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Experimental Investigation into the Physical and Mechanical Properties of Cement-Stabilized Earth Bricks Incorporating Marble Dust Waste

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ABSTRACT:

The generation of marble dust during the cutting and polishing of marble creates serious disposal and environmental problems while the demand for low cost and low energy walling materials continues to grow. This study investigates the use of marble dust waste in cement stabilized earth bricks of size 230 × 100 × 100 mm. Two mixes were prepared using gravelly sand soil collected near the college campus together with marble dust and Ordinary Portland Cement. The mix proportions by mass were 80:10:10 for mix M1 and 55:25:20 for mix M2 and 15 ml of superplasticizer was used in both mixes. The bricks of mix M1 were tested after 7 days and the bricks of mix M2 after 14 days for compressive strength and first crack load and water absorption. The compressive strength was 1.30 MPa at 7 days and 3.48 MPa at 14 days with ultimate failure loads of 30 kN and 80 kN respectively. The water absorption was 2.6% at 7 days and 8% at 14 days which is well below the 20% limit given for common burnt clay bricks. The results show that marble dust waste can be used effectively in cement stabilized earth bricks to produce a sustainable walling material.

Keywords: Cement stabilized earth brick; Marble dust; Compressive strength; Water absorption; Waste utilization

I. Introduction

Bricks are one of the most widely used walling materials in the construction industry. The common burnt clay brick consumes fertile topsoil and a large amount of fuel for firing and releases considerable carbon dioxide to the atmosphere. Earth bricks stabilized with cement offer a practical alternative because they are not fired and have a much lower embodied energy than burnt clay bricks [3]. The addition of cement improves the strength and durability of earth bricks and reduces their shrinkage and moisture movement [1] [2].

At the same time the marble industry produces a large quantity of fine waste in the form of dust and slurry during the sawing and polishing of marble blocks. A considerable portion of the processed block is lost as this waste. Its disposal on open land affects the soil and water sources and the airborne fine particles cause health and environmental concerns [4] [5]. Marble dust has been studied mainly as a filler or partial replacement material in concrete and mortar where it has shown useful effects on the mechanical properties [4] [5] [6].

Marble dust is rich in calcium carbonate and consists of very fine particles. When it is added to a soil cement mixture it can fill the voids between the soil particles and improve the packing of the mix. This is useful for gravelly and sandy soils which are common near many construction sites and have been used successfully for soil cement blocks [2]. However the use of marble dust waste in cement stabilized earth bricks has received limited attention.

This study therefore examines cement stabilized earth bricks of size 230 × 100 × 100 mm made with marble dust waste. The objectives are (i) to prepare two mixes of gravelly sand soil with marble dust and cement and a superplasticizer (ii) to determine the compressive strength and first crack load of the bricks after 7 and 14 days of curing and (iii) to find the water absorption of the bricks and compare the results with the limits given in the Indian Standards.

II. Materials and Methodology

This experimental study used soil as the main constituent of the bricks with Ordinary Portland Cement as the stabilizer and marble dust waste as the additive. A superplasticizer was added to improve the workability of the mix. The methodology adopted for the study is shown in Fig. 1.

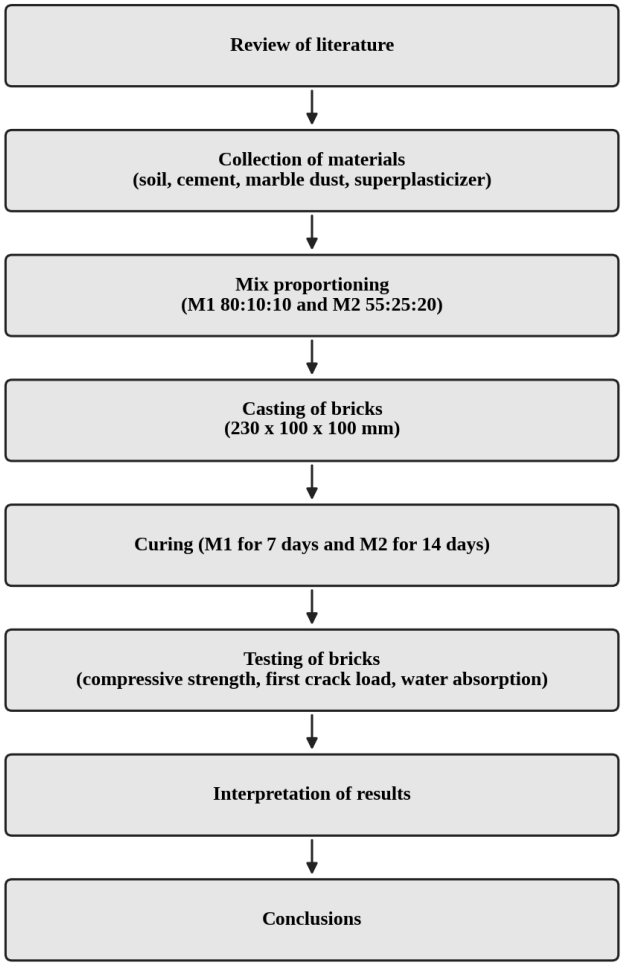


Fig. 1 Methodology flowchart

Materials

Soil: The soil was collected near the college campus and is a gravelly sand. It was used as the main constituent of the bricks and forms the bulk of the mix.

Cement: Ordinary Portland Cement (OPC) of 53 grade was used as the stabilizer. It binds the soil and marble dust particles through hydration and gives the brick its strength and resistance to water.

Marble dust: Marble dust is a fine powder obtained as waste from the cutting and polishing of marble. It was used in place of a part of the soil to fill the voids between the coarse particles and to make use of the waste material.

Superplasticizer: A superplasticizer was added at a dosage of 15 ml in both mixes to improve the workability and the compaction of the mix.

Mix Proportions

Two mixes M1 and M2 were prepared. The proportions of soil and marble dust and OPC cement were taken by mass and 15 ml of superplasticizer was added to both mixes. The bricks of mix M1 were tested after 7 days of curing and the bricks of mix M2 after 14 days of curing. The mix proportions are given in Table 1.

TABLE I
Mix Proportions by Mass

Mix	**Curing age**	**Soil (%)**	**Marble dust (%)**	**OPC cement (%)**	**Superplasticizer**
M1	7 days	80	10	10	15 ml
M2	14 days	55	25	20	15 ml

The size of the brick was taken as 230 mm × 100 mm × 100 mm and its volume was calculated using Equation (1).

$$V = L \times B \times H = 0.23 \times 0.10 \times 0.10 = 0.0023 \text{ m}^3 \quad (1)$$

Casting and Curing

The materials were batched by weight in the proportions given in Table 1 and mixed thoroughly with the superplasticizer. The mix was filled into moulds of size 230 mm × 100 mm × 100 mm to cast the bricks. The bricks were removed from the moulds and cured for 7 days (mix M1) and 14 days (mix M2) before testing.

Testing of Bricks

Each brick was placed in a compression testing machine of 2000 kN capacity and loaded until failure as shown in Fig. 2. The load at which the first crack appeared and the ultimate failure load were recorded. The compressive strength was calculated from the ultimate load using Equation (2) where the loaded area A was taken as 230 mm × 100 mm = 23000 mm².

$$f_c = P / A \quad (2)$$

where f_c is the compressive strength in MPa and P is the ultimate failure load in N. The first crack strength was found in the same way from the first crack load.

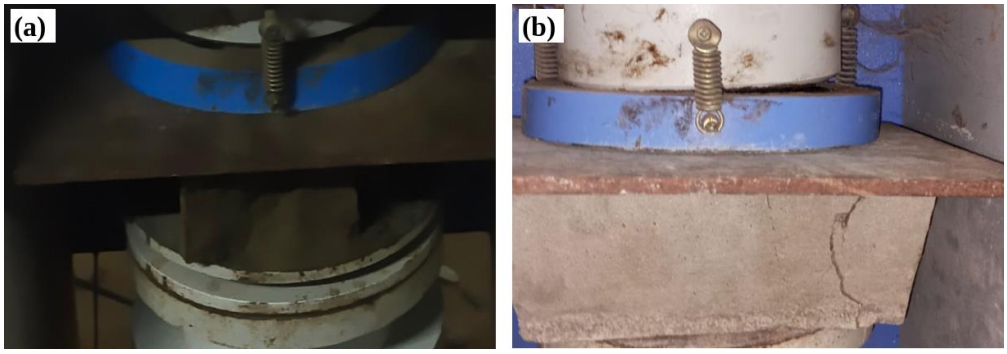


Fig. 2 Compression testing of bricks: (a) mix M1 brick at 7 days (b) mix M2 brick at 14 days showing cracks

For the water absorption test the dry weight of the brick (W_d) and the weight of the brick after immersion in water (W_w) were measured. The water absorption was calculated using Equation (3).

$$\text{Water absorption (\%)} = (W_w - W_d) / W_d \times 100 \quad (3)$$

III. Results and Discussion

The results of the tests on the bricks after curing for 7 days (mix M1) and 14 days (mix M2) are given in Table 2.

TABLE II Test Results of the Bricks

Parameter	**M1 – 7 days**	**M2 – 14 days**
Dry weight of brick (kg)	4.87	4.90
Wet weight of brick (kg)	5.00	5.30
Water absorption (%)	2.6	8
First crack load (kN)	25	25
First crack strength (MPa)	1.08	1.08
Ultimate failure load (kN)	30	80
Compressive strength (MPa)	1.30	3.48

A. Compressive Strength

The compressive strength of the bricks was 1.30 MPa for mix M1 at 7 days and 3.48 MPa for mix M2 at 14 days as shown in Fig. 3. The ultimate failure load increased from 30 kN to 80 kN. The strength at 14 days was about 2.7 times the strength at 7 days. This increase can be attributed to the combined effect of the longer curing period and the higher cement content of mix M2 (20% against 10%) and its higher marble dust content (25% against 10%) which gives a denser packing of the gravelly sand. Since the mix and the curing age differ between the two sets of bricks the effect of each cannot be

separated from these results. The compressive strength of earth blocks also depends on the shape of the specimen and the test conditions [7] so the values reported here apply to the brick size and loading arrangement used in this study.

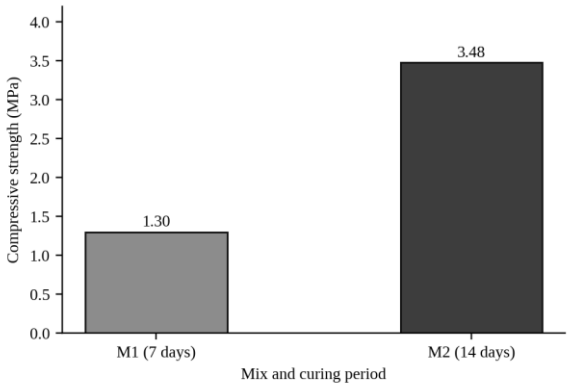


Fig. 3 Compressive strength of the bricks

The strength of 3.48 MPa for mix M2 is close to the minimum average compressive strength of 3.5 MPa specified for the lowest class of common burnt clay bricks in IS 1077 [8] and for stabilized soil blocks in IS 1725 [9]. The strength of mix M1 at 7 days is lower than this value as expected for an early age and a low cement content of 10%.

B. First Crack Load

The first crack appeared at a load of 25 kN in both mixes which corresponds to a first crack strength of 1.08 MPa. For mix M1 the first crack appeared at about 83% of the ultimate load of 30 kN so the brick failed soon after cracking. For mix M2 the first crack appeared at about 31% of the ultimate load of 80 kN which shows that the brick carried a large additional load after the first crack and had a greater reserve of strength.

C. Water Absorption

The water absorption of the bricks was 2.6% for mix M1 at 7 days and 8% for mix M2 at 14 days as shown in Fig. 4. Both values are well below the limit of 20% specified for common burnt clay bricks in IS 1077 [8] and show that the bricks have a dense structure with low water intake. The higher absorption of mix M2 may be related to its higher marble dust content and to differences in the compaction and the pore structure of the bricks and should be confirmed by testing a larger number of specimens.

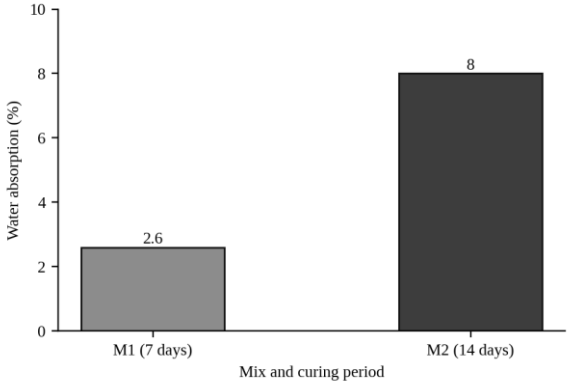


Fig. 4 Water absorption of the bricks

IV. Conclusion

Cement stabilized earth bricks of size 230 × 100 × 100 mm were made using gravelly sand soil with marble dust and Ordinary Portland Cement in the proportions 80:10:10 (mix M1) and 55:25:20 (mix M2) with 15 ml of superplasticizer. The compressive strength was 1.30 MPa for mix M1 at 7 days and 3.48 MPa for mix M2 at 14 days and the ultimate failure loads were 30 kN and 80 kN. The first crack load was 25 kN in both mixes with a first crack strength of 1.08 MPa.

The water absorption was 2.6% at 7 days and 8% at 14 days which is within the limit of 20% for common burnt clay bricks. The study shows that marble dust waste can be used in cement stabilized earth bricks to give a sustainable walling material while reducing the disposal problem of the waste. Further work on longer curing periods and durability tests will help to confirm the performance of the bricks.

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