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Shrinkage Characteristics of Cement Stabilized Rammed Earth

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Abstract

The introduction of stabilization techniques to earth construction has seen its immergence as a good alternative walling material in the recent times. Further popularisation of earth construction has resulted due to the increased awareness on sustainable construction.

Research and development work was carried out on stabilized rammed earth technology with several soil types available in Sri Lanka. It was found that gravelly and sandy lateritic soils which are commonly available in many parts of the country are the best suited for stabilization with well accepted chemical stabilizer; cement. Several studies have been carried out to determine the optimum cement content, compressive strength with different soil types and flexural strength of stabilized rammed earth. All these studies have shown that stabilized rammed earth is a desirable material for single storey construction with possible extension to two storey load bearing construction.

Rammed earth offers an alternative, which could reduce the skilled labour requirement. One of the systems devised in Sri Lanka recently was a combination of cement stabilized earth blocks as corner columns and rammed earth walls in between them. However, the shrinkage of the wall panels should be carefully attended since excessive shrinkage can lead to wide cracks between the cement stabilized soil columns and the rammed earth walls. Thus, studies into the shrinkage characteristics of different composition of soils will be very useful. It is also useful to determine the effects of curing on the shrinkage characteristics.

Three different commonly available lateritic soils were used in the experimental programme to measure shrinkage strains. It was found that gravelly laterite soil gives the minimum shrinkage strain. The main findings of this paper have been used to propose solutions that can be used to minimise the cracks occurring due to shrinkage of walls constructed with rammed earth.

1. Introduction

Rammed earth technology was reintroduced to many countries as a good alternative material for house construction. Unlike the other building materials, general suitability of soil composition for construction is not readily standardised because of its inherent natural variability. However, it is considered as an ideal material to reduce the environmental impacts, green house gas emission and embodied energy (Bahar et.al, 2004, Morel et.al, 2001).

Rammed earth walls are generally constructed in layers, using a formwork system, which can be moved upwards. Since this technology needs vertical guides to slide the formwork system upwards, corner columns constructed with compressed stabilized earth blocks were successfully used in some countries. Even though both the raw material used to construct corner columns and walls are of similar nature which is stabilized earth, their shrinkage properties can differ to some extent. CSE blocks are generally used in column construction after 28 days of manufacturing which are considered to be after a major portion of shrinkage in the blocks has occurred, but the rammed earth masonry is constructed as insitu walls. Further to that, the type of soil used and the amount of stabilizer used can also differ. All these variations can introduce differential shrinkage properties which can ultimately result some shrinkage cracks. This paper is focused on a study done to determine the shrinkage properties of stabilised rammed earth walls. The problem identification was done with a field study carried out in a housing project which consists of 25 rammed earth houses in the southern province of Sri Lanka. An experimental programme was carried out to determine the magnitude of shrinkage likely to occur in stabilised rammed earth walls. The results were used to propose solutions to minimise shrinkage cracks in stabilized rammed earth walls.

2. Objective

The main objective of the research presented in this paper is to quantify the shrinkage in rammed earth walls constructed with commonly available soil types and to propose solutions to rectify this problem.

3. Methodology

In order to achieve the above objective, the following methodology was adopted:

a. A field study was carried out to investigate the nature of cracks occurred in the houses constructed with rammed earth walls, in a housing project where few problems were encountered.
b. Wall panels were cast in the laboratory with three commonly available soil types in Sri Lanka which are usually used for rammed earth construction.
c. Shrinkage was monitored over a period of time until the readings became stable.
d. Further testing was carried out by changing the curing period to investigate whether there is any effect due to curing on shrinkage properties.

4. Construction of Rammed Earth Panels

Stabilized rammed earth contraction should be done with proper soil selection, stabilized with three different means such as mechanical, physical, chemical and with proper workmanship during construction (Houben and Guillaud, 1994, Australian Earth Building Hand book, 2002, NZS 4297:1998).

Soil selection should be done in accordance with the accepted standards (Walker, 2003). The soil should be reasonably well graded between gravel to clay size particles. However, the clay content in the range of 10 – 20% is generally sufficient for binding since higher clay contents may cause excessive shrinkage. Hence the fines content (clay and silt) of 35% has been recommended for stabilized earth construction (Perera and Jayasinghe, 2003). The selected soil is generally sieved by a desirable mesh size, (18 mm used in Sri Lanka) for physical stabilization. Considering the soil types available in the country and the public acceptance, cement was selected as the chemical stabiliser. Desirable cement content was selected considering the design strength requirement and the soil type (Jayasinghe and Kamaladasa, 2006). Steel slip form shutters are generally used in Sri Lanka to construct rammed earth walls as shown in Figure 1 (Kamaladasa and Jayasinghe, 2005). A suitable soil is mixed with the recommended stabilizer quantity and compaction was carried out at the optimum moisture content. Since different types of laterite soils are used for this purpose, in the experimental programme three different varieties of lateritic soils were used, such as sandy, clayey and gravely. When mixing soil with water, optimum moisture content should be achieved by sprinkling water. This can be checked by carrying out the drop test [Walker, 2003].

Figure 1 Slip form mould

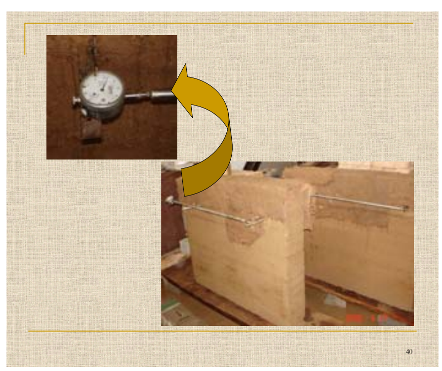

Figure 2 Test assembly to measure shrinkage

5. Experimental programme

Two identical wall panels of size1000 mm (length) x 800 mm (width) x 150 mm (thickness) were constructed for each soil type. In the experimental programme, all the soil types were stabilized with 8% cement. The panels were kept in a moist environment for 14 days in the series 1. The test panels were covered by wet gunny bags and cured with water, using a spray can in the morning and afternoon in order to keep all the panels in a moist environment for the entire duration of curing. In order to measure the shrinkage, the test assembly shown in Figure 2 was used which consists of a stainless steel rod fixed to the rammed earth panel with a dial gauge at one end to measure the horizontal movement. By measuring the elongation of the steel rod, shrinkage strain can be evaluated. Dial gauge reading was taken daily to monitor the shrinkage strain in the wall.

In order to take account of any thermal expansion occurred in the steel rod, daily temperature was monitored inside the laboratory and the thermal expansion was taken into account in the calculations. Temperature readings were found to be in the range of 27^{0}C to 30^{o}C and the relative humidity was in the range of 75% to 85%.

Further testing was carried out to investigate whether there is any effect due to extended curing periods on shrinkage characteristics. For this (Testing series 2), gravely laterite soil was used in the experimental programme. Curing period was varied as 7 days, 14 days and 21 days considering the hardening of soil cement mixture and other practical constraints.

6. Results and Analysis

6.1 Shrinkage Strains with Different Soil Types

Dial gauge readings were recorded daily and shrinkage strain was evaluated for each soil type. The average strains obtained for different soil types are given in Table 1. Shrinkage strain was evaluated based on the ratio of change in length of the wall panel to the initial length of the panel. All the panels have taken about 50 days to reach the maximum strain after which the reading remains at the same value with time. The minimum shrinkage was recorded in the wall panels made out of gravely laterite soil. Clayey and sandy lateritic soils gave almost the same results.

Table 1 Average shrinkage strains for different soil types

Soil type	Shrinkage strain
Sandy laterite	0.0029
Clayey laterite	0.0028
Gravely laterite	0.0017

Chart 1 shows the variation of shrinkage strain with time for all three soil types. It can be clearly seen in all the graphs first 10 to 12 days there is an expansion portion followed by shrinkage. This could be related to the expansion caused as a result of curing of the wall panels. The gravely laterite where the gravel and coarse sand content is about 55% gave much better results compared to sandy laterite (gravel and coarse sand content is about 35%).

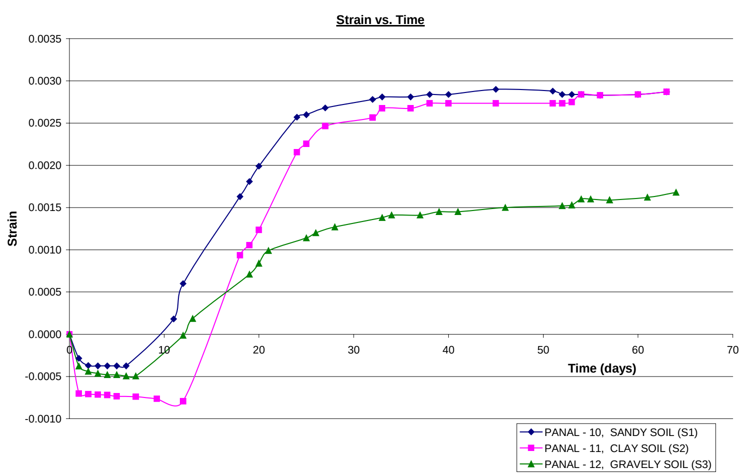

Chart 1 Shrinkage strains for different soil types

6.2 Shrinkage Strains With Different Curing Periods

Since gravely laterite soil gave lower shrinkage strain, this soil type was selected for further testing with different curing periods. Three curing periods of 7 days, 14 days and 28 days were selected in the study. Despite a higher period of expansion, the wall panels which were cured for 28 days have shown the lowest shrinkage strains, which gave a magnitude less than 0.0002. However, it may not be practically possible to cure the walls over 28 day period, and therefore a minimum of 14 days curing period is recommended for stabilized rammed earth walls which gives a shrinkage strain around 0.0005. Since shrinkage is inevitable in rammed earth it is important to determine the range of shrinkage strain so that precautions can be taken to avoid any cracks. With this study the shrinkage strains were experimentally determined for different soil types and for different durations of curing. Although the shrinkage strain is less for the panel cured for 28 days, it is practically difficult to implement 28 day curing. Therefore 14 day curing period can be recommended for the rammed earth construction. This gives shrinkage strain around 0.0005 which is very useful to find strategies to achieve crack free walls.

7. Field study

A housing project consists of 25 single storey houses constructed with stabilised rammed earth walls and compressed stabilized earth block columns was selected for this study. In about six houses there were cracks observed at wall column junctions as shown in Figure 3. The reason for these cracks has been identified as shrinkage occurred in walls, poor bond between the wall and the column etc. It was observed that most of the cracks appeared are in the range of 5 mm in width.

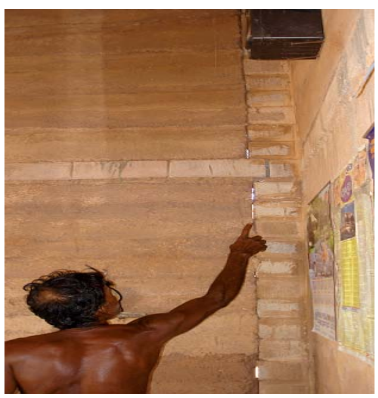

Figure 3 Cracks identified at the wall column junction

8. Proposed Solutions

In the field study, the maximum recorded crack width was in the range of 5 mm. Since the average wall length is 3 to 4 m in single storey houses, the actual shrinkage strain is 5 x 10^{-3} /3.0 around 0.0017. This value is in the same range as what is observed in laboratory testing. Therefore it is suggested to have a groove at the wall column junctions. This vertical groove can either be filled with a flexible material or a plaster after about 50 days of construction when the shrinkage is over or the groove can be left as an architectural feature. It is also recommended to cure the rammed earth walls for a minimum period of 14 days for better results.

9. Conclusions

Stabilized rammed earth can be considered as a good alternative material for the wall construction especially in the residential buildings. Although this material possesses many desirable properties such as relatively low embodied energy, comparable performance with strength and durability; shrinkage has been identified as a property which may cause some defects in the walls. Therefore a detail study was carried out to investigate the magnitude of lateral shrinkage so that some solutions can be devised to minimise the impact.

When rammed earth walls are constructed with the corners out of cement stabilized earth blocks or reinforced concrete columns, it is recommended to have a vertical groove of about 10 mm and seal it after 50 days with a suitable finishing material. It was also found that during the curing period, the wall expands and shrinkage starts afterwards. Hence a 14 day curing period is recommended for the cement stabilized rammed earth walls. Since shrinkage ceases to occur after about 50 days of casting any finishes to the walls can be applied after this period.

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References

1. Bahar R, Benazzoung M, Kenai S. Performance of compacted cement stabilized soil. Cement & Concrete composites, 2004; 26: 811-820.
2. Walker P, Maniatidis V. A review of rammed earth construction, Natural Building Technology group, Department of Architecture and Civil Engineering, University of Bath, United Kingdom, 2003.
3. Standards Australia, The Australian Earth Building handbook, Standards Australia, Sydney, Australia, 2002.
4. Perera AADAJ, Jayasinghe C. Strength characteristics and structural design methods for compressed earth block walls, Masonry International, 2003; 16(1): 34-38.
5. Morel JC, Meshah A, Oggero M, Walker P. Building houses with local material: means to drastically reduce the environmental impact of construction, Building and Environment, 2001; 36:1119 -1126.
6. Houben H and Guillaud H. Earth Construction, A comprehensive guide, CRTerre – EAG, Intermediate Technology Publications, 1994.
7. NZS 4297: 1998, New Zealand Standards, Engineering design of earth buildings, Standard New Zealand, Wellington, New Zealand.
8. Jayasinghe C. and Kamaladasa N., Structural properties of cement stabilized rammed earth, *Engineer*, Journal of Institute of Engineers, 2005.
9. Kamaladasa N., and Jayasinghe C., Development of an efficient construction Technique for Rammed Earth, Transactions, Institute of Engineers, 2005.
10. Jayasinghe, C. and Kamaladasa, N., 2007. Compressive strength characteristics of cement stabilized rammed earth walls. Construction and Building Materials, 21(11), pp.1971-1976.