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Surface Coatings for Stabilized Earth Walls

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Abstract: Wall construction with stabilized earth in houses and low-rise buildings is becoming popular with the promotion of sustainable concepts in the construction industry. Many studies conducted on strength properties of stabilized earth have shown this material is strong enough for the load bearing of two or three storey construction with engineering design. Durability is another key parameter of a walling material. This paper covers the outcome of a detailed study conducted on durability of stabilized earth as a walling material. This includes, levels of stabilization necessary to improve durability, the performance of different surface coatings applied on earth walls and testing of surface coatings on durability properties according to the relevant accepted standards. Two types of stabilized earth walls were considered in the study, such as compressed stabilized earth blocks and stabilized rammed earth.

With the findings of the study covered in this paper now it is possible to select surface coatings for different levels of durability of earth walls, required by the clients. Further the necessary stabilization levels can be selected to maintain both strength and durability.

Keywords: Paints, Surface coatings, Earth walls, Durability

1. Introduction

The provision of good houses at a reasonable cost to the general public has been a key goal that has been attempted to achieve by successive governments in the last few decades. The initiative of the government to promote sustainable construction included the use of stabilized earth as a walling material.

These attempts have resulted in the use of many different construction materials for the external and internal walls. In order to reduce the cost of walls, stabilized earth based construction also has been actively promoted in the recent times.

Out of several stabilization techniques, cement stabilization has gained popularity due to higher strength, durability, availability and ability to obtain acceptable properties with low percentage of cement, especially with laterite soils [01] [03] [04] [05]. Laterite soil is often found in tropical climatic conditions and is readily available in many parts of Sri Lanka either as laterite hills or few meters of sub soil. Thus, the use of cement stabilized soil for walls is gradually gaining popularity with many different forms such as earth bricks, plain blocks, interlocking blocks, solid blocks, hollow blocks and rammed earth.

When compressed stabilized earth blocks (CSEB) or rammed earth is used, it is possible to provide a finish with cement, lime, soil and sand based Plasters, followed by a suitable primer and the paintwork.

However, from the point of view of sustainable construction practices, it is useful to minimize the amount of natural resources based construction materials used in creating built environment [06] [07]. In this context, it is ideal to finish cement stabilized earth walls without a plaster or with plaster of minimum thickness. However, this can raise many issues related to durability, which warrants detailed research to determine the appearance, long-term performance and cost aspects.

Therefore, a detailed study is required to investigate the performance of surface coatings and finishes on earth walls. This paper covers a study to identify the surface coatings and paints suitable for earth walls in terms of durability.

2. Objective

The objective is to identify suitable surface coatings and finishes that could be successfully applied on the earth walls considering the Sri Lankan climatic conditions.

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3. Methodology

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

- Durability testing suitable for tropical climate condition was selected
- Compressed stabilized earth blocks were manufactured manually with different cement contents and tested for durability
- Wall panels were constructed with compressed earth blocks and rammed earth and tested for durability
- Different types of surface coatings were applied on the earth wall panels and tested for durability

4. Test specimens and the finishing coats applied

Different surface coatings, which are available in Sri Lanka, were applied on test wall panels. All the panels were subjected to the selected durability testing.

4.1 Plaster applied on walls

Following plasters were used in the experimental programme:

1. Conventional cement lime sand plaster; 1:1:5 cement: lime: sand.
2. A ready made plaster available in the market, which is made out of cement and silty sand dredged from reservoirs as result of de-siltation process.

4.2 Fillers applied on walls

Two types of fillers were used in the experimental programme. They were Acrylic filler (Figure 01) and Sheet rock. Soil blocks and wall panels finished with the filler coatings and finished with paints on fillers were subjected to testing. Acrylic filler is a water-based coating and four parts of Acrylic filler were mixed with one part of water (1:4, Water: Acrylic filler). Then, the filler coat was applied on the wall by brush application. A trowel was used to apply sheet rock. Sheet-rock is a lime based surface coating that can be directly applied as a thin layer either on rough plaster or on earth walls. This can provide a smooth finish for the wall.

4.3 Paints applied on soil blocks and walls

Weather shield and emulsion paints, which are available in the market, were used as coatings on soil blocks and wall panels. After mixing with optimum amount of water, surfaces were painted by using a brush. The paints were applied on earth surfaces directly on a filler coat and on plastered wall.

The mud paint (1:1:6, cement: lime: soil) (Figure 02) was also introduced as a finishing coat on blocks and walls. For this, laterite soil can be used as the main ingredient, which, should be sieved through a 2 mm mesh. Then, the soil sample was kept in water for about two days before making the mud paint. A reasonably good finish can be obtained with the mud paint applied on earth walls.

Water repellent was also used which is termed as silicone-based emulsion [03] [08]. This can be applied directly onto the surface of the wall. As described in Australian Earth Building Hand book[3], water repellents are suitable for both external and internal wall surfaces. This recommendation was checked against the Sri Lankan weather conditions.

5. Finishes applied on hand moulded soil blocks and wall panels

5.1 Finishes applied on hand-moulded blocks

In order to assess the worse case scenario, hand moulded blocks were used in the testing programme to assess the durability properties of different surface coatings applied on it. Different types of surface coatings used in the testing programme are given in Table 1. Figure 3 shows a specimen block finished with one type of surface coating.

5.2 Finishes applied on wall panels

Wall panels were constructed using commercially available machine made blocks. Different types of compressed stabilised earth blocks are used in wall construction such as earth bricks, plain solid blocks, hollow blocks and interlocking blocks. In order to test all types of blocks with surface coatings, four panels were made from each block type. Thus, a total of 16 panels were constructed. Figure 4 shows a specimen panel.

5.3 Rammed earth wall panel

Another alternative in earth wall construction is rammed earth. Stabilized rammed earth wall panels were made and above coatings were applied on panels. Each rammed earth wall panel was constructed with laterite soil, which was stabilised with 10 % cement. Before mixing

with cement, soil was sieved by using 20 mm mesh and also organic matter was removed. Soil and cement were mixed well and then water was added to the mix. Optimum water content was achieved with the aid of a simple field test called, drop test [3]. Figure 5 shows a face of rammed earth wall panel.

6. Assessment of durability with laboratory testing

Different testing methods, which assess surface coatings and finishes on earth walls were reviewed and the following methods were selected for the experimental study:

a. Water absorption test
b. Accelerated spray erosion test

6.1 Water absorption test on surface coatings and finishes

The main aim of this test is to assess the behaviour of surface coating in order to control the absorption of water into the earth walls [09] [10] [11]. Therefore, hand moulded soil blocks were used for the test. The water absorption of selected specimens was obtained in following steps:

a. The oven dried weight of the specimens was obtained
b. Then the specimens were subjected to a continuous jet of water for 60 minutes to simulate the rain conditions using the erosion test apparatus.
c. Then the wet weight of the specimen was obtained and the water absorption was expressed as a percentage of the dry weight.

The 16 coatings given in Table 1 were applied on earth walls and tested to determine the percentage of water absorption. Figure 6 shows a test being conducted on a hand-moulded block.

6.2 Accelerated erosion test on surface coatings and finishes

Durability problems can be caused when earth walls are subjected to driving rain. It was identified that some of the unstabilized earth walls in ancient houses had erosion problems when the walls were exposed to the driving rain [12].

The aim of accelerated erosion test was to identify the behaviour of the surface coatings against the driving rain conditions [13] [14] 15] [16]. For this, an attempt was made to measure the erosion depth of the hand moulded soil blocks and wall panels (both CSEB and rammed earth) due to accelerated water spray.

The test specimens were subjected a continuous jet of water spray for 60 minutes or until water is completely penetrated the specimen. The apparatus required for the test is shown in Figure 7. It includes a stand mounted 50 mm spray, water pump, pipes, valves, pressure gauge, water sources, filtration screen to remove particulate matter, shield and accessories necessary to mount the specimen.

A set of wall panels (4 panels) applied with 16 different coatings was tested and the test was carried out for 60 minutes on each panel as recommended in the Australian Earth Building Handbook.

Erosion depth or pitting depth was measured by inserting a 10 mm diameter flat-ended rod as shown in Figure 8 [03] [16]. Also, the Figures 9 and 10 show two occasions of the erosion test for CSEB and rammed earth wall panels, respectively.

Further to check the effect of stabilizer content on durability, hand moulded blocks were made with different stabiliser contents and tested in the erosion test apparatus. The results are shown in Figure 11. Stabilizer content was varied from 2% to 10% of soil by volume. It can be clearly seen that the rate of erosion decreases with cement content as expected.

7. Results and analysis

7.1 Water absorption test results

Water absorption test was carried out to identify the behaviour of different types of surface coatings and finishes applied on compressed stabilized earth blocks. The percentage of water absorption was evaluated for each of the 16 coatings. Results of water absorption test carried out on different surface coatings, applied on hand moulded blocks are shown in Figure 12.

According to the results presented in Figure 12, it can be seen that all the surface coatings can reduce the water absorption to a different degree depending on the type of coating. The percentages of water absorption obtained with all the surface coatings are below the recommended maximum value given in the Indian Standards, which is 20% [17].

Therefore, the conventional plaster completed with emulsion and weather shield paints, Acrylic filler or ready mixed plaster could be

recommended as better surface coatings and finishes in terms of minimizing the water absorption. Mud paint on plaster also can give a comparable performance.

7.2 Accelerated erosion test results

The erosion test conducted with erosion apparatus is a rigorous test for simulating the conditions that would arise under driving rain. It can be seen that both CSE blocks and rammed earth did not indicate noticeable erosion when directly exposed to erosion test without any surface coatings. This is a very important observation that indicates the ability of CSE masonry and cement stabilised rammed earth to survive in exposed situations. However, it is practically not possible to use this masonry with its completed form due to aesthetic considerations. Thus, the performance with surface coatings will become important. When coatings are needed, cement soil coating can be considered as the most cost effective in order to give a smooth finish. This coating however, suffered under rigorous conditions created by the erosion test apparatus. Thus, it is advisable to have sufficient eaves that will provide a considerable protection from driving rain.

The application of plaster on a wall with pleasing finish cannot be considered as an activity that falls in line with promoting principles of sustainable development. It needs minimization of the use of natural resources. Nevertheless, if plaster is applied the erosion test indicated that the wall would be able to perform very well without any sign of deterioration.

The above results thus indicate that CSE masonry can be considered as an extremely durable material that can perform satisfactorily once adequate precautions are taken.

Erosion rate is an indication of the susceptibility to suffer under driving rain. For erosion test, both compressed stabilized earth blocks and walls were used. The results of this test are given in Table 2. As can be seen, none of the blocks or walls suffered significant erosion damage. However, some surface finishes were washed away which indicated that such coatings should not be used on external wall surfaces. All the paint combinations have shown the depth of erosion less than 10 mm/hr, which is the maximum allowed erosion depth according to the Australian earth-building handbook.

As can be clearly seen in Figure 11, the erosion rate goes down with the increase in stabilizer content. Considering the strength and durability requirements 5% cement by volume can be recommended.

7. Conclusions

According to the results of experiments carried out, the following finishes performed well.

1) Cement plaster (1:1:5) with emulsion paint
2) Cement plaster (1:1:5) with weather shield paint
3) Ready mix plaster with emulsion paint
4) Ready mix plaster with weather shield paint
5) Mud paint on plaster
6) Water repellent

However, the CSE walls applied with both emulsion and weather shield paints on Acrylic filler are also acceptable in terms of erosion resistance and water absorption criteria. The recommended value for erosion rate is 10 mm/hr and the water absorption is 20% according to the standards (IS: 3495 (part 2): 1992). Only sheet rock did not perform as required. Thus, sheet rock should not be used on external walls. It could still be used on the internal wall surfaces.

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References

1. Arandara K. P. "Durability Properties of Earth Buildings", MSc thesis, Department of Civil Engineering, University of Moratuwa, January 2008.
2. American Society for Testing and Materials, Annual Book of ASTM Standard D 559-44, wetting and drying test of compacted soil cement mixtures.
3. Australian Earth Building handbook, Assessed by Queensland University of Technology, Australia, 2005.

4. Heathcote K. A., "Durability of earth buildings", University of Technology, Sydney, NSW, Australia, 2007.
5. Heathcote K. A., " Resistance of Earth buildings to weathering by Wind-Driven Rain", The Australian Institute of Building Papers, Volume 6, pp 13-20, 1995.
6. Jayasinghe C., "Alternative building material and methods for Sri Lanka", PhD thesis, Department of Civil Engineering, University of Moratuwa, 1999.
7. Jayasinghe C., Perera A. A. D. A. J, "Studies on Load Bearing Characteristics of Cement Stabilized Soil Blocks", The Institution of Engineers, Sri Lanka, Transactions, Vol. 01, Part B, 1999.
8. Joseph O., "Chemical evaluation of Cement-based sandcrete wall deterioration", Cement and Concrete research, Vol 35, p. 2170-2174, 2005.
9. Kerali A. G., "Destructive effects of moisture on the long tem durability of stabilized soil blocks", working paper NO. 52, Development Technology Unit, University of Warwick, United Kingdom, 2000.
10. Ngowi A. B., "Improving the traditional earth construction", a case study of Bostuwana, Construct Building Mater; Department of Civil engineering, University of Bostuwana, 11(1): 1-7, 1997.
11. Norton J., "Building with Earth" a hand book, second edition, Intermediate technology publications, 1997.
12. Arandara K.P. and Jayasinghe C., "Identification of durability problems of earth buildings", *Engineer*, Journal of Institution of Engineers, Sri Lanka, volume XXXX, No. 04, pp 14-21, 2007.
13. NZS 4298:1998, "Materials and Workmanship for Earth Buildings, Standards New Zealand, 1998.
14. Raymend N. Y. and Ouhadi V. R., "Experimental study on instability of bases on natural and lime/cement stabilized clayey soils", Applied Clay Science, 2006.
15. Reddy B. V. V., Jagadish K. S., "Spray Erosion Studies on Pressed Soil Blocks", Building and Environment, Vol 22, No. 2, pp 135-140, 1987
16. Reddy B. V. V., Jagadish K. S., "Influence of Soil-cement blocks, The Indian Concrete Journal, pp 517-524, 1995.
17. Reddy B. V. V. and Jagadish, K. S., "Properties of soil–cement block masonry". Masonry Int., 3, 80–84, 1989
18. IS: 3495 (part 2): 1992, Methods of tests of burnt building bricks-part2: Determination of water absorption, Bureau of Indian Standards, India.

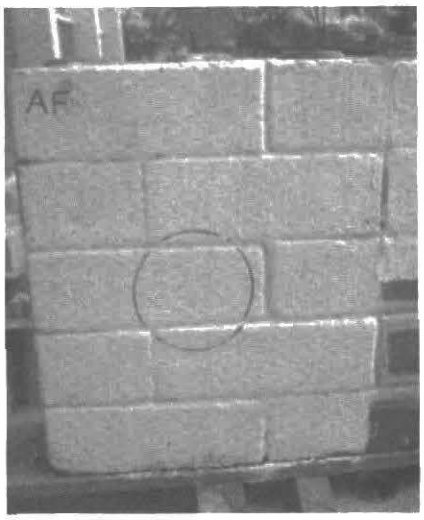

Figure 1: Acrylic filler applied on a test panel made out of interlocking blocks

Figure 2: A wall panel finished with mud paint

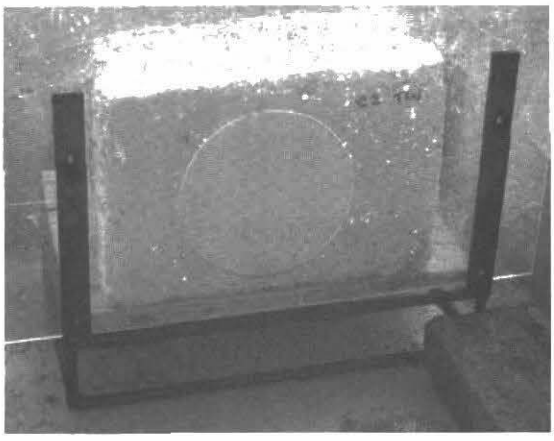

Figure 3: Hand moulded soil block - surface finished with sheet rock

Figure 4: Test panels made out of CSEB

Figure 5: Mud paint on plaster applied on a rammed earth wall panel

Figure 6: Water absorption test on a hand moulded block

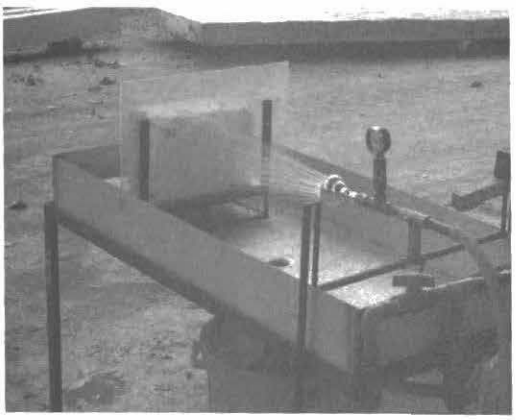

Figure 7: Erosion test apparatus

Figure 8: Measuring the pit depth inserting a rod (10 mm diameter flat ended)

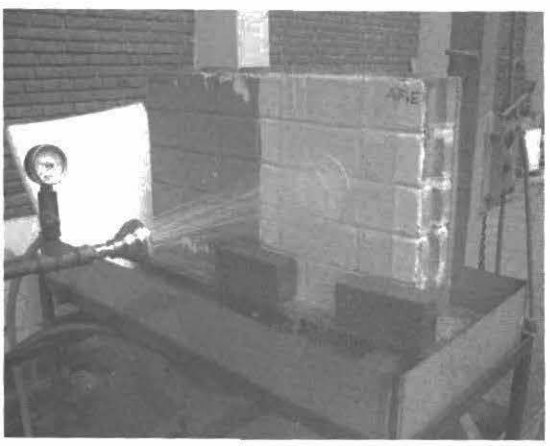

Figure 9: Erosion test on a wall panel made out of CSEB

Figure 10: Erosion test on a rammed earth wall panel

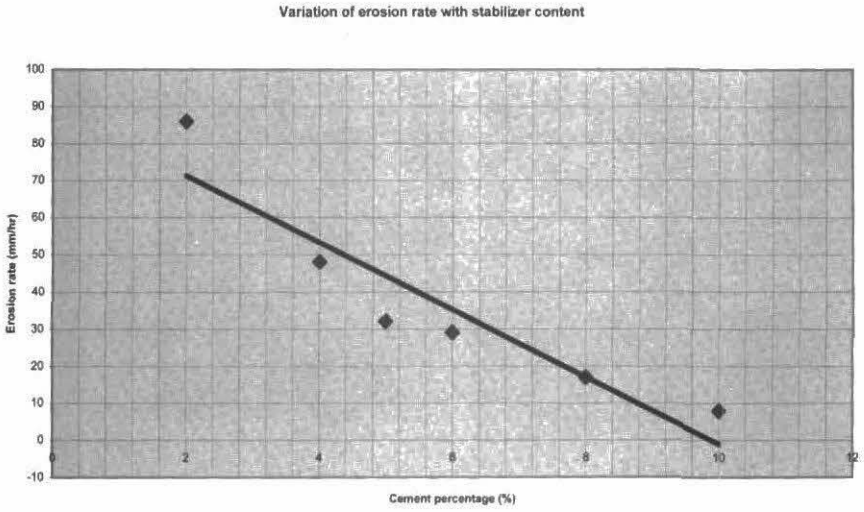

Figure 11: Variation of erosion rate with cement content

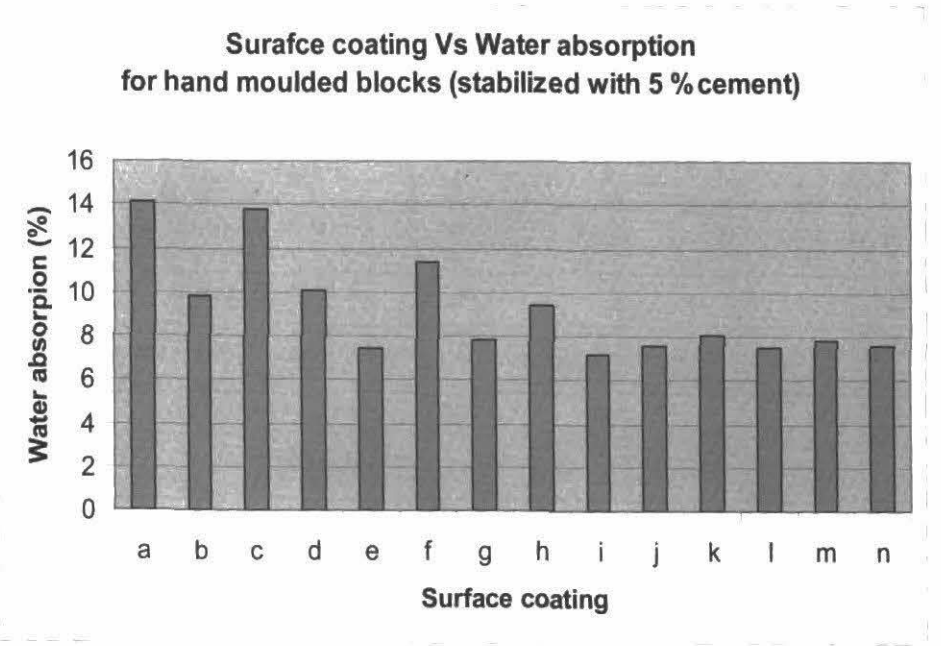

Figure 12: Results of water absorption test

Table 1: Combinations of surface coatings and finishes

ID	Coating type	ID	Coating type
a	No surface coating	I	Emulsion paint on Acrylic filler
b	Acrylic filler only	J	Plaster (1:1:5) only
c	Sheet rock only	K	Weather shield paint only
d	Mud paint on plaster	l	Weather shield paint on plaster
e	Emulsion paint on plaster	m	Ready mix plaster only
f	Mud paint (1:1:6) only	n	Emulsion paint on ready mix plaster
g	Emulsion paint only	p	Weather shield paint on ready mix plaster
h	Mud paint on Acrylic filler	q	Water repellent

Table 2: Results of erosion test on CSE blocks and walls

ID	Coating type	Erosion rate (mm/hr)	Remarks
a	No surface coating	0	No damage to blocks/walls and surface coatings
b	Acrylic filler only	1	Only filler layer was damaged
c	Sheet rock only	2	Only sheet rock layer was damaged
d	Mud paint on plaster	1	Only mud layer was removed
e	Emulsion paint on plaster	0	No damage to blocks/walls and surface coatings
f	Mud paint (1:1:6) only	1	Only mud layer was damaged
g	Emulsion paint only	1	Only emulsion paint layer was damaged
h	Mud paint on Acrylic filler	2	Mud and filler were damaged
i	Emulsion paint on Acrylic filler	1	Emulsion paint was damaged
j	Plaster (1:1:5) only	0	No damage to blocks/walls and surface coatings
k	Weather shield paint only	1	Only paint layer was damaged
l	Weather shield paint on plaster	0	No damage to blocks/walls and surface coatings
m	Ready mix plaster only	0	No damage to blocks/walls and surface coatings
n	Emulsion paint on Ready mix plaster	0	No damage to blocks/walls and surface coatings
p	Weather shield paint on Ready mix plaster	0	No damage to blocks/walls and surface coatings
q	Water repellent	0	No damage to blocks/walls and surface coatings