CHARACTERISTICS OF MASONRY UNITS FROM IRON ORE TAILINGS

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Abstract: This paper deals with an experimental study on masonry units made of iron ore tailings in compressed earth block. Compressed earth blocks (CEB) or stabilised mud blocks (SMB) are widely accepted as energy efficient alternatives to burnt clay bricks. Natural river sand is often used to obtain optimum soil gradation in the production of SMB. In order to reduce adverse impacts of indiscriminate mining of natural sand, iron ore tailings (IOT), which is a mine waste, is used as an alternate to the natural river sand. Based on the gradation of soil used for production of SMB, optimum mix proportion of soil, sand and cement was fixed and the sand fraction was replaced by IOT at 25%, 50% and 100%. The block characteristics like wet compressive strength, water absorption, initial rate of absorption and linear elongation were examined and discussed. From the experimental results it is found that considerable amount of sand can be replaced by IOT without compromising desirable characteristics of SMB used for masonry.

Keywords: Masonry units, bricks, mine wastes, stabilised bricks, iron-ore tailings

1.0 Introduction

Masonry is widely used to construct both small and large structures because of its structural versatility and attractive appearance [1]. Masonry is of considerable volume in most of the structures and masonry units are consumed in bulk quantities [2]. Compressive strength of masonry greatly depends on strength of the masonry units. In order to cater to the different needs of construction, various masonry units have been developed and used. Natural resources are indiscriminately extracted for construction needs. To reduce adverse impact on nature there is a large potential and scope for utilising industrial and mine solid wastes for the manufacture of construction products [3]. India generates huge volumes of mine wastes every year. In the present work iron ore tailings which is a waste generated after extraction of iron ore was investigated for production of stabilised mud bricks.

Stabilised mud bricks are energy efficient alternative to burnt clay bricks [3]. Stabilised mud blocks are manufactured by compacting a wetted mixture of soil, sand and stabiliser in a machine into a high density-block. Natural river sand is commonly used to achieve an optimum clay and sand content in the mix for production of good quality SMB. Crushed stone dust which is a waste from granite industry is also used as replacement to river sand in making SMB. These are cured for 28 days and can be used in the construction of load bearing masonry elements.

2.0 Methodology

The methodology adopted in the present investigation is discussed in the following section. The raw materials used were characterized first and mix proportion was fixed. Bricks were produced with decided mix proportion to study various parameter and results obtained are discussed.

2.1 Characteristics of raw materials

Locally available red loamy soil and natural river sand were used to make SMB with Ordinary Portland Cement of 43 Grade as stabiliser. Grain size distribution of natural sand and IOT were also obtained. The combined grain size distribution curves of soil, sand and tailings are presented in Fig. 1. The physical properties of materials used are given in Table - 1. The IOT is fine graded compared to natural sand used.

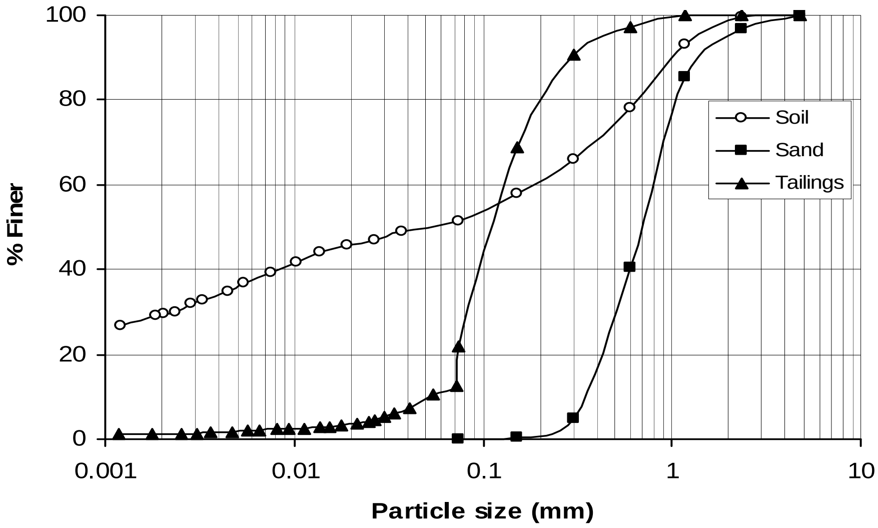

Fig. 1 – *Particle size distribution curves for soil, sand and iron ore tailings*

Table – 1: *Physical properties of raw materials used*

Material	Sand fraction (0.75-4.75mm) %	Silt fraction (0.75-0.002mm) %	Clay fraction (<0.002mm) %	Fineness modulus	Specific gravity
Soil	48.6	22.5	28.9	1.04	2.62
Sand	100	0	0	2.71	2.57
Tailings	78	20.7	1.3	0.4	2.77

2.2 Mix proportioning

Earlier research on SMB has examined in detail the role of clay and its optimum content in the soil for better performance of SMB both with respect to strength and durability [4]. These studies recommend optimum clay content to be in the range of 12% to 16%. Hence, in order to bring the clay content of the soil within desirable limits, ratio of soil to sand was kept as 1:1 by weight. It is also brought out in earlier research that about 7% of stabiliser is sufficient for three storey load bearing masonry of moderate span residential buildings. Hence 7% cement by weight of soil and sand was used to stabilise the soil. In general, water content of about 10% of dry materials by weight is commonly used to make SMB. However, as the river sand is being replaced by very fine IOT, demand for increased moulding water content was expected. In order to arrive at proper moulding water content, optimum moisture contents (OMC) was first determined for each mix with IOT content to replace sand. Also, it is found that for a given mix, moulding water content to the wet side of OMC gives better strength [5]. Hence, for all the mixes, moulding water content was kept 10% more than the respective OMC. The river sand fraction was replaced by IOT at 25%, 50% and 100% and compared with results for mix containing 100% river sand. The bricks made out of the mix with sand to IOT ratios of (1: 0), (0.75: 0.25), (0.5: 0.5) and (0: 1) are designated as A, B, C and D respectively. The target dry density was kept at 1.8 g/cc, which is again based on the recommendations by earlier research on SMB technology. Details of mix proportion and moulding water content are presented in Table – 2.

Table -2: *Details of mix proportion*

Mix type	**Mix proportion by weight**			**Cement content (%)**	**Moulding water content (%)**
	Soil (%)	Sand (%)	IOT (%)		
A	50	50	0	7	12.15
B	50	37.5	12.5	7	12.79
C	50	25	25	7	14
D	50	0	50	7	15

2.3 Brick production

Manually operated press was used to make bricks. Soil, sand and IOT were dry mixed first and then cement was added and re-mixed. Wet mix was prepared by adding water content equal to 10% towards wet side of OMC corresponding to different tailing contents. Weight of wet mix to be pressed to make bricks of 230 x 110 x 70 mm size was controlled to achieve dry density of 1.8g/cc. The bricks so produced were cured for 28 days under wet burlap. The process of brick production using manually operated press is shown in Fig. 2.

Fig. 2 – *Production of compacted SMB using manual press*

3.0 Characterisation of bricks

3.1 Wet compressive strength

Masonry is commonly used to take compressive loads. Hence compressive strength of masonry units is an important characteristic to be considered in selection of bricks for construction of load bearing masonry members. The bricks were tested as per IS: 3495 (Part 1) [6] guide lines in a compression testing machine as shown in Fig. 3. Satisfactory brick strength in wet condition ensures even better strength in dry condition. The results obtained are given in Table -3.

Fig. 3 – *Brick under wet compressive strength test*

3.2 Initial Rate of Absorption (IRA)

Initial rate of absorption gives an idea on what rate the bricks tend to absorb water. This information is useful in understanding the rate of moisture transport from mortar to the brick in masonry construction. As the brick or block-mortar interlocking is mainly due to locking of cement hydration products from mortar [7], brick has to absorb right amount of water along with binder in order to facilitate the bond development. This experiment was carried out as per the procedure given in ASTM C-67 [8] and the results are presented in Table – 3.

3.3 Water absorption

Water absorption was determined as per the procedure laid down in IS 3495 (Part 2):1992 [9]. The bricks were dried till they achieve constant weight and then soaked in water for 24 hours. The water absorption during this period was calculated as percentage increase in weight and the results are presented in Table – 3.

3.4 Linear expansion on saturation

Dimensional stability of SMB is an important issue. This can be measured by monitoring linear expansion on saturation. The variation in length of oven dry bricks was measured in a length comparator set up fabricated in the laboratory and a brick under observation is shown in Fig. 4. Initial length of dry bricks was measured with a digital vernier. The dry bricks were first placed in the length comparator and initial reading of dial guage was recorded. The bricks were then soaked for 24 hours and again placed in the length comparator to measure the dial guage reading of saturated brick. The percentage change in length of dry bricks upon saturation is given in Table – 3.

Fig. 4 – *Length comparator*

Table – 3: *Test results of bricks*

* Number of specimens tested in each case: 8; Standard deviation values are in parenthesis

Mix type	Wet compressive strength (MPa)	Water absorption (%)	IRA (kg/m^2/min)	Linear Expansion (%)	Achieved dry density (g/cc)
A	6.89 (0.42)	12.13 (0.36)	0.59 (0.09)	0.046 (0.02)	1.83 (0.01)
B	6.76 (0.52)	12.35 (0.53)	0.655 (0.18)	0.031 (0.008)	1.84 (0.01)
C	6.77 (0.36)	13.22 (0.83)	0.568 (0.12)	0.041 (0.014)	1.82 (0.01)
D	6.63 (0.27)	15.07 (1.3)	0.582 (0.14)	0.035 (0.02)	1.82 (0.01)

4.0 Results and discussion

4.1 Mix proportions

The details of mix proportions at different IOT contents to replace sand are given in Table -1. The reference mix (i.e. "A") was first selected to have a typical standard mixture with optimum clay and sand contents. In this mix, the sand content was replaced by IOT at different percentage to get three more mix proportions. It was observed that higher the IOT content, higher was the water content to achieve required density. This is due to increase in surface area to be wetted due to finer IOT particles.

4.2 Water absorption, IRA, Linear expansion and Strength

Details of the test results of water absorption, IRA, linear expansion and wet compressive strength are given in Table -2. These results are average of 8 specimens. The water absorption of bricks increases with increase in IOT content to replace sand. The increase in water absorption is in the range of 12.13% to 15.07%. This may be because of increase in voids due to higher fine fraction in the mix. IRA values are also varying as IOT content to replace sand is varied. However, it is not possible to draw any strong conclusion as the variation is in a very narrow range (0.65 – 0.56 $kg/m^2/min$). Similarly, though there is variation, no adverse effect on linear expansion of bricks at different IOT content was observed. Expansion on saturation is within limits and the values fall within the upper limit of 0.1% suggested in earlier research work. This may be attributed to the fact that the clay content which is the main cause of volumetric change remains same in all the four mix proportions. From the results obtained, it is clearly seen that the wet compressive strength, which is the main parameter of concern shows negligible fall in average strength value of 0.25 MPa as the sand was completely replaced by IOT.

5.0 Conclusions

In the present study, sand content of a selected mix proportion for the production of SMB was replaced by iron ore tailings at different percentages. the results shows that it is possible to completely replace natural river sand by iron ore tailings without sacryfying on compressive strength of SMB. Water absorption increases with increase in iron ore tailings content but it is within limits. The results clearly demonstrate that iron ore tailings can be used as sand substitute in SMB production. The wet compressive strength of SMB is about 7MPa when 7% cement was used.

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