Available online at www.sciencedirect.com
ScienceDirect
Construction and Building Materials 22 (2008) 1614–1623
Construction and Building MATERIALS
www.elsevier.com/locate/conbuildmat

Influence of sand grading on the characteristics of mortars and soil–cement block masonry

B.V. Venkatarama Reddy [a,*], Ajay Gupta [b]

[a] Department of Civil Engineering, Indian Institute of Science, Bangalore 560 012, India
[b] Vintech Consultants, K 1/128, Chitranjan Park, New Delhi 110 019, India

Received 8 August 2006; received in revised form 20 June 2007; accepted 25 June 2007
Available online 13 August 2007

Abstract

Sand constitutes bulk of the mortar volume. Sand grading can influence the characteristics of mortar and masonry. Influence of sand grading on the characteristics of two types of mortars and soil–cement block masonry are examined in this paper. Three different sand gradings were used to examine the workability, strength, water retentivity, drying shrinkage and stress–strain characteristics of cement mortar and cement–lime mortar. Bond strength, compressive strength and stress–strain characteristics of soil–cement block masonry were also examined using these mortars. Major findings of the study are: (a) for a given consistency mortar with fine sand requires 25–30% more water, (b) as the sand becomes fine mortar compressive strength and modulus decreases while drying shrinkage increases, (c) fine sand reduces the tensile bond strength of masonry, whereas masonry compressive strength is not sensitive to sand grading variations and (d) masonry modulus reduces as the sand used in the mortar becomes finer.

Keywords: Mortar; Sand grading; Soil–cement block; Masonry; Stress–strain relation; Masonry strength

1. Introduction

Sand is the common ingredient for masonry mortars even though varieties of cementitious materials are used for mortars. Sand constitutes bulk of the mortar volume. Composition of sand and its grading can influence the characteristics of mortars in fresh as well as in hardened state. Also, it could influence brick–mortar adhesion and other masonry characteristics.

There are limited studies on the influence of sand grading on the characteristics of mortars and masonry. Drew and Braj [1] studied the effect of sand characteristics (fineness modulus, void ratio, specific surface, etc.) and water content of the mix on the mortar strength. The tests were performed on Scottish sand samples collected from 30 different places. They observed that water–cement ratio is the largest single factor affecting the compressive strength of mortar irrespective of different types of sand and sand grading. With the increase in void ratio (the percentage of voids in loose conditions) of sand, the water requirement for mortar increases for standard consistency. As the fineness modulus of sand decreases the requirement of water for a particular mix proportion increases. Specific surface of sand has no relation with the water requirement of mortar mix and it does not influence the mortar strength. Balen and Gemert [2] examined some properties of fresh mortar and observed that for a given consistency, mortars with very fine sand required up to 50% more water than similar mortars having normal sand grading. They also observed that the fine sand mortars have better water retentivity as compared to normal sand grading for a given mortar proportion. I.S. 2116 [3] gives grading limits for sand for use in masonry mortars as shown in Fig. 1. Similar sand grading limits can be found in ASTM C 144 [4], BS: 4551 [5] and many other codes of practice.

Anderson and Held [6] investigated the influence of sand grading on the bond strength of cement–lime mortar with three types of bricks. They found that the sand grading

* Corresponding author. Tel.: +91 80 2293 3126; fax: +91 80 2360 0404.
E-mail address: venkat@civil.iisc.ernet.in (B.V. Venkatarama Reddy).

0950-0618/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2007.06.014

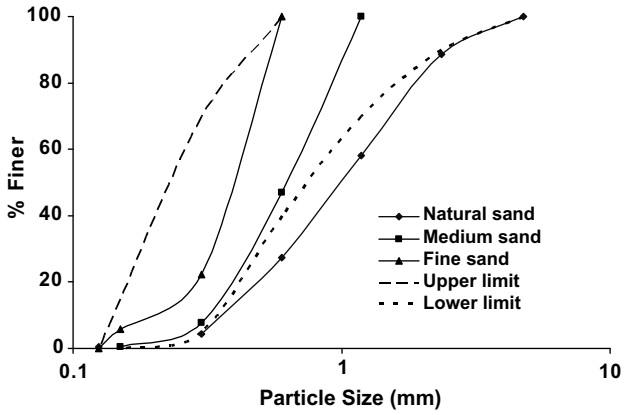

Fig. 1. Particle size distribution of sand.

significantly affects the tensile bond strength of mortar to brick. Mortars using fine sand results in lower bond strength. Groot [7] examined the tensile brick–mortar bond strength by means of cross couplet tests following ASTM C 952 [8] guidelines. Tests were performed on extruded clay bricks (dry), machine moulded bricks (prewetted $\sim$ 15% by mass) and calcium silicate bricks (prewetted $\sim$ 7% by mass). Portland cement mortar, lime–cement mortar and masonry cement mortar with different sand grading ranging from finer to coarser were used to cast the specimens. He observed that the mortars with coarser sand give better bond strength than with finer sand and the type of the masonry unit influences the bond strength more significantly rather than the grading of the sand.

There are limited numbers of focused studies pertaining to influence of sand grading on mortar and masonry characteristics. Hardly any literature exists on the effect of sand grading on the characteristics of mortar related to soil–cement block masonry. Hence, the present investigation is focused on the influence of sand grading on the characteristics of mortars in the fresh and hardened state, and its influence on the characteristics of soil–cement block masonry.

2. Scope of the work and the experimental programme

Influence of sand grading on characteristics of mortars in the fresh as well as in the hardened state and the characteristics of soil–cement block masonry were examined through an experimental programme. Grading curves of natural river sand was varied by removing a portion of the coarse fraction thus obtaining three different gradations for the sand. Characteristics of two types of mortars (cement mortar and cement–lime mortar) and soil–cement block masonry using these mortars were examined. Cement–lime mortar is the most commonly used mortar for masonry throughout the world. In India, cement mortar (1 cement:6 sand) is commonly used for load bearing masonry structures. Hence, in this investigation both cement mortar and cement–lime mortar have been selected. Table 1 gives details of the experimental programme.

3. Materials used in the investigation

3.1. Cement and lime

Ordinary Portland cement conforming to I.S. 8112 [9] was used for the manufacture of soil–cement blocks as well as for the mortars. Locally available commercial grade calcium hydroxide (lime) was used for cement–lime mortar. This is a non-hydraulic type lime.

3.2. Sand

Natural river sand was used in the experiments. Influence of sand grading and its fineness modulus on various properties was examined by reconstituting the natural sand having particles finer than 4.75, 1.18 and 0.5 mm. The grain size distribution curves of natural sand and reconstituted sands are shown in Fig. 1. Upper and lower bound limiting gradations for sand as specified in I.S. 2116 [3] code are also shown in the figure. The natural sand gradation curve falls outside the limiting gradation curves. Details of fineness modulus (FM) and designations of three types of sands used in the experiments are given in Table 1. FM of natural sand, medium sand and fine sand is 3.21, 2.45 and 1.72, respectively.

3.3. Soil–cement blocks

Soil–cement blocks are manufactured by compacting a mixture of soil, sand and cement at optimum moisture into

Table 1
Test programme for mortar and masonry characteristics

Mortar				Sand			Properties investigated							
Proportion (by volume)			Designation	Finer than (mm)	Designation	FM	Mortar					Soil–cement block masonry		
C	L	S					A	B	CS	D	E	T	CS	E
1	–	6	CMN	4.75	Natural	3.21	√	√	√	√	√	√	√	√
1	–	6	CMM	1.18	Medium	2.45	√	√	√	√	√	√	√	√
1	–	6	CMF	0.50	Fine	1.72	√	√	√	√	√	√	√	√
1	1	6	CLMN	4.75	Natural	3.21	√	√	√	√	√	√	√	√
1	1	6	CLMM	1.18	Medium	2.45	√	√	√	√	√	√	√	√
1	1	6	CLMF	0.50	Fine	1.72	√	√	√	√	√	√	√	√

C: cement; L: lime; S: sand; A: flow characteristics; B: water retentivity; CS: compressive strength; D: drying shrinkage; E: stress–strain characteristics; T: tensile bond strength; FM: fineness modulus.