing because of their relatively high permeability, which causes the void spaces in the thatch to hold water for long periods after the rain has ceased, thus lowering durability. These problems do not arise with metal sheet roofing. Since the metal sheeting roofing material will be the major materials cost for the house, the resulting savings could be important.

Asbestos sheets offer a possible solution for countries possessing asbestos fibre minerals, as they can be manufactured locally. A disadvantage is the high breakage loss. Roof tiles made of concrete, burnt

Figure 3

Wall under construction using sun-dried blocks, with mud mortar



clay or slate can also be made locally. Tiles have the disadvantage of heavy weight and short span, thus necessitating a strong roof frame, with the closely spaced purlins made from sawn timber. Neither corrugated asbestos sheets nor tiles seem a general solution for roofing, but their general suitability for the tropics and the possibility of local manufacture make them promising alternatives for public and commercial buildings where strong roof frames and load-bearing walls will be provided anyway.

Walls

There are many satisfactory or promising materials for wall construction in tropical Africa. The traditional materials include grass, poles (generally with mud infill), monolithic earth construction, sun-dried bricks and, less commonly, stone. Recently burnt-clay bricks, concrete, sand-cement and stabilised earth blocks have been used, as well as cement-plastering of the traditional earthen materials (figs 1, 2, 3).

The traditional earthen materials are especially suitable for wall construction, as they offer good heat insulation and the walls can be easily constructed with only simple tools. Most of the materials needed will be close at hand — in urban areas soil is likely to be the only traditional material still freely available. Monolithic mud-wall construction will generally lead to shrinkage cracking if it is placed too wet, and will therefore require patching after the wall earth material has reached its approximate equilibrium water content for the climate. Construction with sun-dried bricks appears more satisfactory because the shrinkage mainly occurs during curing, before the wall is built. If the soil immediately below the surface layer is not suitable, soils from different depths can be mixed. In sandy areas soil from termite mounds can often be used, if available, as these usually have a higher clay content than the surrounding soil (ref 5). A recent report from East Germany (ref 6) shows the potential of earthen materials for even two-storey housing. Erosion of earth walls is not as serious as might

be expected, because the heavy convective tropical storms are generally accompanied by very little wind, and thus the rain has only a small horizontal velocity component (ref 7). Erosion is therefore chiefly caused by rains of lower intensity and occurs mainly on the lower part of the wall. Any likely erosion can be minimised by increasing the width of the eaves to about one metre, which will also prevent heavy rains splashing up on to the walls. The wall durability can thus be greatly improved by a small increase in roofing costs. The provision of verandahs is another effective method of keeping the rain (and the sun) off the walls. The erosion resistance of the walls can also be improved by using stabilised soil blocks for the lower part of the external walls. If available, slaked lime from field kilns can be used to 'whitewash' both the interior and exterior walls, in order to improve their appearance.

In the inner urban areas, land for residential purposes will often be scarce, and two-or-more-storey residential buildings may prove economic. In this case the walls need to be load-bearing, so that concrete or stabilised soil blocks and burnt clay bricks will find more use here than in the rural or semi-urban areas.

Foundations

The durability of the earthen or masonry walls of houses will generally be improved if they are provided with a simple foundation. In few cases will the natural surface alone prove an adequate foundation. For much of the area of tropical Africa, though, it will only be necessary to remove the more compressible surface layers and lay the blocks directly on the bottom of a shallow trench, after levelling out and tamping the trench bottom. The first course of blocks can be placed in a thin layer of sand, if available. Especially for mud-block walls, this rudimentary foundation will be generally satisfactory, since mud-block walls (with mud mortar) are more flexible than concrete or brick walls, and can accommodate more sub-grade distortion.

For soils with a higher clay content, a simple strip foundation will be needed (fig 4). A strip foundation has the chief function of reducing differential settlements, however caused, to safe values. Absolute settlements alone will not cause any structural damage. Also, for one-storey buildings, the load bearing capacity of the soil will rarely be critical and, if it is, the site should be avoided for other reasons (as for example, in swampy areas).



Figure 4

Strip foundation constructed from loose stones

Differential settlements can occur in two main ways:

(a) either the foundation loads and/or the deformation resistance of the soil vary along the length of the foundations.

(b) either the moisture content and/or the swell-shrink properties of the soil vary along the length of the foundations.

Strip foundations thus have the dual function of reducing stresses imposed on the sub-grade (thus minimising both absolute and differential settlements) and reducing the foundation distortions caused by variations in moisture content. Removing the surface soil and using compacted and well-graded granular materials such as stones, crushed rock or laterite gravel for the strip foundation will be satisfactory because granular materials can spread the wall loads over a greater area. They also possess greater volume stability under changes of water content than the surface soils they replace.

Distortions of foundations are likely to occur if walls are built too near large trees, as the roots, in addition to physical disruption of foundations, can withdraw large quantities of water from the soil, thus causing sub-grade shrinkage.

Floors

Floor construction is important from a health viewpoint, even if of minor importance for house durability. For proper hygiene it is essential that the amount of water (whether in liquid or vapour form) rising to the floor surface is kept to a minimum. Thus a ready improvement to traditional housing can be effected by the provision of a capillary - breaking layer of coarse granular material. Stones, broken bricks or blocks, or even coarse sand or lateritic gravels, can be used to provide a capillary barrier. Possible sub-grade intrusion can be minimised by laying a layer of less coarse material next to the subgrade.

Whether a capillary barrier is needed at all depends upon two factors: the grading of the soil under the

floor and the depth to the water table (at its highest level). Using the capillary tube analogy, it can be shown that the maximum heights water can rise from the water-table are typically as follows (ref 8).

| | |
|-------------|---------------------|
| coarse sand | 2-5 cm |
| medium sand | 12-35 |
| fine sand | 35-70 |
| silt | 70-150 |
| clay | 200-400 and greater |

Thus, for example, if the water-table is always more than about 70 cm below the base of the floor and the soil is sandy, no capillary barrier will be needed. If the water-table for a given soil type is closer to the surface than the values given in the table above, a capillary barrier is needed. Again, as can be seen from the table, even a relatively thin layer of coarse sand is effective. Coarser materials, such as gravels or stones, will prove even more effective. The materials for the capillary barrier can always be improved by washing or sieving them to remove fines. If the water-table on occasion rises to the floor level, a capillary barrier will prove ineffective. In this case a different site should be chosen, or the floor system built up above the level of the natural soil surface. Capillary moisture can also move horizontally, provided a potential gradient exists. However, if eaves of adequate width are provided, and the ground around the house is sloped away from the walls, horizontal transfer of water by unsaturated flow will be minimised.

As well as preventing the entry of capillary water, the granular capillary barrier also provides a firm bed for the floor slab, if one is to be provided.

Research required

The aim of building research in tropical Africa must be to improve housing conditions for the majority of people. But because houses are built for people and by people, not only must the improved materials be within economic reach of this majority, but the materials must be readily available, they must be able to be worked using only simple tools and they must be readily acceptable to the people, and perceived as real improvements. The traditional materials as used at present fulfill many of the conditions above and are also suitable for the tropical climate, but their durability needs to be improved. This is probably less of a problem in rural areas, where repair or renewal of grass thatch, for example, can be done with the help of family and friends in the

slack season. Nevertheless, it helps to reinforce the view that the traditional materials are only temporary solutions.

There are other reasons why the traditional materials are being replaced to some extent by newer ones, especially in the towns. The research effort that has gone into materials, such as improved thatch or improved mud structures, is very small compared to the enormous research effort that is continuing into concrete technology, ceramics, metals and other modern construction materials in the industrial countries. Some of the new materials, especially metal roofing sheets, are very easy to build with. In addition, the extensive use of the imported materials in major government and commercial buildings has had a powerful "demonstration value".

The position looks more hopeful when one considers that much of this intensive research can be applied to solving the problems of low-cost housing. Thus there exists a large body of research knowledge on the engineering properties of soils, on the preservation and fire protection of timber, and the biology of the fungi and insects which are the main causes of their deterioration. Much of this work has special reference to temperate climates, but there is an increasing volume of research on tropical soils, timbers, grasses and climate.

Given the above, the tasks facing those working in low-cost housing improvement are clear. They must concentrate on improving the durability of the traditional materials, especially the earthen materials and thatch, in the specific context of housing. Solutions will naturally vary over tropical Africa, depending on the soil and vegetation type, the climatic conditions in each region, as well as the cultural habits of the people. The work will need to proceed along several different lines. The first will involve a survey of the large number of traditional housing constructions in tropical Africa, using the existing literature if possible in order to identify materials and techniques which could be more widely used. In connection with this survey, data on the durability of each construction type and of the component materials for that particular environment would be useful, if available.

The next step after this general survey will include laboratory and field experiments. Laboratory work on mud blocks, for example, must determine the best block size, moulding water content, degree of compaction, soil preparation and curing method, for each soil type and climate, but under manufacturing conditions which can reasonably be expected in rural areas. Eventually a range of specifications will emerge, covering all the different soil and climatic types occurring in the country.

Similarly, for thatch roofing, the best thatch material type, roof slope, thatch thickness and density and degree of support must be found for each region, with its different grass and pole types and availability, and different agents of decay and destruction (fungi, insects, wind and rain).

The erection of test houses in each region is the best way of measuring overall durability and suitability under field conditions; if possible they should be occupied. It is more convenient to evaluate the

durability of existing locally-built houses, but precise data on the date of construction and of any repairs, and on the materials and methods used, are needed. In all cases the work should involve the participation of the people who are to build and live in the improved houses, otherwise improvements promoted by experts, either locally or foreign born, are less likely to gain acceptance.

Conclusions

The traditional building materials, especially bush poles and thatch for roofing, and earthen construction for walls, are the main housing materials in tropical Africa and will maintain their position in the foreseeable future. This is partly because of their many inherent advantages, including ready availability and local familiarity with their use in construction, but also because neither the majority of citizens nor governments of the countries concerned can afford housing constructed with the more modern materials such as concrete blocks or corrugated iron roofing.

Some improvements to traditional housing can be implemented at once, such as the use of granular materials for foundations and capillary barriers under floors. In other cases, especially thatch for roofing, there are problems of durability to be overcome. With a practical research programme along the lines described in this paper, however, the full potential of these traditional materials for the African environment will be realised. If the research is followed up by measures to implement the findings at all levels down to the village level, tropical Africa can enjoy good standard housing with its African character retained.

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