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lateritic soils for rural housing

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Lateritic soils have been used for house building for a long time in Ghana, but, owing to poor selection, houses built from these soils are not durable. The urgency attached to rural housing by developing countries, particularly Ghana, and the lack of funds to provide houses of more durable materials demand rational selection and use of these soils. The author, who is Chief Technical Officer, Building and Road Research Institute, Council for Scientific and Industrial Research, Kumasi, Ghana, proposes a method of selection based on the grading and plasticity of the material, and suggests preventive measures against cracks and erosion which will enable economic and durable houses to be constructed from these soils. Due to differences in climatic conditions this method may not be useful in every other African country, but for some areas this technical paper is certainly a good working guide.

Ghana is one of those developing countries which are placing a great deal of emphasis on rural development. This development invariably entails provision of water supply, houses, roads and other amenities for people in the rural areas. As a large proportion of the land area of the developing countries, particularly Ghana, is rural, large sums of money will be needed in carrying out these development schemes. But this money is not readily available and the development schemes cannot be suspended any longer. So, in order to achieve maximum benefit with the funds that are available, it is necessary to utilise locally available materials. One such building and construction material which exists in abundance almost everywhere in Ghana is laterite soils. This paper deals with ways in which lateritic soils can be used for rural housing.

Definition

There are many definitions of laterite and lateritic materials. The geologist, the pedologist and the chemist have all defined laterite and lateritic materials differently. However, the definition arrived at by the Building and Road Research Institute, Kumasi, Ghana, will suffice for this paper. This definition is a result of several field studies of physical and structural appearance, as well as chemical analyses of laterites derived from different rocks under different conditions of weathering and laterisation. Laterite 'is a hardened or soft (reddish to brownish) product of tropical and sub-tropical weathering which is leached of bases, but enriched in sesquioxides of iron and alumina in the form of clay minerals, especially kaolinite and secondary iron minerals such as goethite, limonite and hematite. There is little or no combined silica in laterite, but depending on the parent rock laterite may have high quantities of quartz.'[1]

Classification and distribution

Like the definition, there are different methods of classification. These methods have been based on morphology and degree of weathering of the parent rock, chemical composition, climatic-vegetational conditions, topography and drainage conditions. All these methods have not been found adequate from laboratory and field experiences.

Nevertheless, experience gained both in the laboratory and in the field on the use of laterite soils enables these soils to be classified texturally into three main groups as shown in Fig. 1.[5]

These groups are:

(i) Laterite 'rock and boulders' (Particle sizes > 60 mm)
(ii) Lateritic gravelly soils and
(iii) Lateritic fine-grained soils (gravel fraction less than 10%)

Any of the three can be found in abundance in most places in Ghana. Sometimes, however, all three groups can be found on the same site and are useful for either road construction or for house-building. The fine-grained soils, however, are most suitable for building because of their plasticity.

Physical and engineering properties

The physical and engineering properties of lateritic soils are influenced by factors of soil formation such as parent rock, topography and drainage conditions as well as degree of weathering or laterisation. Pretreatment of soil before testing and laboratory test procedures also influence the properties.

Particle size distribution

The grading of different types of laterite varies within a very wide range as shown in Fig. 2.

Specific gravity

The specific gravity varies between 2·5 and 3·2. For the same gravel coarse fractions have higher specific gravities than the fines because of concentration of iron oxide in the coarse fraction.

Atterberg's limit

The liquid limits may vary from about 65 to non-plastic and the plasticity index between 40 and non-plastic. It is interesting to note that depending on the parent rock and the climatic conditions a lateritic soil may plot above or below the A-line, whereas halloysitic clays and micaceous soils plot below the A-line. (Fig. 3).

Moisture–density relation

The mode of compaction affects the value of the density when other factors such as grading are controlled. The range of maximum dry densities is (for

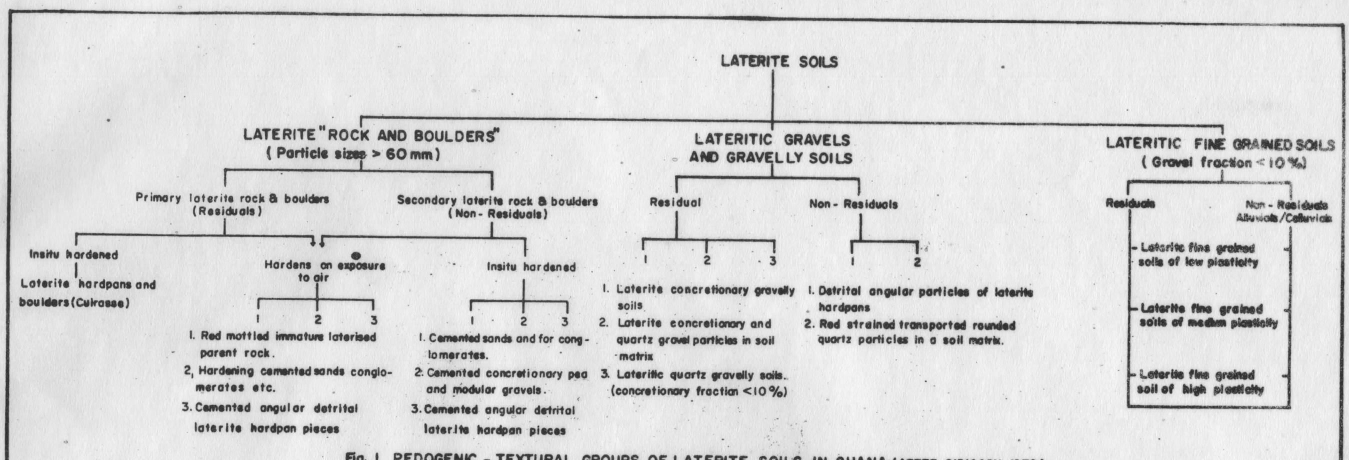

Fig. 1 PEDOGENIC - TEXTURAL GROUPS OF LATERITE SOILS IN GHANA (AFTER GIDIGASU 1970)

Figure 1

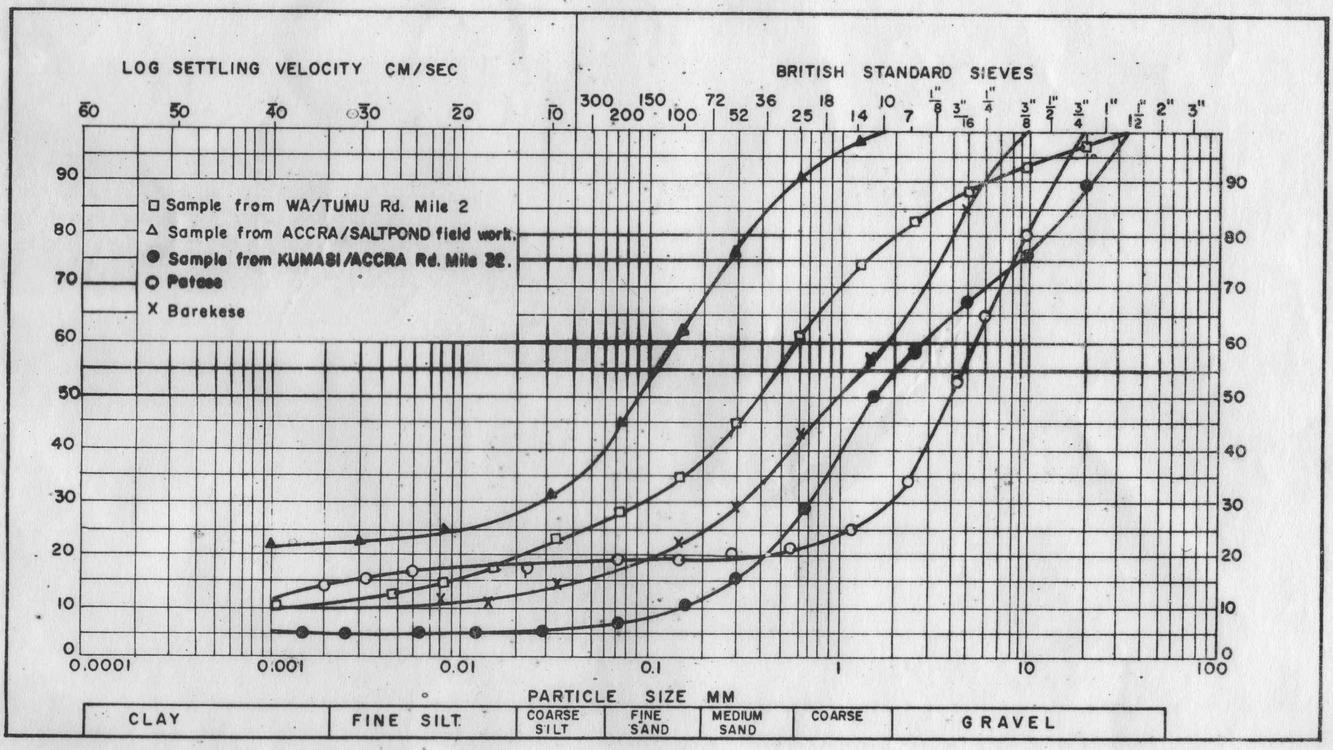

Figure 2 *Grading curves of some lateritic soils*

proctor compaction) between 92 lb/cu ft and 128 lb/cu ft for some lateritic soils. The corresponding optimum moistures range from 9% to 22% (Fig. 4). Bulk densities for laterite hardpans vary between 120 to 130 lb/cu ft.[6]

Water absorption

This property affects only the hardpans. The more homogeneous hardpans have low water absorption usually in the order of 5–10% and the porous ones which are less homogeneous have as high as 20% water absorption.

Compressive strength

Density and moisture have a marked influence on strength properties of fine-grained soils (Fig. 5) and hardpans. The effect of moisture on hardpans, however, is not as great as on fine-grained soils. For fine-grained soil cohesion varies between 0–7 lb/sq in and angle of internal friction between 19–38°. These values are the results from consolidated undrained tests. Compressive strengths for hardpans are between 1000–3000 lb/sq in.

Swell and shrinkage characteristics

These properties affect only the fine-grained soils. The swell for the lateritic fine-grained soils is of the order of 0·8% to 14%, whereas volumetric shrinkage varies between 10 and 50% at liquid limit moistures, and between 10 and 30% at plastic limit moistures.

Consolidation

Figure 7 shows a typical e/log P curve for a fine-grained lateritic soil. The modulus of compressibilities for these soils ranges from 1×10^{-3} to 1×10^{-2} sq ft/ton.[3]

Soil selection

The wide variations of the physical and engineering properties of laterite and lateritic soils demand a rational approach to the selection of these soils for building purposes. For building, sufficiently plastic material is needed for good bond, but not so plastic as to cause swell with ingress of water and shrinkage with drying. Certain criteria for selecting these soils for building are, therefore, necessary. It has been found from laboratory studies and field experience that any lateritic soil that falls within the grading envelope as shown in Fig. 6 is generally suitable for building. These soils are generally sandy clays and clayey loams. Invariably the ranges of values for liquid limit and plasticity index for these soils are 30–40% and 12–20% respectively. The volumetric shrinkage of these soils is not more than 20%.[7]

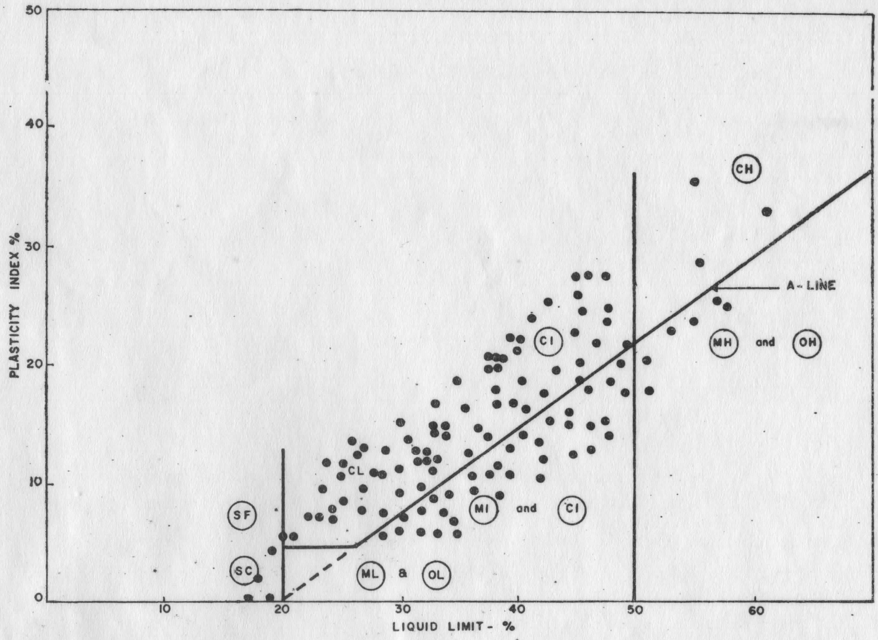

Figure 3 *Plasticity of lateritic soils on a Cassagrande classification chart*

Laterite as building material
Laterite soils are used for building in different forms. The commonest form is as swish, followed by sun-dried bricks, then as swishcrete, as burnt bricks and finally the use of the hardpans as building blocks.

Swish
Swish has been a main building material in Ghana for a long time. About ten years ago, 94% of all rural houses in Ghana were built with swish, 53% of all urban houses were built with swish and only about 8% of all houses in the whole country were built with cement blocks.[9] With good selection of material and improved construction procedures swish could be used for providing low-cost houses on a large scale in the rural areas.

The main defects of swish buildings however are cracks and erosion. Cracks are due to shrinkage of the soil, and shrinkage is also influenced by water. The workability of the soil paste is of great importance to the builder since mixing and placing are carried out manually. The higher the water content the more workable the soil and so the less applied energy on the part of the builder during mixing. Unfortunately, the higher the water content, the greater the degree of shrinkage and therefore the greater the chances of cracks occurring in the building. On a large scale housing scheme all the mixing will be done mechanically. Therefore only optimum moistures need to be added. The soil that would be used should fall within the grading limits in Fig. 6. Further shrinkage and cracks can be reduced by constructing the walls in small lifts of 18 to 24 in. On the other hand, when the building is dry further ingress of water will cause swelling, and so make it less stable. Consequently, precautionary measures against swell and erosion are necessary. The building should be kept dry during and after

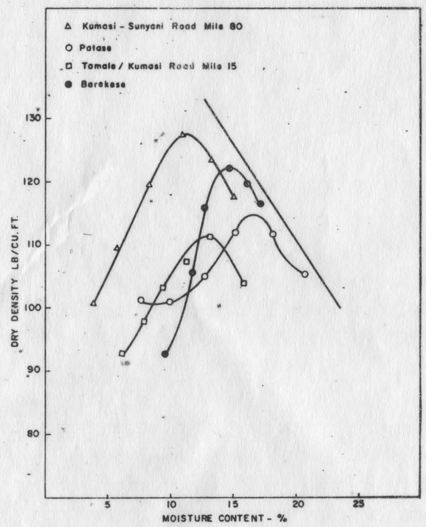

Figure 4 *Typical moisture density relation of lateritic soils (proctor compaction)*

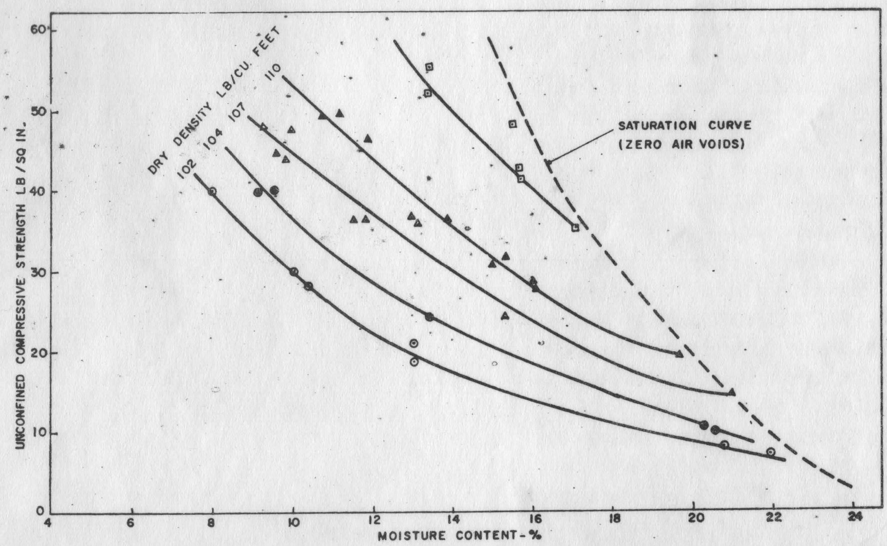

Figure 5 *Relationship between unconfined compressive strength of sandy clay and moisture content at different dry densities of the soil ('Soil Mechanics for Road Engineers 1968')*

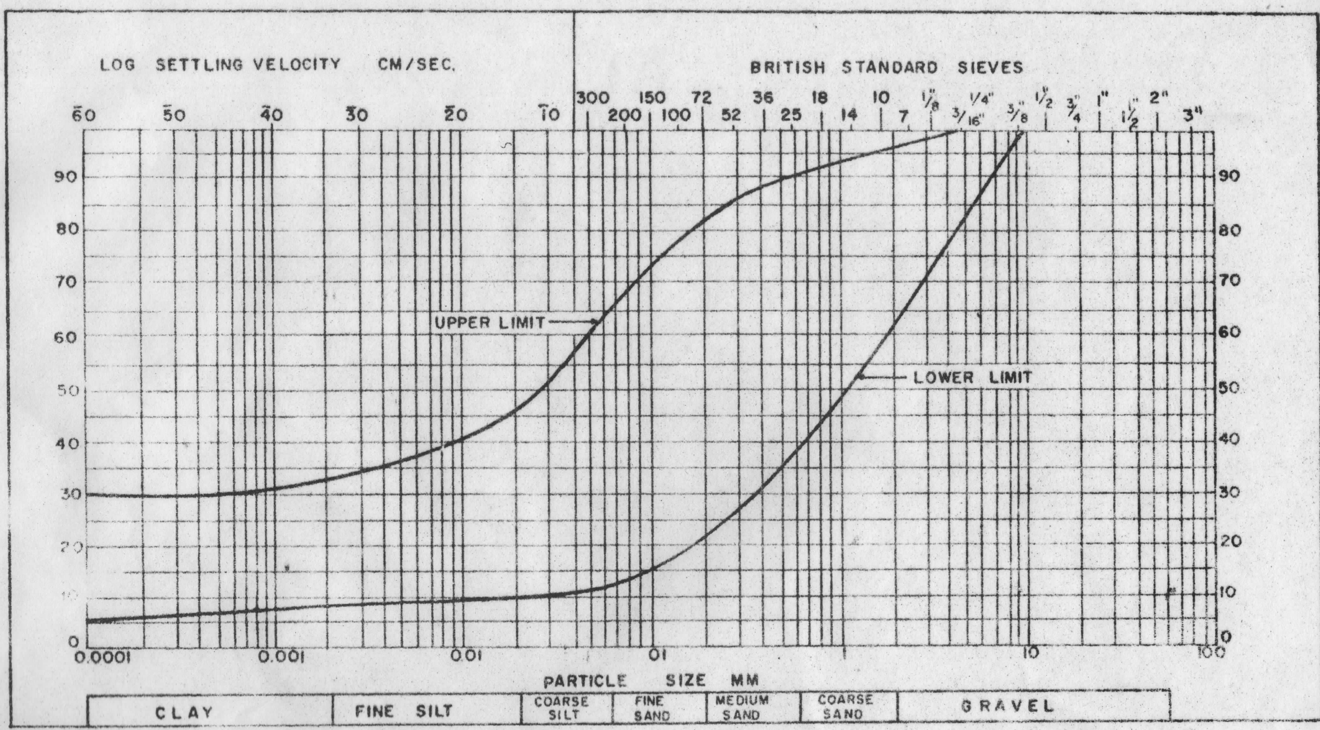

Figure 6 *Grading envelope for selecting lateritic soils for building*

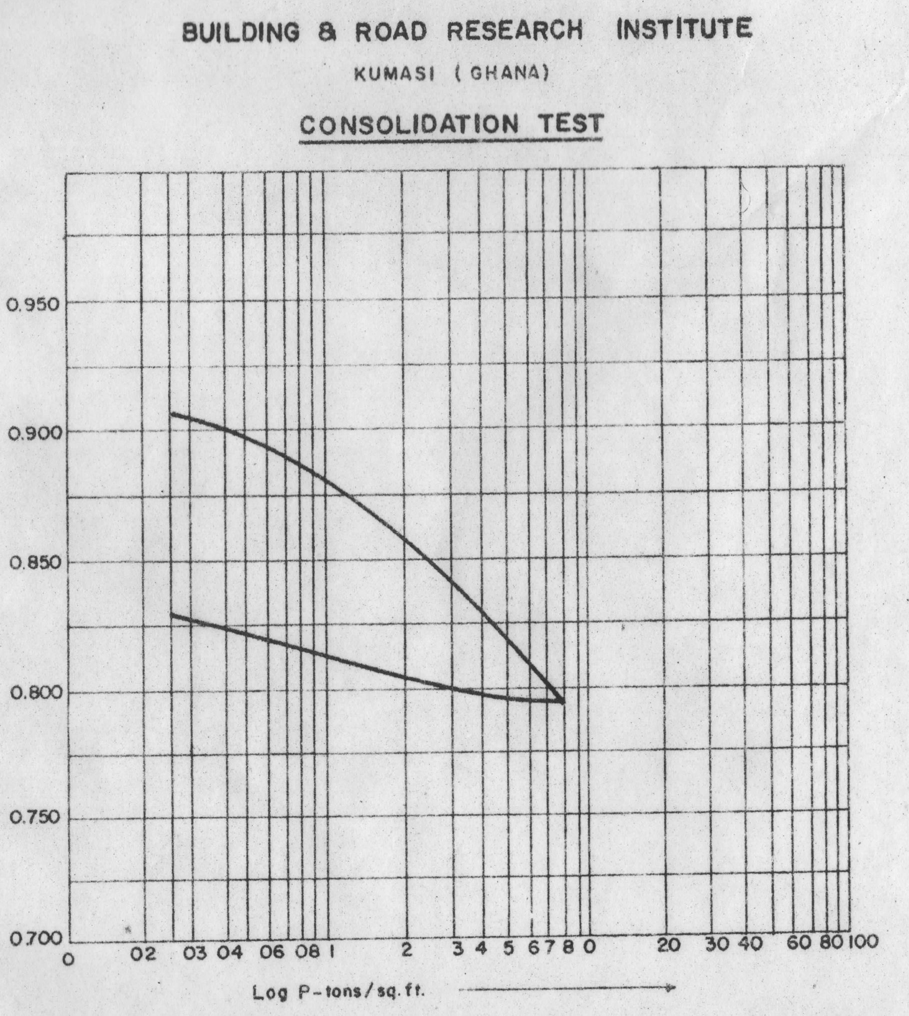

Figure 7 *A typical e/Log P curve of a lateritic clay*

construction. In addition, waterproof plastering, long eaves, gutters and platforms around the building are some of the measures to be taken. Preferably swish buildings should be constructed in areas with low rainfall.

Sun-dried bricks

Sun-dried bricks can also be made from lateritic soils. Like the swish, shrinkage cracks and warping are the main problems. The choice of soil to combine strength and reduction of cracks is very important. Just a sufficient amount of water, say 1 to 2% above optimum, should be added to the soil to make moulding easy. The soil paste is cast in moulds and dried in the sun for at least 14 days. The compressive strength of sun-dried bricks of these soils for 14 days varies from 90 lb to 150 lb/sq in. Sun-dried bricks have advantages over swish for building. The walls have a neat appearance as correct vertical and horizontal alignments can be achieved. Door and window frames can be fitted during construction. Mortar joints can give solid construction. Finishes are less tedious and less expensive and shrinkage cracks are reduced. On the other hand, brickwork is not popular because it demands skills which are largely lacking in the rural areas.[8]

Swishcrete

Swishcrete is formed by adding lime or cement to swish. Shrinkage is reduced and durability and strength are increased by stabilising these soils with lime or cement. Cement stabilisation however seems to be popular in Ghana and in many countries in Africa. The soil-cement can be used for making blocks or can be compacted loose between formwork. Generally soil-cement blocks are preferred to compacting the loose soil-cement material into formwork. For the grading of the soils shown in Fig. 6 as low as 5% of cement should give ample strength. After casting the blocks, they are allowed to set under a shade for 24 hours and cured by keeping them covered with damp sand, or damp sawdust or damp sacking for 7 days. They are ready to be used from 21 to 28 days. The minimum compressive strength should not be less than 200 lb/sq in when tested wet and 400 lb/sq in when tested dry.[4] On a large scale rural housing scheme where the cost of winning the soil is low and labour cost is also low (self-help) soil-cement block for construction needs very serious consideration.

Burnt bricks

Burnt bricks could be made from lateritic clays. This is the most durable of all the different forms of lateritic building material discussed so far. The strength is adequate for building, 1000–2000 lb/sq in. Clay bricks have low moisture movement (0·02%).[2] In areas where the deposits of lateritic soils are predominantly clays, burnt clay bricks for building should be encouraged if there is ample supply of wood for firing. Admittedly, this material for construction is expensive and time-consuming in manufacturing, but it is the best of all the forms of materials so far discussed. Better houses which are more durable can be provided and a brick industry may be established on a rural level.

Hardpans (Cuirasse)

Where this mantle of lateritic rock occurs at sufficient depth to be quarried, it will make a very good building material. It occurs, however, at various stages of weathering. At advanced stages of weathering this rock becomes friable and disintegrates into gravel. At the intermediate stages, it may be compact but porous with relatively low compressive strength. At the earliest stages of weathering, however, it is compact, has low water absorption properties and high strength. When it is in this stage, it makes a very durable building material. It is quarried and used directly as blocks for building. The use of this form of laterite is not widespread, because it is expensive to quarry. In areas where it occurs extensively, it could be used for rural and even urban housing schemes.

Summary and conclusions

(1) The urgency attached to rural development by developing countries coupled with their limited funds for these schemes demands maximum utilisation of locally available building materials. Laterite is one of such materials existing in abundance which could be used for building. But such are the variations within each physical and engineering property that it is necessary to approach the selection of these soils rationally.

(2) Sandy clays and clayey loams should be selected to fit into the grading envelope in Fig. 6. The range of Atterberg's limits should be: liquid limit 30–40% and plasticity 10–20%. The volumetric shrinkage should not be more than 20%.

(3) Laterite can be used in many forms for building—as swish, as sun-dried bricks, as swishcrete, as burnt bricks, and hardpans as blocks.

(4) The main defects of swish buildings are cracks due to shrinkage, and erosion. Precautionary measures such as water-proof plastering, provision of long eaves, gutters and platforms around the building should be taken to keep the swish building dry and stable.

(5) Compressive strength of swishcrete blocks should not be less than 200 lb/sq in for wet tests and 400 lb/sq in for dry tests. The hardpan blocks should not have strengths less than the swishcrete.

Acknowledgements
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