Enhancement of Strength In Cement Mortars Containing Granite Powder

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Abstract - Solid waste management is a big challenge in all around the world. Granite slurry generated from granite stone processing industry is a prime source of solid waste produced in Rajasthan. The generated slurry is indiscriminately dumped on vacant lands, river banks or forest areas. These slurry particles being fine enough are capable of filling pores of the soil, preventing water percolation and making the land futile. In this experimental study, granite powder (dried granite slurry) was used for the production of 1:4 and 1:6 cement mortar mixes. In order to improve performance parameters of mortars containing granite powder (GP), it was planned to use coarse sand (CS) of zone-II to negate the effect of excessive fines. Ratio of 60:40 and 70:30 of CS:GPsatisfied gradation recommended by standards for plaster and masonry mortars. For 1:4 mortar proportion, the adhesive strength increased by 21% and 23% for CS30 and CS40 mixes, respectively as compared to control mortar (FS). Drying shrinkage of cement- sand-granite mortar found to be similar with that of control mortar in 1:4 mix proportion but drying shrinkage in 1:6 proportion exceeded in the range of 20 to 60%. On exposure of mortars to a 5% sulphuric acid medium, portlandite and katoite are converted into gypsum and ettringite, respectively which reduced adhesion between particles of mortars and results in 22% decline in compressive strength at 28 days exposure period. No significant variation in performance across all themixes was observed when mortar mixes were subjected to 20 cycles of alternate wetting and drying. Hence, granite powder as partial substitute (30-40%) of sand in cement mortar mixes has no adverse effect on mechanical as well as durability properties of cement mortar.

Key Words: Compressive strength, Workability, Tensile bond strength, Adhesion test.

1. INTRODUCTION

Development of society demands the urbanisation. Urbanisation requires a good infrastructure to achieve economic growth. In order to achieve the economic growth a rapid industrialization is required in society. The industrialization promotes the consumption of natural resources and generates waste as by-product. Such wastes are dumped in open lands which create a lot of pollution for surroundings. The waste also has disturbed the ability of nature to self-regulation of temperature and atmosphere. For the betterment of upcoming generation, an adoption of sustainable development of society should take place which wouldbalance both living and non-living being on earth.

1.1 Industrial waste used as ingredient for cement composites

A good number of researches are available which have proved that the industrial wastes have potential to be used as cement and aggregates (both coarse and fine aggregate) inconcrete as well as in mortar. Some of recommendations are given in standards. IS 455:1989 recommended that 65% ordinary Portland cement (OPC) can be replaced by ground granulated blast furnace slag (GGBFS). Recommendations for 25% replacement of OPC by fly ash has been given by IS 1489:1991. Use of recycled aggregate, steel slag, iron slag and bottom ash as fine and coarse aggregate in both plain and reinforced concrete to some extent has been allowed by IS 383:2016.

1.2 Objectives of study

There is a need for comprehensive evaluation of performance of mortar mixes with a wide range of mix proportions with granite powder in place of river sand. Therefore, the objectives of the study are:

1. To characterize the waste granite powder obtained from granite processingindustries.
2. To evaluate physical and mechanical properties of mortars made with waste granitepowder as a partial substitute for fine aggregate.
3. To assess the durability characteristics of mortars made with granite powder when exposed to adverse environment.

2. MATERIALS AND METHODS

2.1 Portland pozzolana cement

For the experimental program, Portland pozzolana cement (PPC) was utilized conforming to the specifications set by IS 1489 - Part 1 (1991). The physical properties are presented in Table-1. The scanning image of PPC is shown in Figure-1.

Table -1: Physical properties of PPC

Property	Value
Specific gravity	2.9
Bulk density (kg/m3)	1100
Normal consistency (%)	33
Initial setting time (min)	129
Final setting time (min)	231
Compressive strength after 28th days of curing(MPa)	36

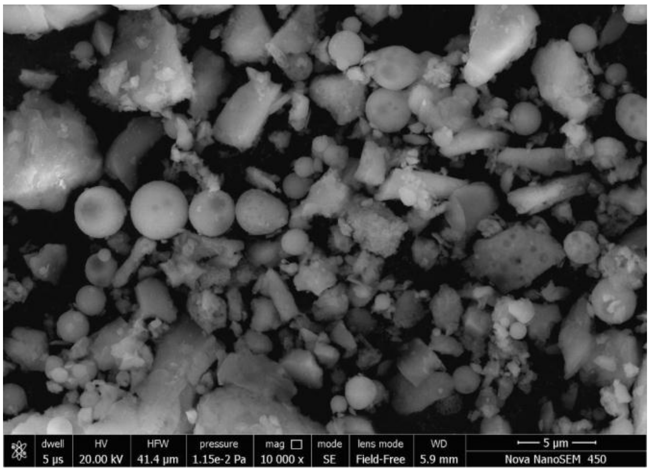

Fig -1: Scanning Image of PPC

2.2 Natural river sand

Two types of conventional natural river sand were used: (i) Coarse river sand (CS), conforming to zone-II as per IS: 383

(ii) Fine river sand (FS), conforming to IS: 2116- 1980 (sand for masonry mortar) and IS: 1542-1992 (sand for plaster).

Both conventional natural river sands were procured locally. Based on the particle size distribution which is represented in Figure-2, they were designated as coarse sand (CS) and fine sand (FS).

Physical properties of both sands are enlisted in Table-2. The SEM image of both sands are shown in Figures-3 and 4 From SEM image it is clearly observed that both natural sands have smooth and rounded surface

Table -2: Physical properties of CS, FS and GP

Fine aggregate	Specific gravity	Water absorption (%)	Loose bulk density (kg/m3)	Fineness Modulus
Coarse river sand (CS)	2.68	7.05	1597	2.65
Fine river sand (FS)	2.65	8.83	1545	1.65
Granite powder (GP)	2.46	15.29	1368	0.9

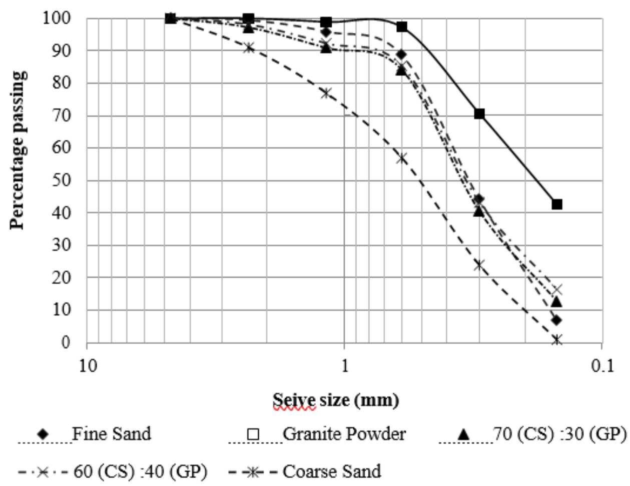

Fig -2: Particle size distribution of used fine aggregate

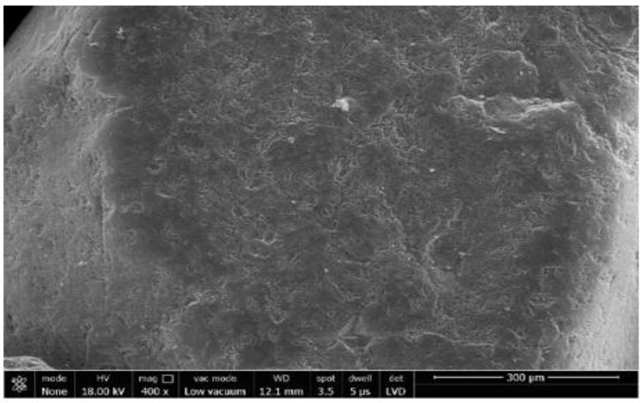

Fig -3: SEM image of coarse river sand (CS)

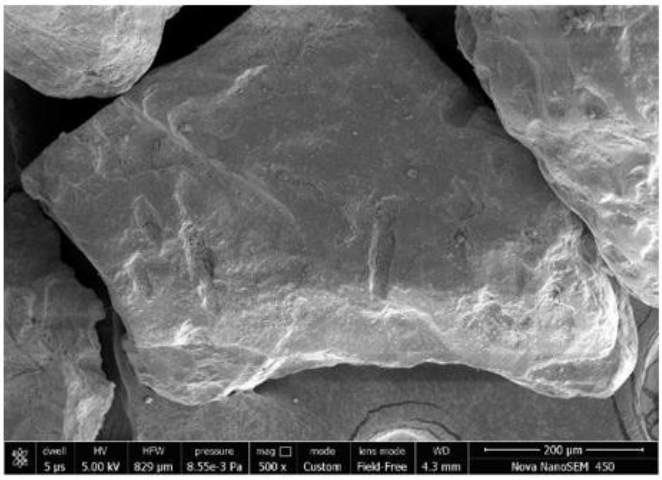

Fig -4: SEM image of fine river sand (FS)

2.3 Natural river sand

In line with the set objectives, river sand was replaced in different proportions by GP for the production of cement mortars. The experimental study was carried out on mortars with mix proportions of 1:4 and 1:6. Two types of conventional natural river sands were used in two stages of this investigation.

In this stage, FS (zone – IV) conforming to IS 2116 (1980) and IS 1542 (1992) was used for the preparation of control mortar. This fine sand was replaced by GP from 0% to 100% in steps of 10% by volume. Quantities of materials required to produce one cubic meter of mortar is given in Table-3 Workability, fresh density, compressive strength, water absorption and permeable voids were evaluated and their results were compared with those ofcontrol mortar.

Table -3: Quantities of materials to prepare one cum of mortar mixes

% Replacement	1:4 Mix				1:6 Mix			
	Cement (kg)	FS (kg)	GP (kg)	Water (kg)	Cement (kg)	FS (kg)	GP (kg)	Water (kg)
0	273	1534	-	328	189	1591	-	337
10	269	1362	135	344	189	1432	141	344
20	266	1195	266	354	188	1268	281	348
30	268	1054	400	351	188	1108	420	351
40	271	913	539	347	187	948	559	354
50	271	760	674	349	186	784	694	361
60	270	607	804	354	185	624	829	366
70	268	453	933	359	183	464	958	374
80	265	297	1056	369	182	306	1085	382
90	261	146	1171	379	180	151	1206	391
100	258	-	1283	390	178	-	1331	398

In this stage, CS (zone – II) and GP were combined such that the resulting composite fine aggregate mixture satisfied the gradation requirements stipulated by IS 2116 (1980) and IS 1542 (1992). Based on trials, the required gradation was achieved when 30% to40% of CS was replaced by GP. Hence mortar mixes of the same two proportions were prepared in which GP constituted 30% and 40% of fine aggregate volume. Quantities of materials required to produce one cubic meter of mortar is given in Table-4. Initially parameters like workability, fresh density and compressive strength were evaluated. These results were compared with those of control mortar prepared by fine sand in Phase-I.

Table -4: Quantities of materials to prepare one m^3 of mortar mixes in second stage

Mix	Cement (kg)	CS (kg)	FS (kg)	GP (kg)	Water (lit)
4FS	273	-	1534	-	328
4CS-30	279	1136	-	416	313
4CS-40	277	964	-	551	322
6FS	189	-	1591	-	337
6CS-30	192	1171	-	430	323
6CS-40	193	1009	-	575	327

2.4 Compressive strength test

The compressive strength test was experimented on 7 and 28 days water cured mortar cubes as per IS 2250 (1981). For each selected curing period (7 and 28 days) four cubes of size 50 mm were tested using a compressive strength testing machine and the achieved values were recorded. The load was applied at a uniform rate of 2 to 6 N/mm^2 per minute on the specimen. The average of the four values was recorded as the compressive strength at the selected age.

Fig -5: Compressive strength of mortar

2.5 Compressive strength test

The tensile bond strength test was performed to determine the bond strength of masonry in tension by crossed-brick couplets method. This test followed the guidelines provided in ASTM C 952 (2002). A crossed brick couplet specimen was prepared using two bricks and bonded together using square mortar paste having each side of 92 mm and 13 mm depth. The formed specimen was compacted using a drop hammer of weight 900 g.

Fig -6: Testing of bricks couplet for bond strength test

2.6 Adhesion Test

This test was conducted to determine the adhesive strength of hardened mortar as plaster on a particular stratum as per the guidelines given in BS EN 1015-12 (2000). A layer of 10 mm fresh mortar was applied on the brick and the specimens were kept in air tight polythene bag at a temperature of 20° C for 7 days. Then these samples were taken out from the polythene bag and were further kept for 21 days in a room having controlled temperature of 20° C and relative humidity of 65%. A core of 50 mm diameter was drilled into the hardened layer of specimens and then the pull heads were attached to the core using a suitable adhesive. A tensile load was applied perpendicular to the test area through pull heads to measure the strength.

Fig -7: Testing of adhesive strength of cement mortar

3. RESULTS AND DISCUSSIONS

Properties of rich and lean cement mortar trial mixes prepared with air dried granite powder were evaluated and compared with those of reference mortar. After this a gradationas per BIS 1542 and BIS 2116 was attempted by mixing coarse river sand (CS) and granite powder (GP) in order to achieve the required specifications of fine aggregate in mortar. The recommended proportion was 70:30 and 60:40 for CS:GP mortar mixes. Mechanical and durability properties were evaluated for mortar mixes 1:4 and 1:6. The results and discussions are presented in detail in subsequent paragraphs.

3.1 Workability

The requirement of water for required flow as per BIS 2250 (1981) is shown in Figure-8.

1. The required flow for mix 1:4 was achieved at 1.2 water-cement (w/c) ratio for reference mortar specimen and at 1.59 for mix containing 100% GP.

2. An appreciable increase in w/c ratio was observed as 27% for maximum utilization of GP in mortar. For other mix 1:6 the increase in water demand was 22%.

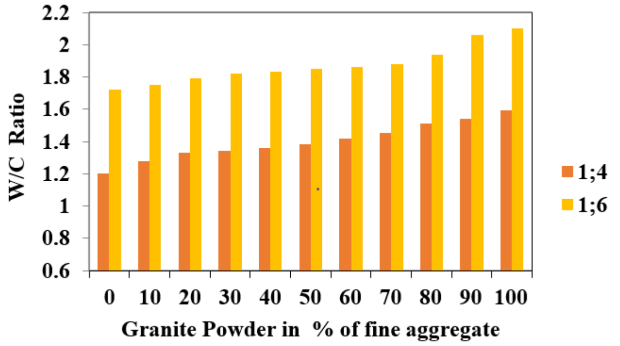

Fig-8: Water-cement ratio of mortars

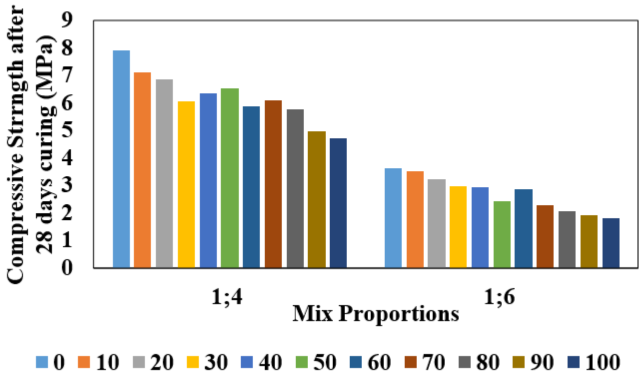

Fig-9: Compressive strength after 28 days

1. The least compressive strength after 28 days of curing was 4.7 MPa and 1.81 MPa for 1:4 and 1:6 mix proportion, respectively which is obtained for mortar mixes prepared with 100% GP. From the above tests on mortars with FS and GP, it was observed that performance of mixes with GP declined as compared to control mortar.

2. The reduction in workability, fresh bulk density and compressive strength is due to presence of excessive finer fraction of granite powder in mortar mixes.

3. Uniform size of GP was unable to fill voids in mortars which are responsible for decline of performance.

4. Therefore, to get the mix well graded and at the same time conforming to BIS:1542 and BIS:2116, it was planned to use coarse sand falling in zone-II in place of FS.

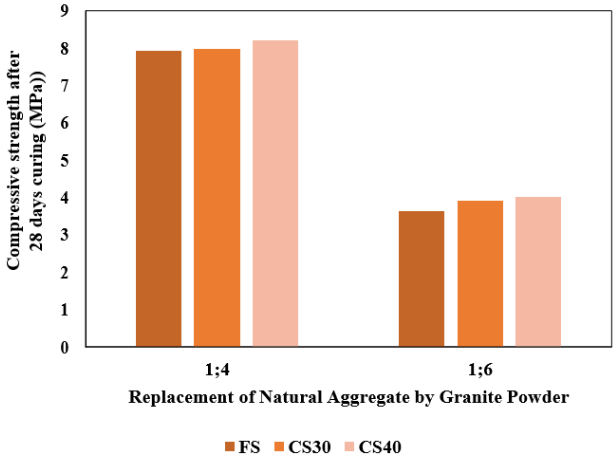

Fig-10: Replacement of Natural Aggregate by Granite Powder

This increment in compressive strength may be due to the decrement in w/c ratio as compared to control mortar. The angular shape of particles as seen in SEM images (Refer Fig-10) also enhances bond between aggregate thus resulting in higher strength. The observed compressive strength values for CS30 and CS40 mixes were higher than the minimum recommended values for respective mortars 3 MPa and 7.5 MPa as recommended by IS-2250:1981.

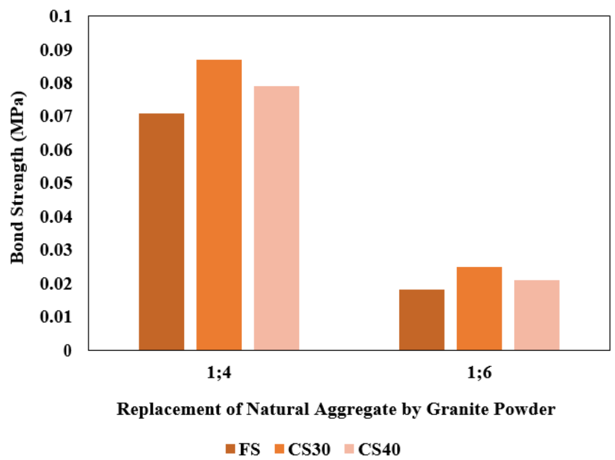

Fig-11: Tensile bond strength of mortar mixes at 28 days

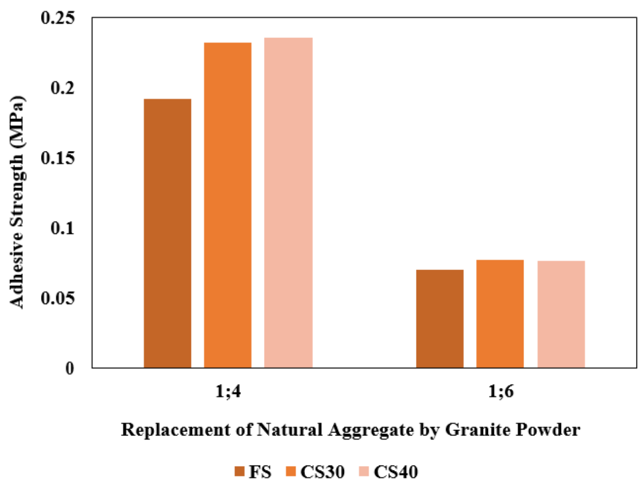

Fig-12: Adhesion of mortar mixes at 28 days

4.CONCLUSION

1. Water requirement to achieve required flow for mortars with GP slightly reduced as compared to that of control mortars.

2. Water absorption capacity and permeable voids of cement mortars with GP were found to be comparable to those of control mortar.

3. The marginal increase in compressive strength for cement mortars prepared with GP was observed due to reduction of water requirement. Angular shape of particles of GP might have enhanced the bond between aggregates.

4. The maximum hike up to 27% in UPV values was observed for mortar with GP when compared with control mortar. It was probably due to better packing of particles in mortar matrix.

5. Dynamic modulus of elasticity has also improved for mortars with GP due to less w/c ratio.

6. Tensile bond strength of 1:4 and 1:6 mixes increased by 23% and 39%, respectively. Lesser water requirement in GP mortars has provided better bonding between brick and mortar that is why bond strength for such mortars was increased by 39%.

7. Adhesive strength has increased by 23% and 10% in 1:4 and 1:6 mix proportions, respectively. All mixes of 1:4 series failed at the interface between the brick and mortar, whereas cohesive failure was observed in mortar mixes 1:6.

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