

Effect of Lateritic Soils as an Aggregate Substitute on the Strength of Compressed Concrete Bricks

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Abstract

Construction materials used for the interlocking load bearing blocks are cement, sand and crushed granite. With the increase in these material costs in the construction industry, there is a need to find more cost saving alternatives so as to maintain the cost of constructing houses at prices affordable to clients through using local materials. Local materials that show potential to be used as a replacement aggregate is lateritic soil. The substitution of aggregate in the compressed concrete blocks mix with lateritic soil in respect to workability and block strength has been studied. A number of mix proportions were tested and the compressive strength of the cube blocks on the 7th day and 28th day showed that lateritic soils at 25% - 50% , by weight, replacing crushed granite satisfy the required strength to be used for construction of buildings. Using the formulated mixture, interlocking load bearing block is made using the CCA press, the resultant block is tested and the compressive strength is within the required specification for house construction. The design constraints and construction of a pilot house using this lateritic load bearing interlocking block is presented.

Keywords

Lateritic soil, Compressive strength, load bearing interlocking block, mortar-less building system, IBS.

1. Introduction

Construction industry is an important sector that contributes to the Malaysian economy. The most widely used material in construction is concrete. Concrete is made by mixing cementitious materials, water and aggregates. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the proportions of mix, the method of compaction and other controls during placing, compaction and curing.

A major factor affecting the construction industry in developing countries is the cost of building materials. As prices of building materials increase sharply, there is a growing awareness to relate research to local materials as alternatives. The local materials that showed potential to be used as a replacement aggregates are latex, crushed granite, lateritic soil and glass.

Lateritic soil has been one of the major building materials in Malaysia because it is readily available and the cost of procuring it is very low. Lateritic soil has other advantages which make it potentially a very

good and appropriate material for construction, especially for the construction in the rural areas. The production of laterised concrete block can be done at site and laterised interlocking concrete block is used in the construction of structures since it has sufficient strength compared with that of normal concrete.

In this study, the focus will be on using lateritic soil to substitute a certain percentage of the aggregate in the concrete mixture. Specifically, this study looks into the effect of replacement of lateritic soils for granite fines on the compressive strengths of laterised concrete. Granite fines are crushed granite in fine particle forms.

2. Lateritic Soil Properties

Lateritic soil is a material that has been used in the building construction industry for a very long time, especially in the rural areas, but there is lack of adequate data to fully understand the behaviour of this abundant material. There is need to improve the indigenous technology on the practical usefulness of lateritic soils in building and allied industries. A lot of research activities are now being carried out on lateritic soils. Adepegba (1) compared the strength properties of normal concrete with those of laterised concrete and concluded that laterite fines can be used instead of sand in normal concrete for structural material. He also concluded that when sand is mixed with laterite fines, the most suitable mix for structural applications is 1:1.5:3. (cement:sand plus lateritic fines:gravel) with a water/cement ratio of 0.65, provided that the laterite content is kept below 50 per cent. Felix F. Udoeyo et al(2) established from their study that the finer the grain size of lateritic soils, the higher the compressive strength of the unstabilized cubes made from such soils. They also reported that the compressive strength of lateritic soils is dependent on the source from which they were collected which was also supported by Nasly et al (3).

Studies have also been carried out on how the performance characteristic of the lateritic soil can be improved. Stabilized and unstabilized lateritic soils have been reinforced with different reinforcements (e.g. rope, grass, sawdust, kenaf, etc.) and results have generally shown that performance characteristics of lateritic soils can greatly be improved using such reinforcements.

Before using lateritic soil for the engineering purposes, the investigation of the physical characteristics of the soil needs to be done. The characterisation of the soils such as density, bulk density, strength and its composition is important.

2.1 Laterite Soil Particles Characteristic

In laterization process, the changes of physical-chemical in the genesis rock in the form of laterite to the materials rich with chemical constituent such as clay soil (kaolin) and other minerals (Fe, Al, Ti, Mn) whereas the ratio of the composition is 1:1. laterite soils included in pisoliths type. Lateritic soils have characteristics reddish shades which appear to be due to the various degrees of iron, titanium and manganese hydration. The shades also reflect the degree of maturity.

The geotechnical characteristics and field performance of lateritic soils can be interpreted in the light of all or some of the following parameters (4):

- i) Genesis and pedogenic factors
- ii) Degree of weathering
- iii) Clay mineralogy
- iv) Clay size content

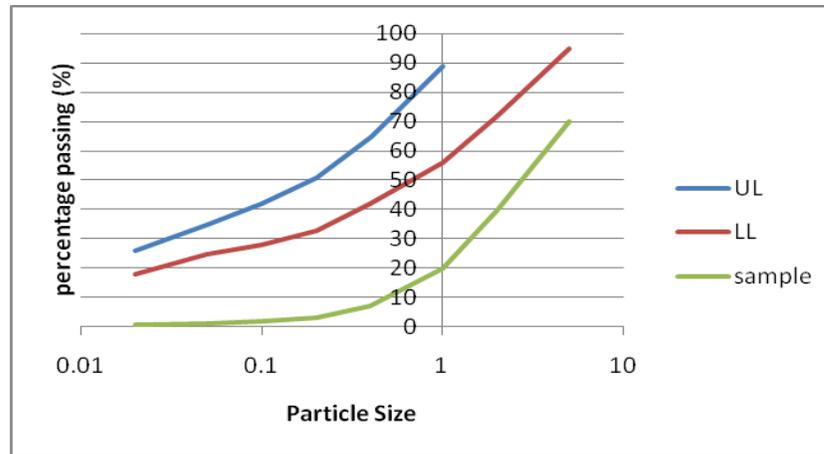
2.2 Specific Gravity and the Density

Lateritic soil particles (pisoliths) are generally porous. Van Ganse (5) has found that the apparent density of pisoliths varies with the sizes of the particles. For example, pisoliths of between 20 and 40 mm in size

with a thin cover of wax gave an apparent specific gravity of about 2 while it was about 2.5 for smaller particles. The density of lateritic soils also depends on the content of ferum oxide which the mineral has high density.

2.3 Soil Sample Source

The lateritic soils used for this investigation were collected from a site near the Universiti Teknologi Malaysia's Observatory Tower which is located about 5 km away from the Department of Structures and Materials Laboratory. The lateritic soil is first crushed and then sieved using the sieve size 6mm. From this sample a sieve analysis of particle distribution is carried out as shown in Figure 1.



Note : UL Upper Limit, LL Lower Limit

Figure 1 : Particle size distribution

3. Experimental Work

3.1 Production of Cube Sample

A total of 60 cubes of sample will be used as test material and the size of cubes used is 100 x 100 x 100 mm. Five different mix proportions used in this study (1:2:3:1, 1:2:3:2, 1:2:3:3, 1:2:4:1 and 1:2:4:2) and the ratio represent cement: sand: crushed granite: lateritic soil. The maximum volume of water used is 10% from the total of each mix proportion. 12 samples were prepared for each mix proportion. Table 1 shows the content of materials at each proportion.

Table 1 : Content of Materials at Different Mix Proportions

Mix Proportion	Cement (kg)	Sand (kg)	Crushed granite (kg)	Laterite Soil (kg)	water (ml)
1 : 2 : 4 : 1	1.575	3.15	6.3	1.575	1000
1 : 2 : 4 : 2	1.4	2.8	5.6	2.8	1000
1 : 2 : 3 : 1	1.8	3.6	5.4	1.8	1000
1 : 2 : 3 : 2	1.575	3.15	4.725	3.15	1000
1 : 2 : 3 : 3	1.4	2.8	4.2	4.2	1000

For each mix proportion, cube samples for three different densities i.e. 2.0kg, 2.1kg and 2.2kg is used and the sample is air cured for 7 and 28 days at room temperature.

The mixture sample is weighed for 2.0kg, 2.1kg and 2.2kg and it is poured into a special mould and is hydraulically compressed to the size required. The cube is then extracted by forcing it out of the mould in the opposite direction. The procedure is repeated for all the samples needed for the study.



Figure 2: Cube Sample extracted from mould

3.2 Compression Cube Test

Compressive strength cube test is the most important test for hardened concrete and is considered in the design of most concrete mixes. The test is carried out to get the value of the compressive strength of cube samples produced. The tests were done using the Tonipact Machine with load rate of 0.3kN/second. Before the test run, the cube after 7 or 28 days air-curing is weighed to get the mass of the cubes after curing.



Figure 3: Tonipact machine for compression test of cube - The cube failure

4. Results and Discussion of Compressive Strength Test

Figure 4 shows the compaction force required for different densities of different mix ratios to produce the cubes. The compaction force was measured using load cells located at the top mould plate. The 2 kg cube have an almost no effect on the compaction force. The higher density cubes gave a significant resistance to the compaction during production.

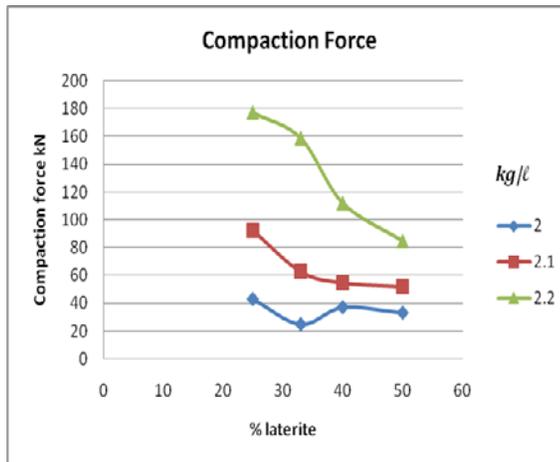


Figure 4 : Compaction force vs laterite % (weight) as aggregate

Figure 5(a) and (b) shows the result of compressive strength and of the cube samples for 7 and 28 days air-cured cube samples respectively. The results show that there is a slight increase in strength with respect to time of curing but there is significant compressive strength increase with denser cubes.

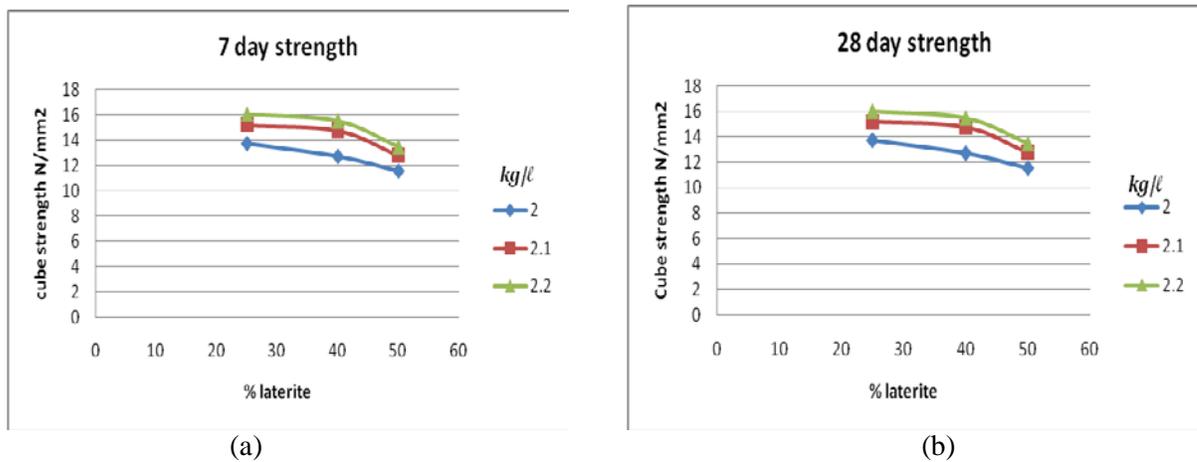


Figure 5 : 7th and 28th day Cube strength versus laterite % as aggregate

Finally Figure 6 shows the relationship between compaction force during production and the result cube strength at 28 days. The cubes were air dried and not much difference in the strengths of the cubes at age 7 days to 28 days.

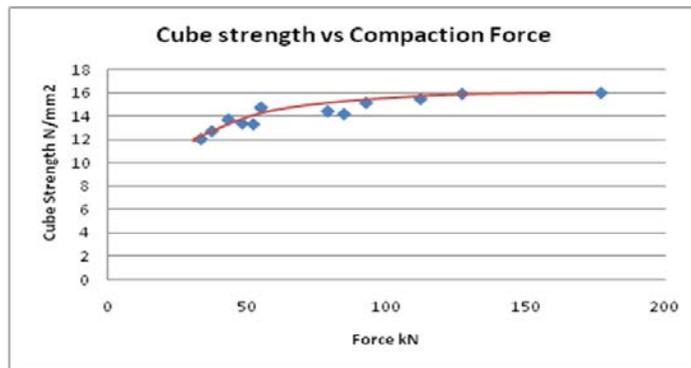


Figure 6 : Cube strength (28th day) vs Compaction Force

From the entire graphs shown, we observed that the higher the quantity of lateritic soil in the concrete mix, the lower was the cube compressive strength. Another observation is that the higher the content of lateritic soil in the mixture the easier it was to compact the mix during production.

5. Interlocking block technique

5.1 Production of Interlocking Blocks

Interlocking blocks are produced in special moulds, in which compaction is done mechanically, depending on the type of block, material used, required quality and available resources. The blocks can be made directly at the building site, or on a larger scale in a production yard.

Concrete blocks are the common manufactured interlocking load bearing blocks that require high compaction force. After opening the lid and ejecting the block, it was removed and flipped before stacking them in a shaded place for curing and hardening. Moist and shaded environment is to ensure uniform curing and hardening of the blocks.

A typical compressive strength of hollow concrete blocks are 7N/mm^2 while the typical compressive strength of laterised concrete blocks could be less. Hence when constructing a house using the load bearing interlocking block technique, care must be taken to use the concrete blocks in critical areas such as the ring beams and columns.



Figure 7 : Hydraulic powered block press

5.2 Block Types

The block's sizes are modular and rectangular (100 mm high, 125mm to 150 mm wide and 300 mm long) in shape. Its dimensions permit multi-dimensional walls making configuration such as buttresses, lintels or columns possible. Corner or junction block is required to maintain right angled corner or a proper T junction.

The interlocking blocks are different from conventional bricks since they do not require mortar to be laid during bricklaying work. Because of this characteristic, the process of building walls is faster and requires less skilled labour as the blocks are laid dry and lock into place.

Concrete blocks may be produced with hollow centres to reduce weight, avoid seepages or improve insulation. The holes inside the concrete block allow rebar and concreting (creating reinforced concrete) to run vertically through the block to compensate for the lack of tensile strength. Rebar used can be of mild steel instead of the usual higher grade steel. Once a section of wall is built, grout holes are filled with a lean cement mixture to seal the wall and making a permanent solid wall. The amount of grout used was calculated to be less than 7.5% of the mortar used in conventional masonry.

5.3 House Construction using Load Bearing Interlocking Block System

Initially the foundation, ground beam and ground slab is laid with the appropriate vertical steel implanted as shown in Figure 8a. It takes normally a week for the foundation to set then the first layer of interlocking load bearing blocks is arranged to ensure that the wall is straight and right angle at corner as shown in Figure 8b.

After that the crew of six workers can independently stack up the blocks to the required height. Horizontal bars are placed for the construction of ring beam around the house for added stiffness.



(a) Foundation slab



(b) First layer of blocks

Figure 8 Typical construction site of an interlocking load bearing concrete block house



Figure 9 House using interlocking blocks from concrete and laterised concrete

Similar process of arranging the blocks was done up to the roof beam where another two layers of channel blocks were used to simulate the roof ring beam. This process takes two weeks to complete, then the roofing, plumbing, electrical, sanitary and finishing will take another two to three weeks.

The construction time taken to complete a typical bungalow is 40 days. As the workers gained more experience building more houses, the construction time can be reduced further with permitting weather.

6. Conclusion

The following conclusions can be derived from the tests carried out:

- The compressive strength of laterite concrete increases with the increases of age of maturity.
- The compressive strength of laterite concrete decreases with the increases of laterite content in the mixture.
- The compaction force applied to compress the mixture into the cube sample decreases when the lateritic soil content increases.
- From the results of the tests on the value of cube compressive strength, all values show that lateritic soil can be used as an aggregate substitute. All samples have compressive strengths more than the required concrete block strength of 7N/mm^2 as specified by the Malaysian Standards.
- The interlocking load bearing block using lateritic soil as a partial replacement to crushed granite satisfies the required specification for the construction of single storey houses.

7. References

1. D. Adepegba, A comparative study of normal concrete which contains laterite fines instead of sand. *Building Science* **10** (1975), pp. 135–141
2. Felix F. Udoeyo, Udeme H. Iron, Obasi O. Odim. *Strength Performance of Laterised Concrete*. Department of Civil Engineering, Faculty of Engineering, University of Uyo, Nigeria. *Journal of Construction and Buildings Materials*, 2005
3. Nasly M.A. , A.A.M. Yassin et al, (2010) Compressed Stabilised Earth as Load Bearing Interlocking Block, *International Journal of Civil Engineering & Geo-Environmental* , ISSN 21802742, vol 1, Issue 1.
4. K. S. Bawa. *Laterite Soils and Their Engineering Characteristics*. Proceedings of the American Society of Civil Engineers. 1957
5. M.D. Gidigasu. *Laterite Soil Engineering: Pedogenesis and Engineering Principles*. Amsterdam, New York. Elsevier Scientific Publishing Company, 1976

Acknowledgements

The authors acknowledge the Malaysia Technology Development Corporation (MTDC) for grant provided that has resulted in this article. The authors also wish to acknowledge cooperation given by the CCA Systems Sdn Bhd for sharing the research works and the contractor Teras Maju Dinamik for actual construction using the blocks.