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Compressive Strength Development for Cement, Lime and Termite-hill Stabilised Lateritic Bricks

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ABSTRACT

This study evaluated the compressive strength of lateritic bricks stabilised with cement, lime and termite-hill, moulded with CINVA-Ram. The engineering characteristics and classification of the lateritic soil sample were determined, also the characteristic compressive strength of stabilised bricks as well as the unstabilised bricks were investigated after 7, 14 and 28 days of curing. The total number of bricks moulded was ninety and they were 290 mm x 140 mm x 90 mm in size. Each of the three stabilisers were added in varying proportions of 8%, 10% and 12% by weight of the lateritic soil for producing the bricks. Compressive strength test conducted after 28 days curing revealed that the cement stabilised bricks developed a rapid increase in strength than the lime stabilised and termite-hill stablised bricks. In all, the compressive strength increased with increasing proportion of the stabilisers. However, the unstabilised bricks developed strength which was more than the 10% termite-hill stabilised bricks after 28 days. It was deduced that cement stabilization is adequate where early strength is targeted on the field.

KEYWORDS: *cement, compressive strength, laterite bricks, lime, termite-hill*

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I. INTRODUCTION

As the population of the world continues to grow, so does the need for housing. The increase in trend of housing shortage for the urban and peri-urban poor in developing countries has motivated research into several technological solutions including increased varieties in the improvement and use of local soil. Soil stabilization is the process of mixing additives with soil to improve its volume stability, strength, permeability and durability [1, 2].

The imperatives of soil stabilisation in brick-making for low-cost building cannot be overemphasized. Good quality compressed and stablised earth blocks improve hygiene (that is, there will be less surface cracks for insects to lodg e in), reduce maintenance and repair costs and, in general, prolong the life span of a building [3].

Understanding the constituent requirement of stabilisers for local soil material is important in order to ascertain the strength and durability of lateritic soil bricks. The properties of cement, lime and bitumen stabilized lateritic soils and recommendations for field trials were summarized by [4]. Also, the basic guidelines for cement stabilization and a recommendation of 5 to 10% cement stabilization for manual pressing, in order to achieve a saturated and satisfactory compressive strength in the range of 1-3 N/mm^2, was suggested by [5].

It was revealed by [6] that bricks may be improved by paying attention to the mix composition and the mixing process, compression, stabilization and curing. In this, the properties of the material in relation to the particular application for which it is being designed become paramount.

It was observed that compacting soils using mechanical press improves their strength [7]. He observed that the higher the density achieved, the greater the compressive strength obtained.

The main objective of this study was to evaluate the compressive strength of lateritic bricks stabilised with cement, lime and Termite hill, moulded with CINVA-Ram.

II. MATERIALS AND METHODS

2.1 Materials and Preparation

The lateritic soil sample used for the study was collected from a borrow pit within the Federal University of Technology Akure, Nigeria. Cement and lime stabilisers used were Ordinary Portland and slaked lime [$Ca(OH)_2$], respectively and they were obtained from a retail shop in Akure. Termite-hill material used was obtained from the precinct of the University Sport Complex. Potable water was used while mixing the materials for producing the bricks.

2.2 Methods

2.2.1 Geotechnical Tests

Preliminary tests such as particle size distribution and Atterberg limit (Liquid limit and plastic limit) tests were conducted on the lateritic soil sample in order to classify the soil. The procedure adopted for these tests are in accordance with [8] which recommend terminologies and the Unified Soil Classification System (USCS) to describe and classify soils for engineering purposes.

2.2.2 Brick Preparation

Batching of brick materials were done by weight. This was derived by determining the quantity of the lateritic soil that would make a brick size 290 mm x 140 mm x 90 mm, through a control tests. The constituent materials were weighed according to the batching calculations. Materials were mixed thoroughly to achieve a homogeneous mixture using shovel and masonry trowel. Water was added carefully with the intermittent use of sprinkler in order to prevent water from flowing away from the mixture.

2.2.3 Brick Moulding and Curing

CINVA-Ram machine (Fig. 1) was used for moulding the lateritic soil bricks. The machine has been used extensively in developing countries for the production of bricks. After thorough mixing of the constituent materials, the mould box of the CINVA-Ram machine was greased with oil to allow easy removal of bricks. Mixed samples were fed into the mould box and covered. It was then compressed by a hand operated toggle level and piston system, which exerted a minimum compacting pressure of about 2 MN/m^2. After compression, the cover was removed while the mould box was jacked upward to remove the brick. Fig. 2 shows a produced brick. A total of ninety bricks were moulded, comprising of nine bricks produced for each proportion of the stabilisers used and also nine for the unstabilised bricks.

Figure 1: CINVA-ram machine used for the study

The moulded wet bricks were air dried for three days after which water was regularly sprinkled on them using a watering can, for a period of 28 days. This was necessary for the brick to attain its maximum strength.

Figure 2: Brick moulding with CINVA-ram machine

2.3 Testing

Prior to testing of the hardened bricks, their physical characteristics were observed. Bricks were inspected for physical cracks and colour change on the 7th day, 14th day and 28th day of curing period. Their weights were measured and compressive strength were determined after 7 days, 14 days and 28 days of curing using weighing balance and compression testing machine respectively. The average crushing strength of the bricks for each of the percent stabiliser content was determined.
Comparison was made between strength development in bricks with stabilisers and the unstabilised bricks.

III. RESULTS AND DISCUSSION

The results of the geotechnical tests on the lateritic soil, physical characteristics of the bricks, and the compressive strength of the bricks are presented in this section. Also, the results were discussed.

3.1 Particle Size Distribution and Atterberg Limits Test

It was deduced from the particle size distribution chart (Fig. 3) that 25 % of the soil passed through 75 µm sieve. According to the Unified Soil Classification System, the soil is of the sandy clay group.

The Atterberg limits test revealed a liquid limit and plasticity index values of 35.7 % and16, respectively. This shows that the lateritic soil is of intermediate plasticity, according to [9].

3.2 Physical Characteristics

The observed physical changes in the bricks are presented in the Table. Cement stabilised bricks showed a rapid colour change from reddish brown when they are fresh to whitish brown after three days of curing. This change in colour could be attributed to rapid hydration which was as a result of cement content reaction with moisture. Also, tiny cracks were observed on the bricks as they got dry. However, not much change was seen on the lime and termite-hill stabilised, and the unstabilised bricks until after seven days of curing. Colour changed from reddish brown to deep brown as drying continued. It was deduced that the rate of hydration was slow in the lime stabilised bricks, also no visible crack was seen. Meanwhile, Termite-hill stabilised and the unstabilised bricks showed no indication of hydration process during curing.

3.3 Water Absorption

The percent water absorption by the stabilised bricks after curing are presented in this section. These were obtained by comparing the weight of bricks before curing to their weights after 7, 14 and 28 days curing periods. Figures 4, 5 and 6 show the plots of water absorption versus curing days for bricks stabilised with 8%, 10% and 12% proportions of stabilisers respectively.

With 8% stabilisers, it was observed that cement stabilised bricks absorbed more water after 7 days curing than the lime and termite-hill stabilised bricks. Though, the three were in the range of 15 - 20% water absorption, but the high value obtained from cement stabilised samples could be attributed to higher hydration that occur in fresh cement mix. It was inferred from figure 4 that water absorption in lime and termite-hill stabilised bricks initially decreased after 14 days of curing. Meanwhile the cement stabilised bricks absorbed water uniformly after 14 days curing.

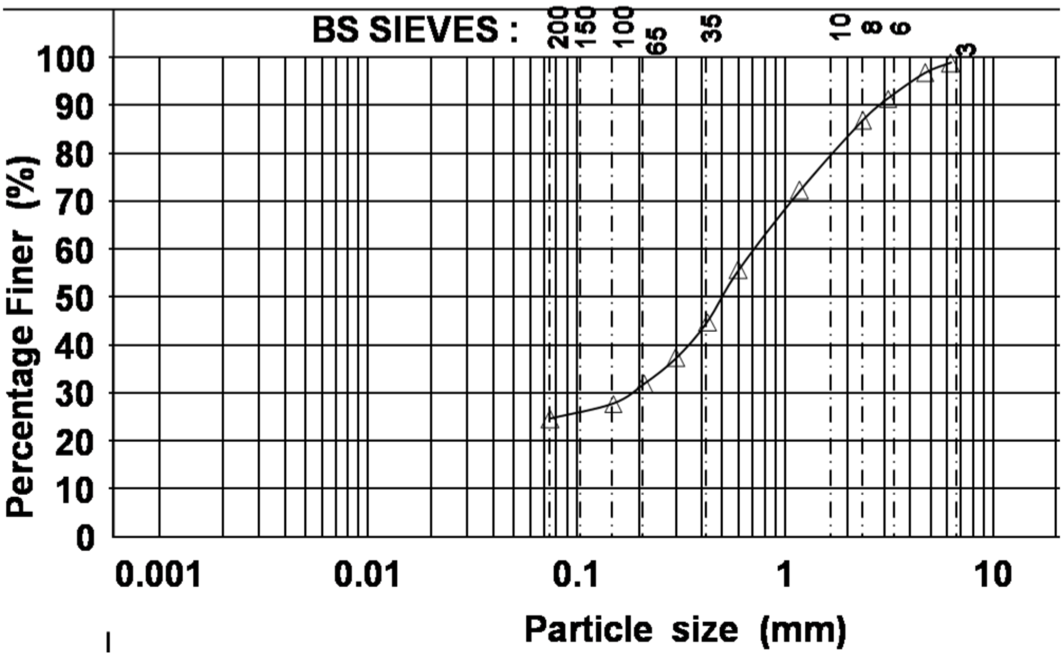

Figure 3: Particle size distribution for lateritic soil

Table: Physical Changes in Bricks Properties

Brick Type	Physical Changes		Remarks
	Colour	Crack Pattern	
Cement Stabilised	Changed rapidly from reddish brown to whitish brown after the 3rd day of curing	Tiny cracks observed	Rapid colour change indicates rapid hydration
Lime Stabilised	Changed from reddish brown to whitish brown after the 7th day of curing	No visible Cracks	Slow colour change indicates slow hydration
Termite-hill Stabilised	Changed from reddish brown to deep brown	No visible Cracks	No hydration
Unstabilised	Changed from reddish brown to deep brown	No visible Cracks	No hydration

With 10 % stabilisers (Fig. 5), it was seen that cement and lime stabilised bricks absorbed less water after 7 days but their water absorption was increased after 14 days curing, however the lime stabilised bricks possessed higher absorption rate. Termite-hill stabilised bricks experienced a reduction in water absorption from 7 days to 28 days curing. With 12 % stabilisers (Fig. 6), cement, lime and termite-hill stabilised bricks showed the same pattern of water absorption, it decreased from 7 days to 14 days and increased as the curing continued to 28 days. The water absorption appeared irregular, and this could be traced to the method of curing (by sprinkling water on the samples) adopted. This, however, was necessary because of the low rate of early strength development experienced.

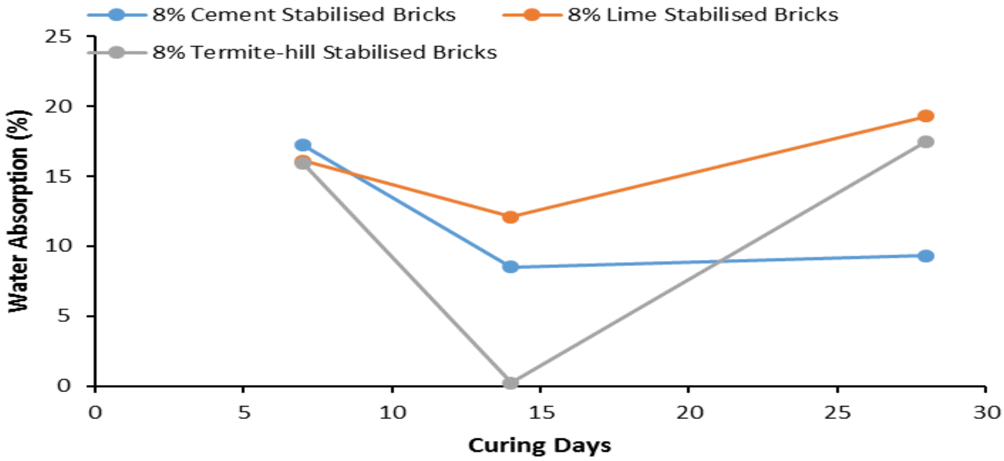

Figure 4: Variation of water absoption with curing days for 8% stabilised bricks

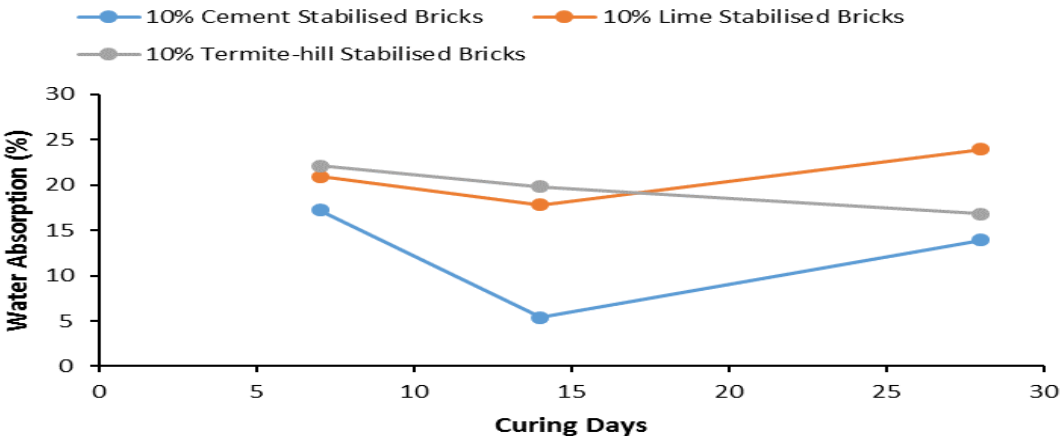

Figure 5: Variation of water absoption with curing days for 10 % stabilised bricks

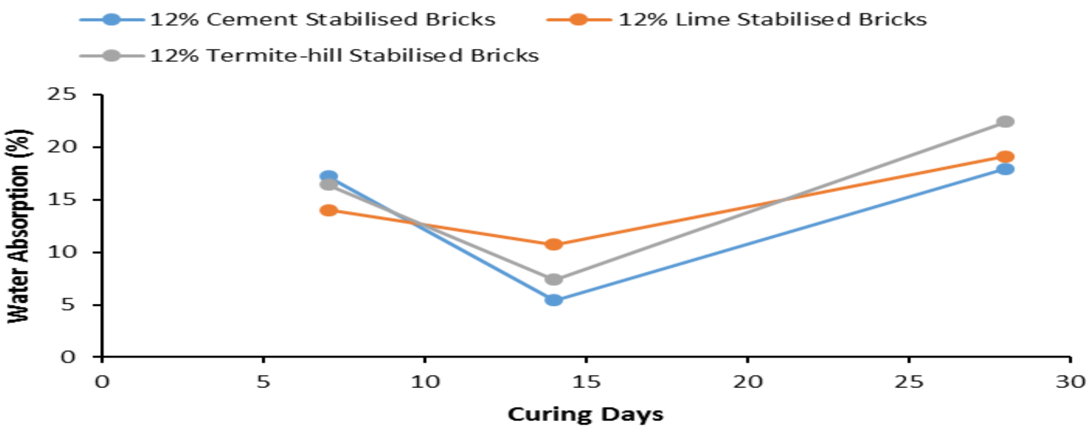

Figure 6: Variation of water absoption with curing days for 12 % stabilised bricks

3.4 Compressive Strength

The compressive strength obtained from bricks stabilised with different proportions of stabilisers after 7, 14 and 28 days from the day they were moulded are presented in Figures 7, 8 and 9, respectively.

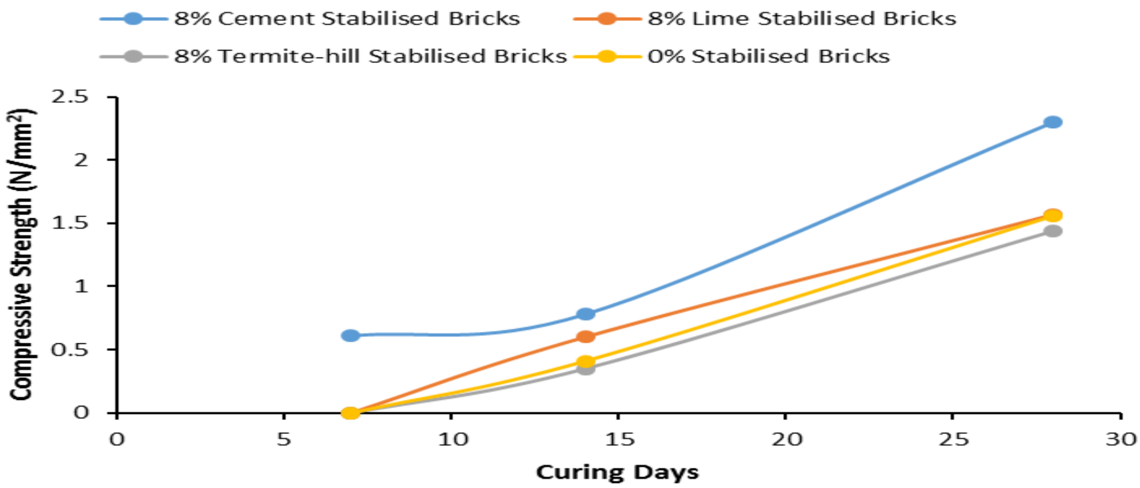

Figure 7: Variation of compressive strength with curing days for 8% stabilised bricks

With 8 % proportion of stabiliser, it was observed from Fig. 7 that only the cement stabilised bricks developed an appreciable increase in strength after 7 days with average strength value of 0.61 N/mm^2. It further increased to 0.78 and 2.3 N/mm^2 after 14 and 28 days respectively. The high rate of hydration reaction between cement and water influenced the hardening of the cement stabilised bricks, and this particularly enhanced the early strength gained in the bricks.

However, lime stabilised bricks developed no significant strength on the 7th day but had average compressive strength of 0.6 and 1.57 N/mm^2 after 14 and 28 days respectively. This effect could be attributed to the slow rate of hydration process in lime stabilised bricks.

Also, the termite-hill stabilised bricks only developed 0.35 and 1.44 N/mm^2 after 14 and 28 days respectively. Unstabilised bricks gained no significant strength at 7 days but developed 0.41 and 1.56 N/mm^2 after 14 and 28 days respectively.

It was deduced that cement stabilization would be adequate where early strength is targeted on the field.

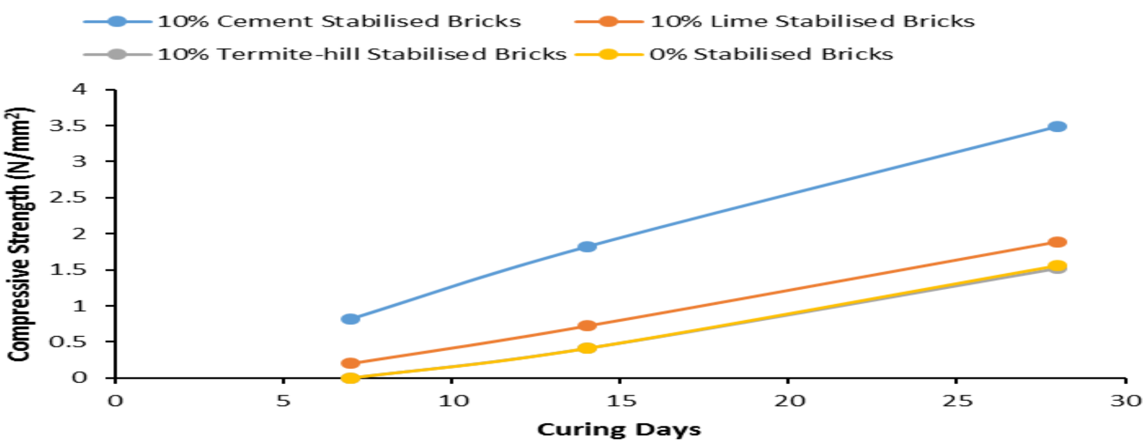

Figure 8: Variation of compressive strength with curing days for 10% stabilised bricks

With 10 % stabiliser (Fig. 8), cement stabilised bricks developed an average strength of 0.82, 1.82 and 3.49 N/mm^2 after 7, 14 and 28 days respectively. Lime stabilised bricks developed strength of 0.2, 0.72 and 1.89 N/mm^2, after 7, 14 and 28 days respectively. It was inferred that as the quantity of cement and lime in the bricks were increased, compressive strength slightly increased from the 7th day to the 28th day.

Whereas termite-hill stabilised bricks developed no strength at 7 days but its strength was 0.41 and 1.52 N/mm^2 after 14 and 28 days respectively. Similarly, the unstabilised bricks developed no strength at 7 days but its strength was 0.41 and 1.56 N/mm^2 after 14 and 28 days respectively. The influence of termite-hill in the lateritic bricks was not significant with 10 % proportion since the unstabilised bricks developed an appreciable strength than the termite-hill stabilised bricks. It was realized that compressive strength increased with increase in proportion of stabilisers in the stabilised bricks. However the unstabilised bricks developed strength which equaled the strength developed by 10% termite-hill stabilised bricks.

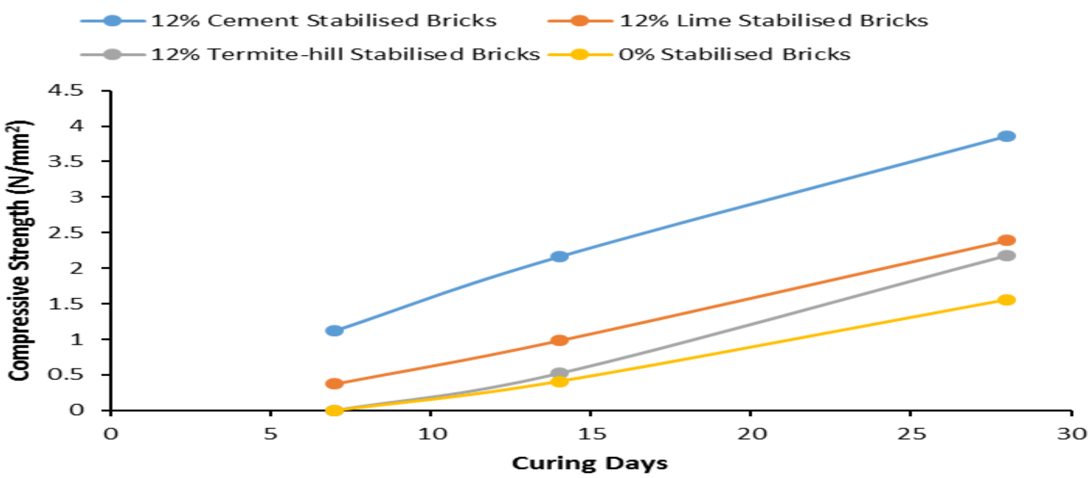

Figure 9: Variation of compressive strength with curing days for 12% stabilised bricks

Figure 9 showed the compressive strength plot against curing period for bricks stabilised with 12 % proportion of stabilisers. It was seen that cement stabilised bricks developed strength in the range of 1.12 – 3.86 N/mm^2 between 7 and 28 days. Lime stabilised bricks developed strength in the range of 0.37 – 2.39 N/mm^2 between 7 and 28 days. It was observed that compressive strength in the cement and lime stabilised bricks increased steadily, and this is attributed to higher rate of hydration caused as the cement and lime contents are increased in the bricks. On a general note, 28th day testing revealed that the cement stabilised bricks developed a rapid increase in strength than the lime stabilised and termite-hill stablised bricks.

Unlike lime and termite-hill, the mineralogy and granulometry of cement treated soil have little influence on the reaction since the cement powder contains in itself everything it needs to react and form cementitious products. Cement creates physical links between particles, increasing the soil strength; meanwhile lime needs silica and alumina from clay particles to develop pozzolanic reactions.

Meanwhile, both the termite-hill stabilised and the unstabilised bricks showed no strength gain after 7 days, but bricks with termite-hill developed 2.18 N/mm^2 which was higher than the 1.56 N/mm^2 developed by the unstabilised bricks. It was inferred that if higher proportion of termite-hill was used in lateritic bricks, it would influenced the compressive strength adequately.

IV. CONCLUSIONS

The study has brought to light the effects of cement, lime and termite-hill stabilization of lateritic bricks. The particle size distribution showed that the soil sample is 25 % finer than the 75 µm BS sieve size, and the Atterberg limit tests revealed a liquid limit and plasticity index of 35.7 % and 16 respectively. These test results corroborated the recommendation of [10] that the plasticity index and liquid limit of soil for stabilization should be less than 20 and 40, respectively, in order to ensure effective stabilization and proper mixing.

Water absorption pattern in the stabilised bricks was irregular; it decreased from 7 to 14 days, and increased till 28 days curing. This irregularity was traced to the method of curing (by sprinkling water on the samples) adopted. This, however, was necessary because of the low rate of early strength development experienced.

Compression tests revealed that using cement as a stabiliser significantly increased the brick compressive strength. It was inferred that Cement stabilization is ideally suited for well graded aggregates with a sufficient amount of fines to effectively fill the available voids. Compressive strength value of 0.61 N/mm^2 was obtained from 8% cement stabilized bricks after the 7 days curing which indicated an appreciable strength development when early strength is considered.

However, Lime and termite-hill proportions also increased the strength of bricks but slightly. The compressive strength of the stabilised bricks increased with increasing proportion of stabilisers and also increased with age.

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