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Research Paper

A study on laterite stones as building material

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Abstract

In this study we have classified laterite stone based on its strength characteristics from 5 major quarries of the South Canara region in Karnataka, India. This study includes investigation of the laterite stone for construction purposes. The inherent properties of laterite such as texture, colour, structure and hardness were investigated. The engineering properties laterite building blocks freshly quarried from various depths of the quarry are studied. The mechanical and physical properties of laterite were found to be dependent on the inherent profile characteristics of the quarry. The properties of laterite varied significantly, depending upon the depth and location of the quarry. The methods of choosing a good laterite block suitable for construction is also discussed in this paper.

Keywords: Laterite; compressive test; unconfined compressive test; engineering properties.

1 Introduction

Amongst the numerous rock forms that ascend in the tropic and sub-tropical region, laterites are of distinct importance for building construction. Laterite brick stones are a vital component in all building construction, specifically in coastal regions, where it is found in abundance. Hence, an understanding of the origin, development and use of laterite rocks is essential for the field and laboratory people who work with them. The following is a brief evaluation of the laterite development process and a discussion about the properties which impact strength of laterites. All types of laterites are formed of materials which have undergone a complex chemical and physical weathering process. These are extremely weathered soils, which comprise of large, quantities of iron and aluminium oxides, as well as quartz and other minerals. They are found in large amount in the tropics and sub-tropics, where they are usually found just below the surface of extensive grasslands or forest clearings in areas with high precipitation. The colors can vary from yellowish-brown to red, brown, violet to black, depending mostly on the concentration of iron oxides. This weathering process is complex because it takes large number of years and during the process the major agents such as physiography, geology and climate affect the laterite growth. The difficulty is further compounded by the fact that laterites which are formed within a few feet of each other can have very altered properties; however, each of these laterites can be similar to other laterites located thousands of miles away. The resemblances and variances between all laterites are generally measured in terms of their chemical, mineralogical and physical properties. Majority of the laterites are categorized into one or more systems depending upon their properties.

Investigation based on physical properties and behaviors are of great interest to engineers, since laterites with similar physical characteristics can often be used in building construction of similar facilities even though the laterite may exhibit different chemical and mineralogical properties. Physical behavior of laterite is of prime importance to engineers because it reflects the strength characteristics of the laterite. [1] Researchers have studied the geotechnical features of some lateritic samples from the sedimentary region of the Lagos – Ibadan Highway. Samples of the foundation soil of an unstable section around Sagamu were studied with an intention to characterize them as highway sub-grade laterites and also tests were conducted to establish any geotechnical basis. Parameters such as grain size distribution, optimum moisture content, consistency limits, unconfined compression, Permeability and california bearing ratio were investigated [2]. The effects of rock flour on engineering properties of lateritic soil have been studied [2]. Various tests conducted so far include measurement of properties such as Atterberg limits, natural moisture contents, shrinkage limits, California bearing ratio, compaction, and unconfined compressive strength of the soil with rock flour contents varying from 2%, to 10% by weight of the dry soil. This paper gives the strength characteristics of laterite stones collected from the Mangalore region determined with various tests so that the properties found out may be beneficial for building construction.

2 Experimental Methodology

Field investigations were carried out at five major quarries of Mangalore region, which are recognized as large resources of Laterite in South Canara district. For this investigation, quarries selected are: IN-Innoli, KE-Kedembadi, MA-Malar, MU-Muloor and SA-Sambarthota. The Mangalore region lies in coastal region of Karnataka surrounded by Arabian Sea and western ghats and divided by many rivers. The Laterite profiles of Mangalore region are mostly situated in the mid-land regions consisting of rolling terrain of narrow valleys and hills. These quarries were selected based on the high volume of quarrying.

Field studies were carried out in the five laterite quarries by investigating the exposed vertical face. Distinct zones of textural and morphological variations were examined with the help of a geologist. Samples were taken in the form of standard size blocks as per IS: 1121 (Part I) – 1974 (Reaffirmed 2008) to determine the engineering properties. The bedding surface of specimen was noted during the time of collection. The physical hardness of the specimen was tested by scratch test and studied based on mineral composition specified by the Moh's scale of hardness. Samples were collected in the polythene bags to conduct field moisture content test. The samples selected represented the true average of the type or grade of the stone under consideration. Also the test samples were selected from the quarried stone or taken from the natural bed of rock. The selected laterite block specimens were sealed and their engineering properties were characterized in the laboratory.

Test pieces were made from samples selected in accordance as per IS: 1121 code. Table 1 gives test specimen dimensional data and they were dried in an oven at 105 ±5 °C for 24 h and cooled in desiccators to room temperature (20 to 30°C) to remove the moisture content.

Table 1: Test specimen data.

Sl. No.	Type of test	Specimen type	Specimen dimension in mm.
1	Cube compressive strength	Cubes	150 x 150 x 150
2	Cube compressive strength	Cylinders	45 dia x 90 length

For compressive test, specimen were made as per IS: 1121 (Part I) – 1974 (Reaffirmed 2008). The compressive strength of laterite or ultimate strength of laterite is defined as the load which causes failure of the specimen divided by the area of the cross section in Uniaxial compression, the load being applied without shock and increased continuously at a rate approximately 140 kg/cm2 per minute until the resistance of the test sample breaks down and no greater load is sustained. Care is taken in the preparation of the sample while loading to avoid large variation in the results of compression test. It is however, realized that in an actual structure, the laterite at any point is in a complex stress condition and not in uniaxial compression. However, it is customary to conduct the test in uniaxial compression only. The samples were 150mm cubes, made as per IS code of practice IS 456 – 2000. The advantage of selecting IS: 1121 (Part I) – 1974 is that this standard stipulates the procedure for the assessment of compressive strength of natural building stones used for construction purposes.

Unconfined compression test was conducted as per IS:9143 using Universal testing machine. For preparation of cylindrical specimen, the compaction was done using circular mould. The specimen was of dimension 40mm diameter and 76mm height. The purpose of the test is to obtain a quantitative value of compressive strength of laterite. We have measured this with the unconfined compression test, which is an unconsolidated un-drained test where the lateral confining pressure is zero (atmospheric pressure). The unconfined compression (UCC) test is one of the simplest and quickest tests used for determining the compression strength.

An inspection of 3 active quarries in within a diameter of 1 km in the Malar region revealed that the depth of laterite suitable for building construction within quarry varied from 2 to 9 m. The typical Malar quarry selected for the study had a total depth of 7.5 m. The three specimens1,2, and 3 were taken from 3 different levels, from a depth of 2, 6 and 7.5. Total depth of quarry is about 7.5 m below the ground level. The top portion (thickness of 0 to 0.6 m) consists of reddish brown gravelly soil with organic materials like living organisms (humus zone) and roots of vegetation. The Malar laterite quarry is dark red in color which is found useful for constructional purposes. Even though the texture of the laterite was uniform across depth, the results indicated a variation in hardness and other engineering properties. A typical observation is an increase in clay content and softening of material with increase in depth. Further, clay content increased across the depth of the profile i.e. 10%.15% 24% for the samples 1, 2, 3 respectively. The moisture content for the crushed laterite samples 1, 2, 3 was 1.78, 2.46, 14.56%, respectively. The pH range for the laterite is 6.5 for lateritic clay to 7.02 for lateritic gravel. The lateritic clay with higher moisture content also tends to be more acidic than the gravel. Based on the wet analysis, the clay contents present in the crushed soil increases with its increasing depth from 10% to 20%. A typical malar profile is shown in Figure 1.

Figure 1: Malar laterite profile.

3 Results and Discussion

The compressive strength and unconfined compression test result obtained for the Malar Quarry laterite specimens are tabulated below. Based on the values obtained from the various tests carried out on the laterite samples, high compressive strength and low water absorption is seen in samples located in the top portion of laterite profiles. Physical Hardness of all laterite samples is found to be in the range of 1–4 according to Moh's scale, and decreased with depth for all laterites. Table 2 gives the results of compressive strength on cubes obtained from Malar quarry; and Table 3 gives results of unconfined compressive strength obtained from Malar quarry.

Table 2: Test results of compressive strength on cubes obtained from Malar Quarry.

Sample No.	Depth from the top (m)	Hardness (Mohs scale)	Specific gravity	Compressive strength (N/mm^2)
1	2	3 to 4	2.7	4
2	6	2 to 3	2.48	2.58
3	7.5	2 to 3	2.62	2.34

Table 3: Results of unconfined compressive strength obtained from Malar quarry.

Load (N)	Deformation (mm)	Strain	Corrected area (mm2)	Compressive stress (N/mm2)
0	0	0	0	0
18.86	0.5	0.006	1393.46	0.014
584.69	1	0.011	1401.56	0.417
1131.65	1.5	0.017	1409.76	0.803
2112.41	2	0.029	1426.44	2.010
3583.55	3	0.034	1434.93	2.497
4838.71	3.5	0.040	1443.52	3.352
5149.00	4	0.046	1452.22	3.546
5771.41	4.5	0.052	1461.02	3.950
5281.03	5	0.057	1469.93	3.593

Similar tests were also conducted on the samples collected for the other quarry locations. The values are represented in the graphical form. It can be seen that the laterite samples in the top portion of profiles show high compressive strength and low water absorption. For all five quarry laterites, there was a decrease in the specific gravity and compressive strength, and an increase in the water absorption with increase in depth. This trend seems to suggest that the degree of hardness decreases with depth. It is also observed that at greater depths in the quarry the clay content is higher. Shown in Figures 2, 3 and 4 are variations of water absorption, compressive strength and specific gravity respectively with increasing depth of the laterite profile at various quarries. Figure 5 shows the stress-strain relation obtained for the Malar quarry.

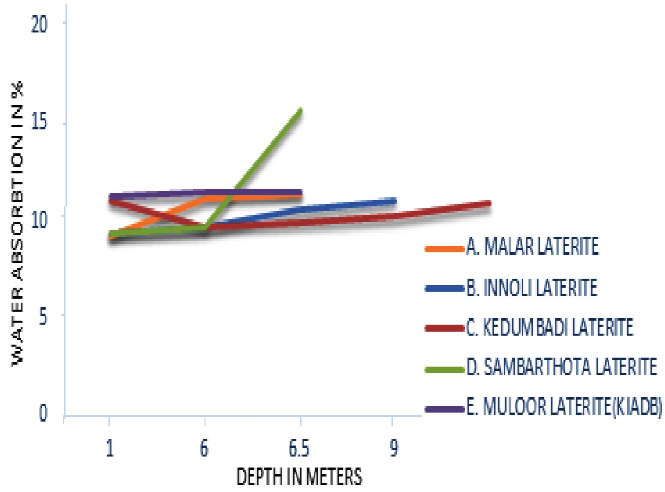

Figure 2: Variation of water absorption with depth.

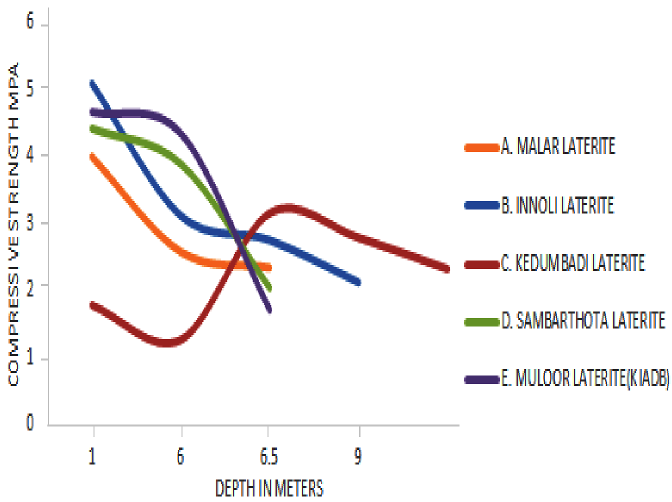

Figure 3: Variation of compressive strength with depth.

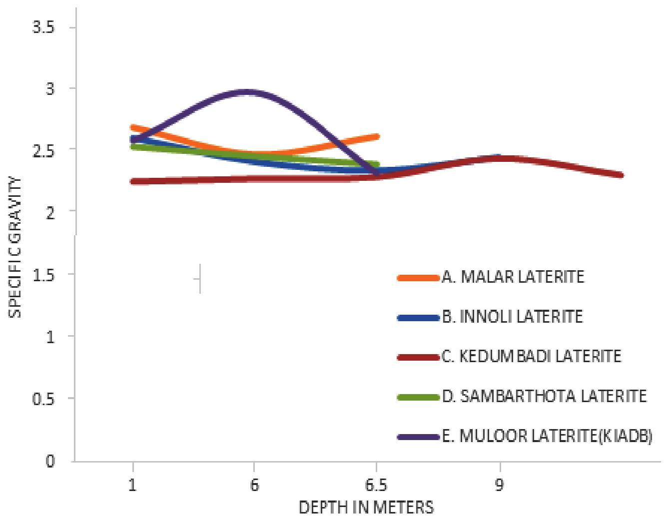

Figure 4: Variation of specific gravity with depth.

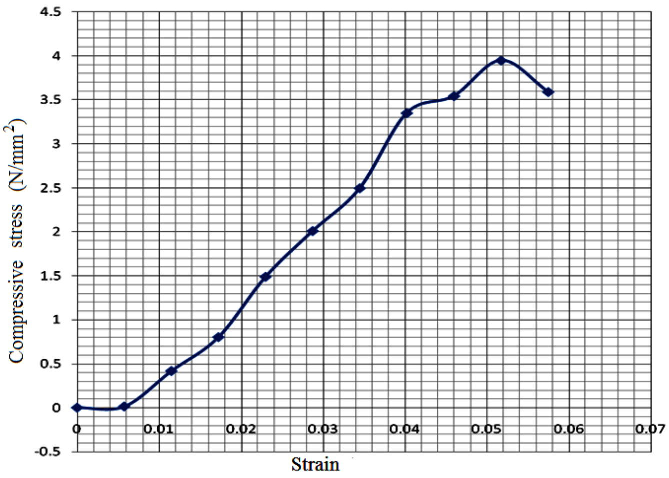

Figure 5: Stress-Stain obtained from UCC of Malar profile.

Table 4: Depth available for extraction of laterite stones.

Sl. No.	Quarry names	Depth (m)
1	Innoli	2 to 9
2	Kedembadi	2 to 8.5
3	Malar	0.5 to to 6.5
4	Muloor	1.5 to 9
5	Sambarthota	2 to 16

Shown in table 4 is a comparison of experimental values with the IS code; it can be seen that the depth available for extraction of building stone from various laterite quarrys.

4 Conclusion

From this study it can be concluded that laterite obtained in the South Canara region can be categorized as weak rock useful for low-rise buildings and partition walls. Also the properties of the laterite stone depend on the location of the quarry as well as the depth within a quarry. Based on the study following conclusion can be derived: (a) Good quality laterite for building purpose is located in the top portion of laterite profiles, (b) The general morphology distributions of strata were similar in almost all the 5 quarries, (c) As the depth increases the physical Hardness of all laterites decreased, and (d) With increase in depth, there was a decrease in the compressive strength and specific gravity, and an increase in the water absorption.

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