Identification of Soil Property Impacts on Manufacturing of High Strength Soil Bricks in Selected Areas of Hambanthota and Ratnapura Districts

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Abstract

Soil Cement Bricks (SCB) are cost effective, energy efficient and environmental friendly alternative building material which address the problems related to fired clay bricks such as costly masonry, high energy usage and other environmental problems. Characteristics of soil have a great influence on the strength and performance of SCB. This paper presents an experimental study carried out on the influence of soil properties on the characteristics of SCB. Eight soil samples, collected from the soil excavation sites located at Hambanthota and Ratnapura districts were used to produce bricks with 10% of ordinary portland cement and a 1.8:1 volume compaction ratio through a locally fabricated pressing machine. Dry and wet compressive strengths and water absorption of the bricks were analyzed with physical properties of the soils. In this study, it was depicted that well graded soils with high coefficient of uniformity and plasticity index lower than 15% are suitable for manufacturing high strength, durable and quality SCB.

Keywords: Cement, Compaction ratio, Compressive strength, Cost effective, Soil Cement Bricks, Soil characteristics

1 Introduction

Fired or sun-dried clay bricks are the conventional building materials used for housing in Sri Lanka. However, clay which is the main component of burnt clay bricks is not abundant throughout the country. As a result, fired clay brick industry has been constricted to a few regions in the country. Moreover, the conventional process consumes a lot of energy for the burning of green (raw) bricks in order to get the required strength and durability, generally with firewood. This may reduce the biomass cover of the country and increase the air pollution. Therefore, the development of alternative building materials is of great significance to address these issues [1]. One such building material is the earth and this can be utilized for housing in many ways [1-5]. However, there are certain drawbacks such as loss of strength when saturated with water, erosion due to wind and rain, and low dimensional stability. They can be overcome by stabilizing the earth with a chemical binding agent such as cement [1,5]. Cement stabilized soil can be compacted via manually or hydraulically operated machines into individual high density blocks which are termed as Soil Cement Bricks (SCB) [6]. They are cost effective, energy efficient and environmental friendly alternative materials to the conventional burnt clay bricks, and they are used for load bearing masonry structures [6–8].

The typical soil type used for SCB is the lateritic soil which mostly occurs in the humid tropical and subtropical zones of the world. These lateritic soils are enriched of iron and aluminium in high concentrations [9]. Laterites have several significant geotechnical properties such as high compressibility, low permeability and high stabilization resulting extensive usage of lateritic soils for producing SCB [9]. However, the characteristics of SCB are mainly influenced by parameters such as soil characteristics, cement content, and densification of the mixture [10]. Being a tropical country, Sri Lanka is abundant with lateritic soils, particlulary in the southwestern and northern parts of the country [11]. In this regards, SCB can be widely utilized for housing projects in Sri Lanka.

According to [10], soil properties is one of the parameters which control the characteristics of SCB. Identifying desirable properties of soils to acquire high strength and durability in SCB, will be useful when manufacturing SCB. Moreover, cement content and densification factor affect the characteristics of SCB and numerous research have been carried out to analyze this effect. According to [12], optimum cement content and volume compaction ratio to produce high strength SCB at low cost were 10% and 1.8:1 respectively. Since they have derived the optimum cement content and volume compaction ratio to obtain high strength SCB, the effect of soil properties on the performance of SCB were invesigated. In this study, it was decided to concentrate on various soil types in Hambanthota and Ratnapura districts since a building material for low cost housing will be more beneficial to people in these areas, due to their high poverty level (1.2% in 2016) and population density (599,903 in 2012). In conclusion, this paper focuses on the study of the influence of soil properties on the strength and durability of SCB through an experimental investigation.

2 Methodology

The following methodology was adapted to achieve the objectives of the research.

2.1 Sample Collection

A total of eight soil excavation sites were selected for sampling, as six in Hambanthota district and two in Ratnapura district. Sampling locations are situated in Weeraketiya, Walasmulla, Thangalla, Hambanthota and Embilipitiya areas as illustrated in Figure 1. About 50 kg of soil was collected from each excavation site.

2.2 Assessment of Physical Properties of Soil

Samples were first air dried and prepared for testing. 1000 g and 300 g of each sample were subjected respectively for sieve analysis test and atterberg test according to the British Standards (BS).

Figure 1: Sampling Locations.

2.3 Brick Preparation

After sieving by the 2.36 mm aperture mesh, each sample was mixed with 10% cement content. Dry soil-cement mixture was thoroughly mixed while spraying water to achieve the necessary green strength. The mixture was compacted via a locally fabricated machine to a volume compaction ratio of 1.8:1, i.e filling the mould with soil up to 180 mm and compacted to 100 mm. A total of 48 bricks, six from each sample were prepared and kept for curing for 14 days.

2.4 Determination of Dry and Wet Compressive Strengths

Out of six bricks of each sample, Three bricks were tested for dry compressive strength by using the compression testing machine. Other three bricks were soaked in water for 24 hours and tested for wet compressive strength.

2.5 Determination of Water Absorption

Dry and wet weights of the bricks of each sample were measured.

3 Results

Table 1: Summary of Sieve Analysis Test Results.

Location	% larger than No.4 sieve size	% in between No.4 and No.200 sieve sizes	% smaller than No.200 sieve size
1	2.80	94.40	2.80
2	4.70	92.90	2.40
3	4.35	94.70	0.95
4	6.85	92.65	0.50
5	2.30	96.75	0.95
6	4.75	93.95	1.30
7	5.90	93.60	0.50
8	7.49	92.06	0.45

Table 2: Summary of Atterberg Test Results.

Locations	Atterberg Limits		
	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	56.92	42.61	14.31
2	47.18	32.30	14.88
3	47.30	12.80	35.22
4	45.87	10.36	35.51
5	43.55	21.38	22.17
6	54.10	40.35	13.75
7	49.50	25.19	24.31
8	33.40	16.76	16.38

Table 3: Summary of Experimental Characteristics of Bricks.

Location No.	Dry compressive strength (MPa)	Wet compressive strength (MPa)	Water absorption (%)
1	3.66	2.65	5.76
2	3.04	2.14	5.80
3	3.38	1.29	10.62
4	2.81	1.52	8.35
5	2.37	1.24	10.97
6	3.15	1.75	7.01
7	2.20	1.18	11.46
8	2.70	1.92	6.95

A summary of sieve analysis test results is shown in Table 1 and Table 2 shows the test results for Atterberg Limit test. Experimental characteristics of bricks including dry compressive strength, wet compressive strength and water absorption are shown in Table 3.

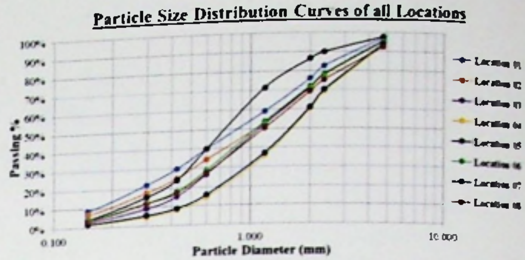

Figure 2: Particle Size Distribution of Soils.

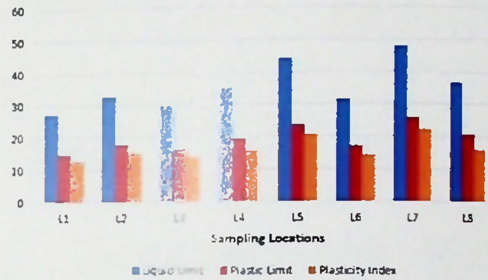

Figure 3: Variation of Atterberg Limits of Soils.

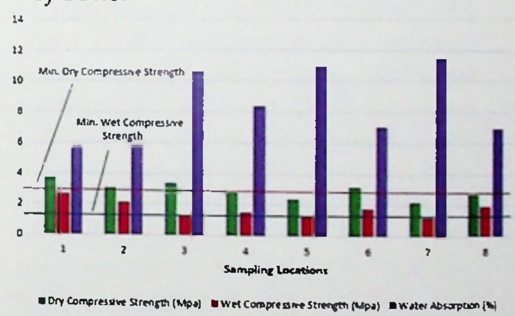

Figure 4: Variation of Experimental Characteristics of Bricks.

Figure 2 and 3 illustrate particle size distribution and variation of consistency limits of each soil sample respectively. Moreover, variation of characteristics of bricks made by each soil sample is graphically shown in Figure 4.

4 Discussion

Soil classification provides behaviour characteristics of a soil which is commonly based on grain size and soil consistency. According to Unified Soil

Classification System (USCS), a soil can be mainly classified as coarse grained (gravel, sand) and fine grained (silt, clay) [13]. According to the results shown in Table 1, all soil samples are classified as sandy soils. Table 4 shows the criterias used in USCS.

Table 4: Unified Soil Classification System.

Soil		Size Range
Coarse grained	Gravel	>4.75 mm (No. 4 sieve size)
	Sandy	4.75 mm - 0.075 mm
Fine grained		< 0.075 mm (N0.200 sieve size)

Gradation is an indicator of several engineering properties of soils such as compaction, shear strength and hydraulic conductivity. Generally, soils are graded as well graded, poorly graded and uniformly graded. Table 5 shows the criteria for grading of soils [14]. As illustrated in Figure 2, all soils are well-graded and therefore they are classified as well-graded sandy soils.

Table 5: Criteria for Gradation of Soils.

Grading	Criteria
Well-graded	$C_u \geq 4$ & $1 \leq C_c \leq 3$
Poorly graded	$C_u < 4$ & or $1 > C_c > 3$
Uniformly graded	$C_u = 1$

Engineering properties of soils such as compaction and hydraulic conductivity are concerned as main governing factors of compressive strength and water absorption of SCB. Therefore, gradation of soil has a great significance when analyzing the suitability for producing SCB. A well graded soil contains particles of a wide range of sizes which can be compacted well and thus, increasing the strength of bricks. Moreover, a compacted well graded soil has low hydraulic conductivity, resulting low water absorption [15].

Laterite soils with Plasticity Indices (PI) less than 35%, are prone to proper compaction. Moreover, cement stabilization of a soil is quite high when PI significantly does not exceed 15% [9]. Furthermore, well-compacted soil is considered as a cohesive soil. According to the results shown in Table 3, soils of L1, L2, L3, L4, L6 and L8 are both cohesive and can be highly stabilized with cement. Therefore, these soils are suitable for producing bricks. However, soils of L5 and L7 exhibit PI values significantly higher than 15% making them unsuitable for cement stabilization. Thus, these soils are not suitable for manufacturing bricks.

As stated in SLS 1382-1: 2009, minimum dry and wet compressive strengths of SCB for masonary are 2.8 MPa and 1.2 MPa respectively. Moreover, maximum water absorption that can be endured for high quality bricks is 15%. As illustrated in Figure 3, dry compressive strength of bricks of L1, L2, L3, L4 and L6 are greater than 2.8 MPa. Therefore, these SCB are in adequate strength for construction purposes. However, bricks of L5, L7 and L8 have not exceeded the specified limit. Therefore, these bricks are not strong enough for construction purposes. Moreover, bricks of L1, L2, L6 and L8 show high wet compressive strengths and all bricks except L7, are above the specified limit (Figure 3). Therefore, all bricks except L7 are suitable for masonary work. Water absorption of bricks of all locations are below the specified limit as shown in

Figure 3. However, bricks of L1, L2, L6 and L8 exhibit lower values whereas bricks of L4, L3, L5 and L7 have higher values. Therefore, bricks of L1, L2, L6 and L8 are much more suitable for construction.

Although all soils were identified as well-graded sandy soils, L5 and L7 have low C_u values. Furthermore, L5 and L7 bricks show low compressive strengths. Therefore, well graded soils with high C_u values will produce high strength SCB. Moreover, all soils are cohesive and prone to proper compaction. However, only soils of L1, L2, L3 and L6 are suitable for cement stabilization. This can be compared with the fact that dry and wet compressive strengths of bricks of L1, L2, L3 and L6 are above the specified limits. Therefore, soils with low PI which do not significantly exceed 15% are more suitable for manufacturing bricks. Water absorption of bricks of L1, L2, L6 and L8 are lower than others. Further, these soils have high C_u values as well. Therefore, soils with high C_u values produce bricks with low water absorption which is good for durability of SCB.

5 Conclusions

Based on the analysis of results, it can be deduced that a soil type consisting of following physical properties are more suitable for enhancing strength and performance of SCB.

- A well graded sandy soil with high coefficient of uniformity.
- Plasticity index should not significantly exceed 15%.

According to the cost analysis of SCB, production and masonary cost are lower than other conventional building materials. Furthermore, incase of in-situ manufacturing, transportation cost will be eliminated resulting lower cost of production. In conclusion SCB is a cost effective, energy efficient and environmental friendly alternative for current building materials and manufacturing these bricks will benefit the local economy as well as low income communities in Sri Lanka.

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