Study on compressive strength of self compacting mortar cubes under normal & electric oven curing methods

G J Prasanna Venkatesh, S S Vivek* and G Dhinakaran

School of Civil Engineering, SASTRA University, Thanjavur-613401, India

*Email: vivek@civil.sastra.edu

Abstract. In the majority of civil engineering applications, the basic building blocks were the masonry units. Those masonry units were developed as a monolithic structure by plastering process with the help of binding agents namely mud, lime, cement and their combinations. In recent advancements, the mortar study plays an important role in crack repairs, structural rehabilitation, retrofitting, pointing and plastering operations. The rheology of mortar includes flowable, passing and filling properties which were analogous with the behaviour of self compacting concrete. In self compacting (SC) mortar cubes, the cement was replaced by mineral admixtures namely silica fume (SF) from 5% to 20% (with an increment of 5%), metakaolin (MK) from 10% to 30% (with an increment of 10%) and ground granulated blast furnace slag (GGBS) from 25% to 75% (with an increment of 25%). The ratio between cement and fine aggregate was kept constant as 1: 2 for all normal and self compacting mortar mixes. The accelerated curing namely electric oven curing with the differential temperature of 128°C for the period of 4 hours was adopted. It was found that the compressive strength obtained from the normal and electric oven method of curing was higher for self compacting mortar cubes than normal mortar cube. The cement replacement by 15% SF, 20% MK and 25%GGBS obtained higher strength under both curing conditions.

Key words: Self compacting mortar, silica fume, metakaolin, ground granulated blast furnace slag, compressive strength, oven curing.

1. Introduction

The appearance of any structure was made brittle, shiny, ornamental and aesthetic through the process namely plastering. The type of plastering constitutes materials such as lime, cement, cement-lime and stucco plastering. Strength of mortar should not be more than the strength of masonry unit and higher thickness could also be avoided. Once the failure occurs on the masonry unit, the plastering surface would sacrifice itself by formulation of cracks and propagating into the load bearing masonry wall. Thus it was regarded as non-structural cracks and could be repaired through maintenance. On recent developments of concrete and construction materials technology, the study on plastering (with different materials) plays a major role to cater the issues on crack repairs, damp proofing and rehabilitation issues of the structures. Self Compacting (SC) mortar was a highly fluid type which has the tendency to pass, fill and flow on the desired form to repair and rehabilitate the structures. The compressive strength of concrete cubes by different curing methods was studied and found that ponding method of curing obtained highest compressive strength than others [1].

The compressive strength of OPC mortar shown improvement (ranges from 57.5 MPa to 76 MPa at 7 and 90 days) and reduction was studied from the water curing period of 6 hours, air cured and after 20 hours of oven curing (by supplying 60 DC) [2]. An experimental investigation was made on lime-fly ash-gypsum mixtures for the masonry blocks by normal and accelerated curing methods.. It was found that steam curing for the duration of 24 hours at 80°C attained highest strength with the optimum content of gypsum as 2%. For normal curing conditions, the ratio of lime- fly ash of 0.75 obtained more compressive strength [3]. The humidity effects on mechanical properties of Portland cement mortars by formulating cube and prism specimens subjected to different curing conditions for simulating the effects of climatic conditions of Turkey regions was studied [4].

Study on self compacting concrete by replacing cement with fly ash, silica fume and by their ternary combinations were developed and found that cement replacement by 15% silica fume and 30% fly ash got highest compressive strength at 28 days of normal curing [5]. The compressive strength of cement mortars subjected to heated water curing for the duration of 20 hours and then air curing was resulted in highest compressive strength when compared with ASTM, BS and Iraq standards [6]. An experimental investigation on self compacting concrete using shrinkage reducing admixtures concluded that, the age of curing increases the pore size refinement and reduces shrinkage at early ages [7]. The research on self compacting mortar (SCM) containing mix proportions of 1:1 and 1:3 with w/c ratio of 0.34 and 0.5; with the influence of self curing chemicals namely Polyethylene Glycol 4000 & 200 enhance fresh properties, strength and durability [8].

Study on OPC replacement in binary/ ternary blend system using fly ash and spent fluid catalytic cracking catalyst improved the compressive strength up to 106 MPa at the age of 90 days [9]. The influence of zeolite and metakaolin on compressive strength of lime mortars under different humidity conditions of curing was investigated and the effect of pozzolanas cause reduced shrinkage on lime mortars was concluded [10]. For developing precast products, 50% of cement was replaced by fly ash, ground granulated blast furnace slag and rice husk ash under different curing methods and found that mortar specimens cured under hot water resulted on highest compressive strength (Evi et al., 2016) [11]. By simulating the climatic conditions of spain under curing conditions reveal that the micro structure C-S-H link was stable at higher temperatures and thus improved the mechanical properties of self-compacting concrete was studied [12]. SCC flow properties and compressive strength using silica fume as cement replacement was studied [13]. The research on metakaolin based SCC by determining fresh properties and compressive strength [14].

The simple way of SCC mix design was developed [15]. SCC mix was designed using metakaolin as cement replacement [16]. The mix design of SCC and its fresh properties test was conducted according to EFNARC guidelines [17 & 18]. In present study, the self compacting mortar (SC) cube was developed with replacing cement by three mineral admixtures namely, metakaolin (MK) from 10% to 30% (with an increment of 10%), silica fume (SF) from 5%to 20% (with an increment of 5%) and ground granulated blast furnace slag (GGBS) from 25% to 75% (with an increment of 25%) respectively. Finally the comparison of compressive strength was made between conventional cement mortar and self compacting mortar cubes in terms of normal water and electric oven curing methods.

2. Material used

Cement: OPC 53 grade of ASTM Type I [20] was used.
Fine aggregate: Natural river sand free from impurities (< 4.75 mm) grading Zone III of ASTM was used. The physical properties were determined as per ASTM 127 and their particle size distributions confirmed to the requirements of ASTMC33 [21].

Mineral admixtures: silica fume (SF) from 5% to 20%, metakaolin (MK) from 10% to 30% and ground granulated blast furnace slag (GGBS) from 25% to 75% was used as cement replacement as per ASTM C 1240-99 [19 & 22].
Chemical admixtures: High range super plasticizer (1.25% by weight of cement) and stabilizer (0.1% by weight of cement) were used for making flow of mortar and to control segregation of mix.
Water: water free from acid and base was used.

3. Experimental Programme

3.1 Basic test on materials

The constituent materials of the experimental programme where undergone the following tests namely, consistency and initial setting time of cement, specific gravity of cement, SF, MK and GGBS was determined. In order to study the properties of fine aggregate, the test on fineness modulus was conducted.

3.2 Mix proportions

For conventional mortar cubes (based on consistency test results water-cement ratio was achieved. But for self compacting mortar cubes, the water-powder ratio was fixed by adjusting the dosages of water content, super plasticizer and stabilizer (VMA). Hence the cement mortar mix proportion of 1:2 with water- cement ratio of 0.38 was used for both.

3.3 Fresh Properties test - Slump test

For ascertaining the flow behaviour of self compacting mortars by different mineral admixtures replacement, slump flow test was conducted and spread of mortar flow diameter was measured. It was done by pouring of mortar mixes on Abram's cone of dimensions, top and bottom diameter 10 cm and 20 cm with a height of 30 cm. After filling of mortar up to the top level of cone without compaction, lifted up and the resulting flow measured by spread diameter was studied.

3.4 Preparation of mould & de-moulding

The timber mould was prepared with inner dimensions of 100 mm x 100 mm x 100 mm and properly dressed with application of oil coat on its inner surfaces. Then prepared ordinary cement mortar (CM) was poured and well compacted. But for self compacting mortars, the fresh mortar was poured on the mould without any compaction (Figure 1a & 1b). After 24 hours of casting, the cubes were removed from the mould and allowed for curing (Figure 2a, 2b & 2c).

Figure 1a. Mixing of fresh SC mortar

Figure 1b. Pouring of fresh SC mortar

Figure 2a. Casting of SC mortar

Figure 2b. Hardened state SC mortar

Figure 2c. State of cube specimens after de-moulding

3.5 Curing methods

The curing of cube specimens were undergone two series namely, series 1 consists of normal water curing for the age of 3, 7, 14 and 28 days respectively and the series 2 comprise of an accelerated curing method namely electric oven curing method (Figure 3) was adopted by maintaining initial temperature of 30°C and dried with differential temperature of 128°C for the duration of 4 hours.

Figure 3. Cube placements in Electric oven

3.6 Compressive strength

Once curing was completed by two methods, the compressive strength between conventional and self compacting mortar cubes was determined by Automatic Compression Testing Machine (ACTM) (Figure 4). The specimen was loaded up to the state of failure and fracture took place.

Figure 4. Test on Compressive strength of cube specimen

4. Results

The results obtained from the experimental programme illustrates mechanical properties of conventional and self compacting mortars by cement replacement with different mineral admixtures (SF,MK & GGBS) under normal and electric oven curing methods were discussed as follows:

Table 1. Basic test on materials

Fine aggregate	Fineness modulus:3.16
	Specific gravity:2.55
Cement(OPC)	Initial setting time:31 minutes
	Std. consistency:31%
	Specific gravity:3.13
Metakaolin (MK)	Specific gravity: 2.5
Silica fume(SF)	Specific gravity:2.1
GGBS	Specific gravity:2.81

Table 2. Self compacting mortar fresh property test

Self compacting mortar mix	Slump flow values (mm)
SF 5%	680
SF 10%	710
SF 15%	725
SF 20%	665
MK 10%	695
MK 20%	750
MK 30%	660
GGBS 25%	655
GGBS 50%	780
GGBS 75%	705

Table 3. Compressive strength on Cube mortars (in MPa)

Mix	Compressive strength				Compressive strength of Electric oven curing at 128°C for 4 hrs
	3Days	7 Days	14 Days	28 Days	
CM	19.68	28.71	42.54	47.60	52.54
SF 5%	18.73	27.32	43.54	45.08	54.25
SF 10%	19.18	29.23	42.67	49.11	53.98
SF 15%	19.86	29.94	41.92	50.00	56.72
SF 20%	20.07	28.42	44.27	45.76	52.94
MK 10%	22.32	30.65	44.23	49.65	51.64
MK 20%	21.45	29.98	45.1	48.87	55.17
MK 30%	22.75	31.23	42.79	50.75	53.84
GGBS 25%	23.69	32.87	49.72	53.25	54.63
GGBS 50%	21.56	30.23	41.17	49.27	52.19
GGBS 75%	17.21	27.23	39.99	44.25	50.07

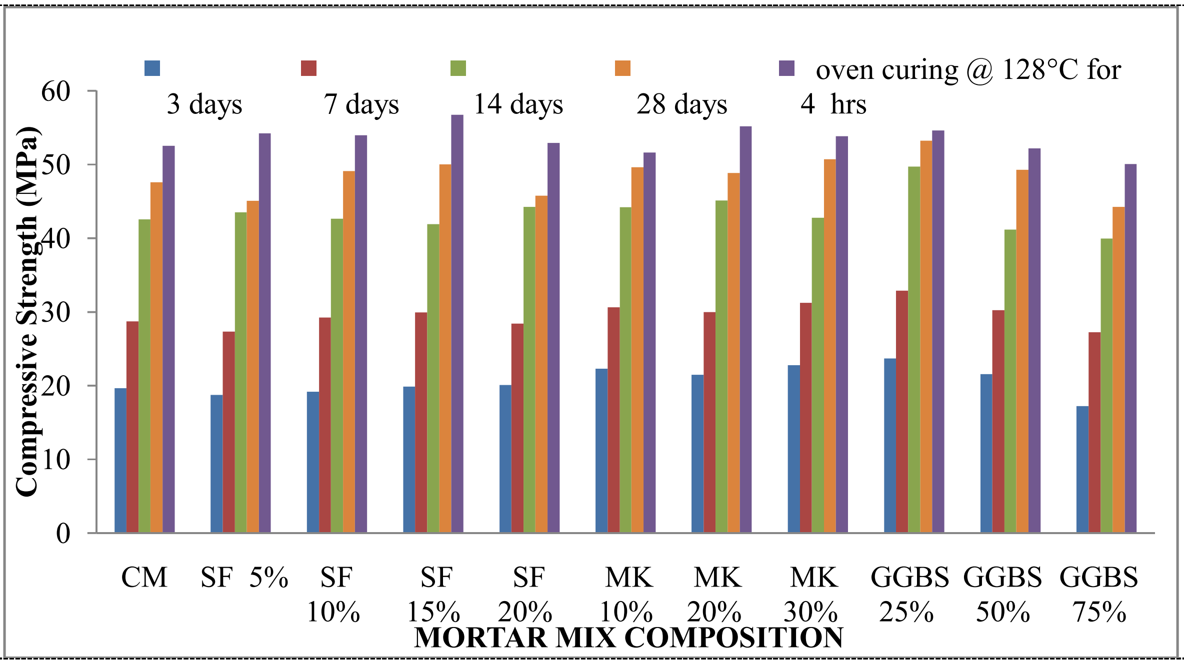

Figure 5 Compressive strength (MPa) Vs Mortar mix

4.1 Discussion

4.1.1 SC mortar by Slump flow test. This study was similar to slump test conducted in laboratory. Self compacting (SC) mortar which was replaced by three mineral admixtures was considered (Table 2) . Within SF mixes, the SF 15% made highest slump flow value compared to SF 5%, 10% & 20% respectively. It was due to optimum powder content causing influence on flow ability of SC mortar. The slump flow was made possible by fixing optimum water-powder ratio content and the optimum dosages of super plasticizer and stabilizer. In cement replacement by MK 10% to 30%, MK 20%

shown better results in comparison with other MK percentages. The mortar mix containing MK more than 20%, made the restriction on flow behaviour was noted by the lesser slump value of MK 30%. As higher the powder content the flow and the rheology of mortar gets modified. When cement mortar was replaced by GGBS from 25% to 75%, 50% replacement had shown better results, this was due to refinement of pore space causing flow ability of mortar. For the above slump flow values, the recommended range of values were taken from European Federation of Nationalised Association Representing Concrete (EFNARC Guidelines). From the overall slump flow results, GGBS 50% having spread diameter of 780 mm was higher than SF and MK mixes was due to the homogeneous behaviour between cement and mineral admixtures.

4.1.2 Mortar Compressive strength by normal curing. The cube mortar specimens prepared by conventional cement mortar and self compacting mortar containing mineral admixtures were undergone normal water curing for 28 days (Table 3). It was tested for 7 days compressive strength and obtained minimum 60% of strength achieved by self compacting mortars. The maximum compressive strength obtained by SC mortar- GGBS 25% was 10.61% higher than conventional cement mortar was due to the formation of denser C-S-H gel because of addition of slag as cement replacement at the age of 28 days. Similar trend was obtained for SF15% and MK 30% addition as partial cement replacement.

4.1.3 Mortar Compressive strength by oven curing. It was possible to obtain more than 100% of compressive strength by accelerated curing methods for the total duration of 7 hours. In present work, the cube specimens were undergone electric oven curing from the initial temperature of 30°C to the final temperature of 158°C for the duration of 4 hours after 24 hours of casting. This study resembles the precast applications where accelerated technique namely steam curing was adopted. Hence for model specimens like cubes, etc., electric oven curing was feasible and for prototype the electric furnaces were applicable. Hence the fineness of powder content governs the early strength gain. As the fineness of powder content more than 40 microns leads to later age strength gain and below 7 microns leads to early age strength gain. Here the powder content of SF 15%, GGBS 25% and MK 20% as individual cement replacement improved the refinement of pore space and also the fineness of SC mortar (Table 3). Hence within the 4 hours of electric oven curing , the early gain of compressive strength was obtained and it was higher than the normal curing by 14% (SF 15% & MK 20%) respectively.

5. Conclusion

From the above experimental programme and with the results obtained, the following conclusions were drawn.The flow behaviour of self compacting (SC) mortar was achieved by optimum dosages of chemical admixtures and water-powder ratio by keeping cement mortar proportion of 1:2. The slump flow of SC mortar was well within the limit of EFNARC guidelines. The highest compressive strength of SC mortar by replacing cement with SF 15%, MK 30% and GGBS 25% was obtained under normal water curing conditions. The obtained compressive strength values of electric oven curing was higher than normal water curing method.In SC mortar, the fineness of powder content improved early age strength in oven curing and it was obtained for SF 15%, MK 20% and GGBS 25%. The present study can also be applicable for pre-cast applications by changing the oven curing method into steam curing. Hence binary blend of SC mortar was considered for present study, further developments can also be prepared by SC of the ternary blend type.

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