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The Effect of Waste Granite Powder on the Physical and Mechanical Properties of Cement Mortar

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Abstract

The major goal of this study is to give an alternative to traditional fine aggregate for cement mortar manufacture. For this experiment, two commonly used mortar mix proportions (1:4 and 1:6) were chosen, with granite powder with a fineness modulus of 0.9 serving as fine aggregate. The experiment was carried out in two stages. In the first stage, granite powder was used to substitute fine sand with a fineness modulus of 1.65 in the range of 0% to 100%. The results of workability, fresh bulk density, compressive strength, and water absorption were compared to those of a control mortar. The results showed that when river sand was completely replaced with granite powder, the w/c required to obtain the acceptable workability increased from 1.2 to 2.3. As a result, the compressive strength of these mortar mixes decreased by 41% while water absorption increased by 56%. Granite powder was used to replace 30 percent and 40 percent of the volume of fine aggregate in the second stage. The remaining fine aggregate volume was made up of coarse sand with a fineness modulus of 2.65.

Keywords: Waste Granite Powder, Cement Mortar, Physical and Mechanical Properties

1. Introduction

The Indian state of Rajasthan holds over 20% of the country's total granite deposits. The extracted granite block is sawed and polished with modern techniques to produce a completed product of granite dimensional stone. However, the amount of fine granite dust mixed with water (granite slurry) formed as a byproduct of this industrial operation is significant. The water in the granite slurry (GS) evaporates during dumping, leaving only fine granite dust. This granite powder (GP) gets lifted by the wind and

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blows everywhere, causing environmental and health issues. GP can cause breathing problems and lung ailments in people. Because GP is fine in nature, it plugs the gap between soil particles, reducing fertility and preventing water from percolating into the ground. When GS is dumped in a haphazard manner near riverbeds and lakes, it can degrade the quality of open water sources and harm aquatic life. As a result, for the granite dimension stone sector to be viable, managed GS disposal is critical.

On the other hand, the country's economic progress necessitates a strong infrastructure, which can assist improve the residents' quality of life. The construction materials sector relies on limited natural resources to develop infrastructure. Natural stones in the form of fine aggregate are required in cement composite-based building products. Given the current state of environmental issues, obtaining high-quality fine aggregate is a major task. According to a paper titled "Material Consumption Patterns in India" published by a German company, India will require 1.4 billion tonnes of fine aggregate for construction every year by 2020. In addition, the need for fine aggregate for mortar preparation alone will reach 248 million tonnes per year. The main source of fine aggregates for the aforesaid massive demand is sand from riverbeds. Aside from river sand, there are other industrial by-products that can be utilised to partially replace it as fine aggregate. However, the supply of such waste products is limited and varies by area. As a result, for a state like Rajasthan, which has problems with GP waste from granite production, using it as fine aggregate appears to be a profitable choice. This approach will assist in resolving GP disposal issues while also reducing the use for natural fine aggregate in building.

GP has been studied as a fine aggregate and alternative binder in concrete and brick manufacturing in many studies. There is virtually little research on mortars made with GP in the literature. Bonavetti and Irassar (1994) were the first to discover that replacing sand with granite dust increased the compressive and flexural strength of mortars by 10%. Marmol et al. (2010) developed coloured and masonry mortars using granite cutting waste (up to 10% substitution of cement) without sacrificing compressive strength. Ramos et al. (2013) found that using granite sludge waste as a partial replacement for cement, up to 10%, improves the durability of mortars. According to A.O. Mashaly et al. (2018), replacing up to 20% of cement with granite sludge has no significant impact on the physical, mechanical, or durability aspects of mortars.

1.1. Granite Powder

The finer proportion of granite powder is derived from the crusher machines. Samples containing 40 percent granite powder had the maximum compressive strength. Granite powder, due to its spherical form and tiny size, disperses rapidly in the presence of super plasticizer and fills the spaces between the quarry sand, resulting in a well-packed concrete mix.

Granite powder can be used as a filler since it reduces the amount of total voids in concrete. The pozzolanic reaction is improved by granite powder and quarry rock dust. Quarry rock dust and granite

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powder can be used in concrete to completely replace natural sand. The compressive, split tensile, and durability tests of quarry rock dust concrete were about 15% higher than ordinary concrete. Concrete's resistance to sulphate attack was considerably improved.

2. Literature Review

Bashar Taha and Ghassan Nounu. 2009 The use of waste recycled glass in concrete as recycled glass sand and pozzolanic glass powder has been investigated. The inclusion of recycled glass sand replacement had no significant effect on the compressive strength of concrete. When 20 percent of Portland cement was replaced with pozzolanic glass powder, the compressive strength of concrete decreased by 16 and 10.6 percent at 28 and 364 days, respectively. According to British Standard BS 812 part 123:1998, the potential expansion of concrete due to alkali-silica reaction was monitored. The use of recycled glass sand as a concrete replacement carries a significant risk of alkali-silica reaction growth. When recycled glass sand was utilised as a sand substitute in concrete without any safeguards to reduce the possibility of alkali-silica interaction, such as ground granulated blast furnace slag, Metakaolin, and lithium nitrate, cracks were detected. When the alkali-silica reaction suppressor was employed in concrete, the expansion associated with the reaction was greatly decreased.

Felix F. Udoeyo and Abdul Hyee. 2009 The compressive, split tensile, and flexure strengths of concrete incorporating cement kiln dust as a substitute for conventional Portland cement have been investigated. The study looked at replacement levels of 20, 40, 60, and 80 percent. For comparison, plain concrete containing cement kiln dust was also made. The findings of the study revealed that the strength of cement kiln dust concrete was often lower than that of the reference concrete. However, when up to 20% of the OPC in the concrete was replaced by cement kiln dust, the percentage drop in strength was modest. The findings of the study also verified a prior report that when cement kiln dust is utilised instead of cement, the setting time of cement paste increases.

Radhikesh P. Nanda, Amiya K. Das, Moharana N. C. 2010 The results of a parametric trial for constructing clearing squares with crusher tidy are shown. The physical and mechanical characteristics of eliminating obstructions with fine total substituted by various levels of crusher tidy are investigated. The test results show that substituting fine total by crusher clean up to half by weight has no effect on the loss of any physical or mechanical attributes while saving 56 percent of the money. This also reduces the weight of dumping crusher clean on the ground, reducing environmental pollution.

Divakar Y. , et al. , (2012) The compressive strength of the concrete has risen by 22% as a result of a 35% replacement of fine aggregates with granite fines. With a 50 percent increase in granite particles, the compressive strength will only rise by 4%. For 0 percent, 25%, and 35%, the split tensile strength stays the same. There is a 2.4 percent improvement in strength for a 5 percent replacement, and an 8 percent drop in tensile strength for a 15% replacement. However, we can conclude that when 35

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percent granite fines are replaced with completely sand as fine aggregates, the test results reveal no reduction in strength when compared to the normal mix. We can conclude from the flexural strength of a prism of 10cm x 10cm x 50cm without reinforcement that there is a 5.41 percent increase in flexural strength with a 5 percent replacement, a small decrease in flexural strength up to 5% with 15 percent, 25 percent, and 35 percent replacement with granite fines, and a further reduction in strength (i.e. 6 percent) with a 50 percent replacement with granite fines in comparison to test results of nominal concrete However, none of the adjustments affect the results of the flexural strength test.

3. Material Components

The experimental programme made use of pozzolanic Portland cement (PPC) that met the IS 1489 - Part 1 standards (1991). The specific gravity and loose bulk density, respectively, were found to be 2.9 and 1100 kg/m3.

A local trader in Rajasthan provided river sand with two particle size variations. They were classified as coarse sand (CS) and fine sand (FS) based on particle size distribution (FS). IS 383 classified CS and FS as zone II and zone IV, respectively (2016). Table 1 lists the physical characteristics of the samples.

Table.1: Physical properties of fine aggregates

FINE AGGREGATE	SPECIFIC GRAVITY	WATER ABSORPTION (%)	LOOSE BULK DENSITY (KG/M^3)	FINENESS MODULUS
	IS 2386 Part 3 (1963)			ASTM C 33
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

Granite powder (GP) was obtained at Shahpura Stone Processing Industry in Shahpura, Rajasthan, to replace sand in cement mortar. Before being characterised and used in mortar manufacturing, GP was sun dried to reduce moisture. Following particle size analysis, it was discovered that GP belongs to the IS 383 (2016) zone - IV category. Table 1 lists the physical features of GP.

The X-ray fluorescence (XRF) technique was utilised to conduct chemical analysis on all fine aggregates employed (CS, FS, and GP) (Table. 2). The proportion of silica (SiO2) in all three fine aggregates was essentially similar, as seen in this table. In GP, Fe2O3 and CaO were almost non-existent. GP had somewhat greater levels of Al2O3 and Na2O than both sand samples.

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SEM (Scanning Electron Microscopy) was used to examine the microstructure of tiny aggregates. Figure 1 depicts the SEM images of CS, FS, and GP. Both ordinary sands have a smooth and rounded surface, whereas granite powder has a rough and angular surface.

Table.2:Chemical composition of fine aggregates

OXIDES	COARSE SAND (%)	FINE SAND (%)	GRANITE POWDER (%)
SiO_2	75.82	73.46	74.39
Al_2O_3	10.17	10.78	13.5
Fe_2O_3	3.15	3.38	0.86
MgO	1.19	1.33	0.38
MnO	0.08	0.09	0.02
CaO	3.36	3.58	0.41
Na_2O	2.17	2.25	4.16
K_2O	1.9	2.06	4.79
TiO_2	0.42	0.45	0.17
P_2O_5	0.07	0.08	0.02

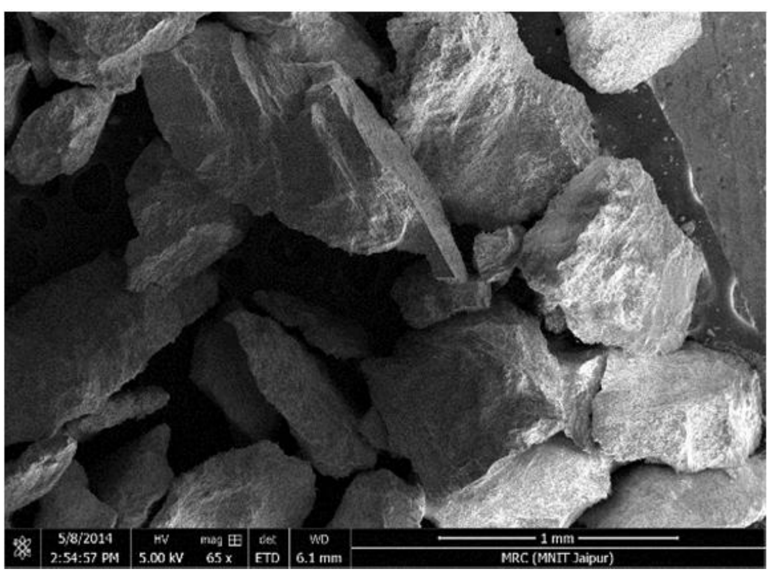

Figure.1:SEM images of fine aggregates

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4. Methodology

River sand was replaced in various quantities by GP for the construction of cement mortars in accordance with the defined objectives. The experiment was conducted out on mortars with 1:4 and 1:6 mix proportions. In two stages of this experiment, two types of conventional fine aggregates were used.

Stage 1

The control mortar was prepared using FS (zone – IV) at this point. This fine sand also met IS 2116 (1980) (standard for building mortar sand) and IS 1542 (1992) particle size distribution requirements (specification for sand for plaster). GP was used to replace FS from 0% to 100% in 10% increments. Table 3 lists the quantities of components needed to make one m3 of mortar. The results of workability, fresh density, compressive strength, and water absorption were compared to those of a control 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

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5. Results and Discussions

Stage 1

Using the flow table test, the workability of all the mortar mixes was determined to be between 110 and 115 percent. To meet the stated criterion, the water cement ratio (w/c) was changed. Table 3 shows that when the amount of GP was increased from 0% to 100%, w/c had to be increased for both mix proportions. Water requirements increased by only 6% (1:4 mix) and 5% (1:6 mix) when FS was 40 percent replaced by GP, however water content increased by around 19% (1:4 mix) and 18% (1:6 mix) when FS was totally replaced by GP. When compared to FS in mixed mortars, this increase in w/c was related to the fineness of granite powder (see Table 1).

Figure 2 depicts the changes in fresh density when FS is gradually replaced by GP. The fresh density of mortars has decreased as the GP substitution level has increased, as shown in this graph. This could be due to granite powder having a lower specific gravity than fine sand (see Table 1). Furthermore, the presence of more water in GP mixes has contributed to the lowering of the same metric.

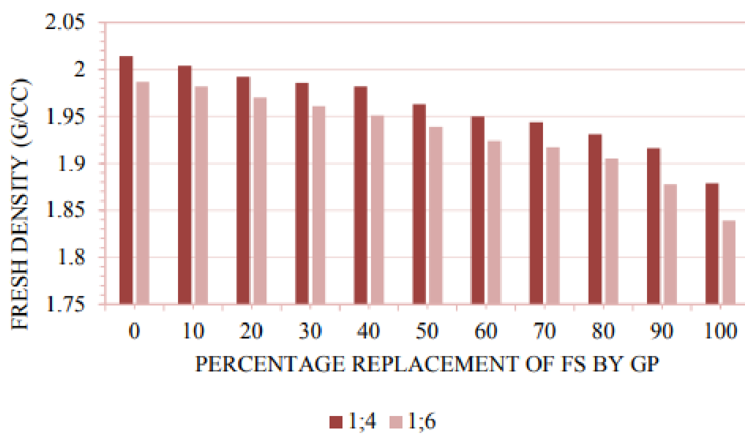

Figure.2: Fresh density of mortars prepared in Stage I

Figure 3 depicts the changes in compressive strength when FS is replaced with GP after 7 days and 28 days of curing. Compressive strength in mortars decreased with GP quantity in both mix proportions and curing times, similar to fresh bulk density. After 28 days of curing, the compressive strength of the 1:4 and 1:6 mix proportions is reduced by 41% and 21%, respectively, at total substitution. The increase in the w/c ratio of mixes containing GP is directly linked to the decrease in compressive strength.

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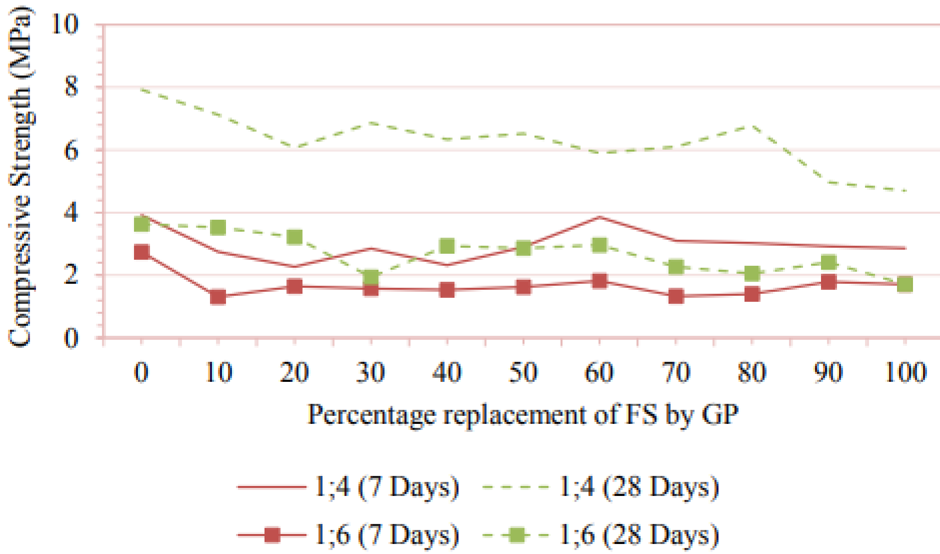

Figure.3: Compressive strength of mortars in Stage I

Figure 4 depicts the variance in water absorption capacity of mixes with GP for both mix amounts. For both mix proportions, the pattern shown here validates the importance of the w/c ratio. As the w/c ratio in mortars containing GP was increased, more voids were produced, and these voids were responsible for the higher water absorption capacity of such mixes when compared to control mortars. As a result, it can be concluded that when GP is used instead of FS, the resulting mortar mixes require more water and so have lower compressive resistance and absorb more water.

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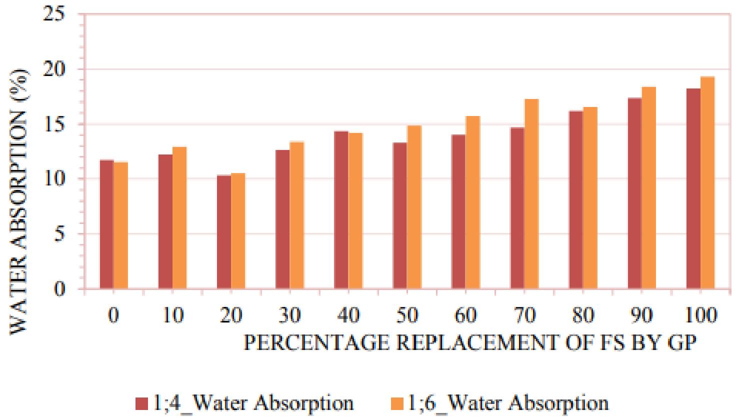

Figure.4: Water absorption of mortars prepared in Stage I

Sand that is significantly coarser in nature was combined with GP to lessen the fineness of the fine aggregates. The next section contains the results of their performance evaluation.

6. Conclusion

The following observations are made about the nature of mortars made from fine sand, coarse sand, and granite slurry:

- Because of its fineness, granite powder boosted the water-cement ratio in mortars containing fine sand. When granite powder is appropriately graded with coarse sand, this problem can be remedied.
- Due to the lower bulk density of granite powder, fresh density was reduced in blended mortars made with fine sand and granite powder. This problem is also resolved in mortars using granite powder and coarse sand. The ability of granite powder to fill the pores between coarse sand accounts for the increase in this parameter.
- Mortars made with coarse sand and granite powder have no detrimental impact on compressive strength (at 30 percent and 40 percent replacement level).
- In comparison to other mortars, the rate of water absorption (sorptivity) of mortar made with coarse sand and 30% granite powder is the lowest.

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