Properties of Granite Powder Concrete

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Abstract

Experimental Investigation on locally available granite powder as a replacement of sand and partial replacement of cement with admixtures in the production of concrete is presented in the paper. The intention of the research is to find the alternate source and fulfil the scarcity of river sand. To study the effect of Granite Powder (GP) on concrete properties, the percentage of granite powder added by weight was 0, 25, 50, 75 and 100% as a replacement of sand used in concrete and cement was replaced with 7.5 % silica fume, 10% fly ash, 10% slag and the dosage of superplasticiser added 1% by weight of cement. The investigation proved that granite powder of marginal quantity as partial sand replacement together with admixtures in concrete mixture has beneficial effect on concrete properties. Therefore, it can be concluded that the granite powder concrete will boon to the construction sector with strength augmentation.

Keywords - Concrete industry, Strength properties, granite powder, HPC and admixtures

I. INTRODUCTION

Sand is an essential component of concrete. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand for natural river sand is quite high in developed countries owing to infrastructural growth. In this situation some developing countries are facing a shortage in the supply of natural sand. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of the construction industry in many parts of the country. Therefore, the construction industries in developing countries are under stress to identify alternative materials to reduce the demand on river sand. Some alternative materials have already been used in place of natural river sand. For example, fly ash, slag and lime stone, siliceous stone powder, rock dust and quarry waste were used in concrete mixture as a partial replacement of natural sand [1]. Hence the assumption is granite powder aggregate could be an alternative to natural sand in preparation of concrete. Granite powder, one of the by-products in granite stone crushing process, not being used for any applications other than filling-up low lying areas is identified as a replacement material for river sand in concrete. The utilization of granite powder in high performance concrete could turn this waste material into a valuable resource with the added benefit of preserving environment. Therefore, this study focused on the possibility of using locally available granite powder and admixtures in the production of HPC, with 28 days strength to the maximum of 60 MPa.

The admixtures can be added to cement concrete as a partial replacement of cement along with superplasticiser as a water reducer to get the high performance. A partial replacement of cement by mineral admixtures, such as fly ash, slag, silica fume, metakaolin, rice husk ash or fillers such as lime stone powders in concrete mixes would help to overcome these problems and lead to improvement in the durability of concrete [2]. A research [3] reported that the compressive strength of concrete incorporating the combination of fly ash and finely ground granulated blast furnace slag is higher than that of individual concrete. Therefore, based on the above observation, to check the possibilities of improving the performance of concrete, admixtures were also considered as a partial replacement of cement in this study. However, the selection and dosage of mineral and chemical admixtures are an important consideration for higher concrete performance. Also, for a better performance of mixture proportions it is required to study scientifically the properties of proposed concrete. Thus, this research was conducted to evaluate the potential use of granite powder as sand replacement together with admixtures as a partial replacement of cement in the production of high performance concrete..

II. CONCRETE MATERIALS

Concrete is made usually from a properly proportioned mixture of cement, water, fine and coarse aggregates and often, chemical and mineral admixtures. Cement is the important binding material in concrete. The most commonly used cement in construction today is Portland cement and hence Ordinary Portland Cement of 43 grades has been selected for the investigation. It is dry, powdery and free of lumps.

Aggregates are inert granular materials such as sand, gravel, or crushed stone that are an essential ingredient in concrete. Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories: fines and coarse. In the present study ordinary blue metal has been used as a coarse aggregate in concrete. Optimum size of the coarse aggregate in most situations was about 19 mm. Sieve analysis of the course aggregates has been done and percentages passing at different sieves are furnished in Table 1. Fine aggregate is an essential component of concrete. It is defined as a material that will pass a No. 4 sieve and for the most part be retained on a No. 200 sieve.

The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. In the present study, the concrete mixes were prepared using locally available river sand and granite powder. River sand ranges in size from less than 0.25 mm to 6.3 mm. Fineness modulus and specific gravity of the sand are 2.33 and 2.63 respectively. Fineness modulus and specific gravity of the granite powder are 2.43 and 2.58 respectively. Sieve analysis was carried out for granite powder and compared with sand as per the standards.

TABLE 1. Sieve analysis results of coarse aggregates

Sl.No	Sieve Size (mm)	Percentage Passing
1	25	100
2	20	98
3	16	87
4	12.5	64
5	10	26
6	6.3	03
7	4.75	00

Water plays a critical role in the production of concrete, particularly in the amount used. The strength of the concrete increases with less water is used to make concrete. In the present work locally available purified drinking water has been used.

On the other hand, admixtures such as silica fume, fly ash, slag and superplasticiser have the inherent ability to contribute to continued strength development and very high durability. Silica fume is a by-product in the production of silicon metal or ferrosilicon alloys. Because of its chemical and physical properties, it is a very reactive pozzolan. It has been reported that the mass of silica fume, when used, represents 5 to 15 percent of the total mass of the cementitious material, the value of 10 per cent being typical. Moreover silica fume is very expensive and wasting a very expensive material is not a good engineering practice [4]. Therefore, in the present study, 7.5% of condensed silica fume was considered as a replacement for cement.

Fly ash is a fine powder recovered from the gases of burning coal during the generation of electricity. Fly ash (Type F) from the Ennoor thermal power plant, Chennai, India was used in the present study. Fly ash is generally cheaper than Portland cement and fly ash do not contribute to the slump loss. It has been reported that the concrete with 10% fly ash exhibited higher early strength followed by an excellent development of strength over time [5]. Hence in the present study 10% fly ash was considered as a replacement of cement. Ground granulated blast furnace slag is often used in concrete in combination with Portland cement as part of blended cement.

Concrete containing slag develops strength over a longer period, leading to reduced permeability and better durability. Let us now consider the inclusion of ground granulated blast furnace slag in the mix. First of all, slag is generally cheaper than Portland cement. Secondly, it does not contribute to the slump loss. On the other hand, mixes that have more fly ash or more slag develop a lower strength, but this can be compensated by lowering the ratio of the mass of water to the total mass of cementitious material. It has also been reported that the higher the amount of slag, the higher the amount of autogenous shrinkage [6].

Hence in the present study, 10% slag is considered along with other two admixtures, viz., silica fume and fly ash as a replacement of cement. Slag that was supplied by the Andhra Cements, Visakhapatnam, India was used in this study.

The use of Superplasticiser in concrete (high range water reducer) has become a common practice. The main purpose of using superplasticiser is to produce flowing concrete with very high slump in the range of 7-9 inches (175-225 mm). The other major application is the production of high-strength concrete at w/c's ranging from 0.3 to 0.4 [7]. It increases the compressive strengths of concrete by 50-110% in 3 days, 40-80% in 28 days, and 30-60% in 90 days. Superplasticiser has been added at a rate of 1% of cement mass according to the producer's instructions.

III. EXPERIMENTAL INVESTIGATION

This experimental investigation was aimed to introduce high performance concrete (HPC) by adding the granite powder together with admixtures in concrete. Research carried out worldwide has clearly established that suitable addition or replacement of any concrete materials in concrete would lead to improvement in strength of concrete. In the present study, an experimental investigation was carried out to study the effect of granite powder together with admixtures in concrete on properties. The testing of concrete plays an important role in controlling and confirming the quality of cement concrete works [8]. In this study, total experimentation consisted of compressive strength test, split tensile strength test and flexural strength test. Detailed study was carried out on concrete as per the specifications prescribed in BIS [9] to ascertain the above properties and the test procedure adopted are described here independently.

A. Compressive Strength Test

Compressive strength test is the most common test conducted on concrete, because it is easy to perform and most of the desirable characteristic properties of concrete are quantitatively related to its compressive strength. Compressive strength was determined by using Compression Testing Machine (CTM) of 3000 kN capacity. The compressive strength of concrete was tested using 150 mm × 150 mm × 150 mm cube specimens. The test was carried out by placing a specimen between the loading surfaces of a CTM and the load was applied until the specimen fails. Three test specimens were cast and used to measure the compressive strength for each test conditions and average value was considered.

B. Split Tensile Strength Test

Knowledge of tensile strength of concrete is of great importance. Split tensile strength was determined using Universal Testing Machine (UTM) of capacity 600 kN The split tensile strength of concrete was tested using 100 mm × 200 mm cylinder specimens. The test was carried out by placing a specimen between the loading surfaces of a UTM and the load was applied until the failure of the specimen. Three test specimens were cast and used to measure the split tensile strength for each test conditions and average value was considered.

C. Flexural Strength Tests

Flexural strength is a measurement that indicates the resistance of a material to deformation when placed under a load. The values needed to calculate flexural strength are measured by experimentation, with rectangular samples of the material placed under load in a 3 point testing setup. The strength of a material in bending, expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in MPa is equal to the (equ.1):

$$\frac{2PL}{bd} \quad \ldots\ldots\ldots \ (1)$$

Where, P = the load applied to a sample of test length L, width b, and thickness d.

D. Modulus of Elasticity Test

To obtain the modulus of elasticity and stress strain behaviour, cylinder specimens of size 100 mm diameter × 300 mm high specimen fixed with compressometer were tested under compression. At every equal load increment, corresponding dial gauge reading in the compressometer was noted and the stresses and strains

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were plotted and the modulus of elasticity was calculated for all the concrete mixes. The test specimens were cast and used to measure the modulus of elasticity for each test conditions.

E. Details of Concrete Mix

The laboratory program conducted in this investigation focused on seven basic mixes and the mixes were designated with the grade of concrete and the fine aggregate type used. Mixes incorporating 0% granite powder (100% river sand), 25% granite powder (75% river sand), 50% granite powder (50% river sand), 75% granite powder (25% river sand), 100% granite powder (0% river sand), without any admixtures but only with 100% granite powder and control concrete (no admixtures and no granite powder) were designated as GP0, GP25, GP50, GP75, GP100, NA100 and CC, respectively. The resultant mixture compositions are shown in the Table 5. ACI mix design method and Bureau of Indian Standards was used to achieve a mix with cube strengths of 60 MPa ([10] and [11]). Concrete specimens were prepared with w/c ratio of 0.25, 0.30 and 0.35 respectively for M60 grade and cured at 35^{o}C (±2^{o}C) water ponding temperature.

Table 5: Mix designation with mixture compositions

Sl. No	Designation of Mix	River Sand (%)	Replacement of sand with granite powder (%)	Cement (%)	Replacement of cement with admixtures (%)
1.	GP0	100	0	72.5	27.5
2.	GP25	75	25	72.5	27.5
3.	GP50	50	50	72.5	27.5
4.	GP75	25	75	72.5	27.5
5.	GP100	0	100	72.5	27.5
6.	NA100	0	100	100	0
7.	CC	100	0	100	0

F. Preparation of Test Specimens

Coarse aggregate was placed in the drum first and batch water was increased to account for the adsorption of the aggregates during rotation. After mixing for 10 to 15 seconds, the fine aggregates with correct proportions was introduced and mixed in for the period of 15 to 20 seconds. This was followed by the final 20% of the water and all the cement were added with fly ash, silica fume and slag, which were mixed in until a total mixing time of 60 seconds was achieved. The superplasticiser was added 30 seconds after all the other materials during the mixing. Specimens were prepared with water to cementitious materials ratio of 0.25, 0.30 and 0.35 for M60 grade. After 1 day, the specimens were demoulded and cured by water ponding temperature (climate condition) at 35^{o}C (±2^{o}C). The temperature was manually noted every hour to find out any variations in 35^{o}C water ponding temperatures. Different batches were adopted for, 1 day, 7 days, 14 days, 28 days 56 days and 90 days of curing ages. The details of different specimens used for the present study are listed in Table 6.

TABLE 6. Details of test specimens

Material Properties	Shape	Dimensions of the Specimens (mm)
Compressive Strength (1, 3, 7, 14, 28, 56 and 90 days)	Cube	150 × 150 × 150
Flexural Strength (1, 7, 28 and 90 days)	Prism	500 × 150 × 100
Split Tensile Strength (1, 28 and 90 days)	Cylinder	100 × 200
Modulus of Elasticity (7 and 28 days)		100 × 300

IV. RESULTS AND DISCUSSION

As per the procedure explained above, tests were conducted in various experimental setups to find the properties of new concrete mixture in which granite powder was used in place of river sand partially as well as admixtures for a partial replacement of cement. The experimental results are presented and discussed here for the concrete mixes GP0, GP25, GP50, GP75, GP100, NA100 and CC (comparison purpose) for various operating conditions.

A. Compressive Strength

TABLE 7. Compressive strength at 35°C water ponding temperature

Mix Design.	W/C Ratio	Compressive Strength (MPa) for						
		1 Day	3 Days	7 Days	14 Days	28 Days	56 Days	90 Days
GP0	**0.25**	40.55	54	57.52	65	69.42	73	75
GP25		45.12	57.75	63.5	70	74	77	80
GP50		41.15	55.66	59	68.2	72.24	75	78
GP75		40.54	52.31	58	65.32	69.7	72.21	75.95
GP100		38.24	50	56	63.8	68.5	70.8	74.11
NA100		36.58	48.12	52	61.23	66.85	68.11	72.55
CC		36.94	49	54	62	67.3	70.5	75.38
GP0	**0.30**	37	48.22	55	60.1	65.8	69.5	71.3
GP25		41.28	52.34	62	68.2	71	75.6	77.54
GP50		39.33	50.28	60.22	65.3	68.4	72.4	75.2
GP75		36.58	48	56.35	62.5	66.2	69.5	71.7
GP100		35.65	46.35	54	60.1	64.2	66.4	70.55
NA100		32.85	44.56	52	59.1	62.3	64.8	67
CC		35.25	46	54	62	62	66.85	70
GP0	**0.35**	33	38.3	49.52	56.45	58	64.5	68.58
GP25		34.52	42.56	54.25	62.5	66	70.5	72.65
GP50		35.12	40.58	51.5	60.5	63.7	66.85	70.85
GP75		32.65	38.55	48.35	57.25	60.5	65	68.45
GP100		29.35	36.55	46.55	55	58.3	62.5	66.82
NA100		26.5	34	44	53.2	56	60.7	65.3
CC		28.55	36.2	45.1	54	58	60	67.2

Compressive strength is considered to be the paramount property of concrete. The effect of introduction of granite powder as a replacement of sand on compressive strength of M60 grade concrete is presented in Table 7. The data presented show that the compressive strength of granite powder concretes was higher than that of reference mix (CC) 10% silica fume 7.5% and superplasticiser 1%). It can be seen from the Figures that GP25 shows a compressive strength higher than all other concrete mixes with granite powder as been observed in the concrete mix with 25% granite powder (GP25) together with admixtures (fly ash 10%, slag well as because of better compatibility than concrete mixes without admixtures. In the present study, a significant increase has for all the days of curing. Concrete mixes with admixtures showed increase in compressive strength in all the mixes conventional concrete (CC) for all the days of curing (1 day to 90 days). The possible reason for this is that more voids are present in the concrete mixes with higher amount of granite powder. More over the crushing strength of granite powder is lower than that of sand and hence the increase in the content of granite powder has resulted in diminished strength. It is to be noted from the Table 7 that the compressive strength of GP25 is 6.12 to 22.14 % greater than that of CC. This shows that the use of admixtures in conjunction with granite powder is a must for harnessing the full potential benefits of granite powder. The trend of decrease in compressive strength for increase in w/c ratio also was observed. Previous research indicates that as the water/cement ratio increases, an increase in the structural porosity of the aggregate–cement paste transition zone occur, which promoted propagation of cracks.

B. Split Tensile Strength

The tensile strength characteristics of concrete are of considerable importance and the split tensile test is a simple and reliable method of measuring the tensile strength. The variation of split tensile strength with age of curing is shown in Table 8. The specimens of 100 mm diameter cylinder have been tested at the age of 1, 7, 28 and 90 days. It can be seen from all the Figures that the tensile strength decreased with percentage of increase in granite powder in the mix, and the results indicate that the optimum replacement over sand was 25% for all the operating conditions. The reduction in strength may be due to the presence of unfilled micro-voids in the concrete mixes as the amount of granite powder increased. Conversely, the test results demonstrate the effect of admixtures in all the concrete mixes. It can be seen from Table 8 that the split tensile strength of granite powder concretes was increases when admixtures are used, which varies between 2.14 to 6.0 MPa respectively for 1 day, 7 days, 28 days and 90 days of curing.

TABLE 8. Tensile strength at 35^{o}C water ponding temperature

Mix Design.	W/C Ratio	Split Tensile Strength (MPa) for			
		1 Day	7 Days	28 Days	90 Days
GP0	**0.25**	3.1	4.16	4.85	5.12
GP25		3.45	4.62	5.6	5.88
GP50		3.38	4.5	5.52	5.65
GP75		3.25	4.38	5.16	5.34
GP100		3.98	3.86	4.88	5.12
NA100		3.52	3.6	4.55	4.88
CC		2.9	3.8	4.78	5
GP0	**0.3**	2.68	3.85	4.41	4.62
GP25		2.95	4.35	5.16	5.25
GP50		2.86	4.26	5.02	5.12
GP75		2.78	4.17	4.65	4.82
GP100		2.58	3.65	4.35	4.5
NA100		2.2	3.28	3.88	4.2
CC		2.46	3.56	4.25	4.38
GP0	**0.35**	2.32	3.5	4.07	4.27
GP25		2.7	4.0	4.64	4.82
GP50		2.52	3.8	4.52	4.65
GP75		2.4	3.62	4.22	4.35
GP100		2.32	3.4	3.94	4.13
NA100		2.1	3.16	3.7	3.9
CC		2.27	3.28	3.88	4.05

C. Modulus of Elasticity

The investigation on the effect of granite powder replacement on modulus of elasticity is presented in the Table 9. The measurements were performed at the age of 7, 28 and 90 days, respectively. The data presented in Table 10 show that similar to the strength properties, modulus of elasticity of the concrete mix with 25 % granite powder was found to be higher than that of other percentages of granite powder concrete mixes as well as reference mix CC for all the days of curing. The range of modulus of elasticity increase in concrete mixes is 4.11 to 6.84 %, 10.16 to 18.54 %, 8.42 to 14.23 %, 6.17 to 8.65 % and 0.77 to 3.14 % for GP0, GP25, GP50, GP75 and GP100, respectively as compared with CC for all ages as presented in Table 9. It is understandable that the increase of modulus of elasticity of concrete mixture with a 25 % granite powder (GP25) is 8.85 to 18.89 % higher than that of CC as presented in Table 9. This could be attributed to the cohesiveness of GP25 mix than other concrete mixes.

Table 9. Modulus of elasticity at 35^{o}c water ponding temperature

Curing Age	W/C Ratio	Modulus of Elasticity (GPa) of M60 Grade Concrete						
		Mix Designation						
		GP0	GP25	GP50	GP75	GP100	NA100	CC
7 Days	0.25	41.42	44.5	43.44	42.66	40.48	38.82	39.35
28 days		41.84	44.92	44.0	42.95	40.56	38.78	39.68
90 Days		42.62	46.3	45	43.82	41.5	40.14	40.74
7 Days	0.30	38.12	41.25	40	39.1	37.25	35.32	36.56
28 days		38.62	41.56	40.2	39.78	37.52	35.72	36.6
90 Days		40.45	42.8	42.12	41.25	39.15	38.2	38.85
7 Days	0.35	35.16	39.12	37.4	35.22	33.56	32	33
28 days		35.5	39.32	38.52	36.5	34.78	32.45	33.72
90 Days		3.45	42.2	40.52	39	37.24	35	36.14

D. **Flexural Strength**

The effect of granite powder and the performance of admixtures on flexural strength for all concrete mixes are presented in Tables 10. From the experimental investigation, it is observed that the sand replacement by large quantities of granite powder showed lesser flexural strength and for 25% sand replacement by granite powder shows increase in flexural strength. It is to be noted that the flexural strength of GP25 is 12.5 to 19.88%, respectively, higher than that of reference mix (CC) as presented in Table 10 for all the days of curing. It is also shown that the flexural strength increases with the increase in days of curing and decreases with the increase in w/c ratios of all concrete mixes.

Table 10. Flexural strength at 35°C water ponding temperature

Mix Design.	W/C Ratio	Flexural Strength for			
		1 Day	7 Days	28 Days	90 Days
GP0	0.25	4.12	5.18	5.9	6.4
GP25		4.62	5.64	6.55	7.0
GP50		4.55	5.52	6.42	6.82
GP75		4.34	5.49	6.0	6.58
GP100		3.98	4.92	5.72	6.16
NA100		3.65	4.65	5.55	5.82
CC		3.9	4.88	5.6	6.12
GP0	0.3	3.84	4.98	5.55	5.9
GP25		4.32	5.55	6.24	6.5
GP50		4.1	5.42	6.00	6.2
GP75		3.82	5.14	5.7	6.0
GP100		3.72	4.7	5.34	5.74
NA100		3.45	4.44	5.0	5.42
CC		3.55	4.58	5.22	5.54
GP0	0.35	3.42	4.52	5.15	5.43
GP25		3.89	5.12	5.7	6.0
GP50		3.75	4.9	5.6	5.85
GP75		3.45	4.62	5.32	5.62
GP100		3.34	4.5	5.1	5.33
NA100		3.18	4.22	4.82	5.12
CC		3.25	4.35	5.0	5.22

V. SUMMARY AND CONCLUSIONS

An experimental study on the high performance concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5 % Silica fume, 10% fly ash and 10% slag subjected to water curing is conducted for finding the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, flexural strength and water absorption characteristics of concrete mixtures. Concrete specimens were prepared with w/c ratio of 0.25, 0.30, 0.35, for M60 grade concrete mix. The test results show clearly that granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete. Of all the six mixtures considered, concrete with 25% of granite powder (GP25) was found to be superior to other percentages of granite powder concrete as well as conventional concrete and no admixtures concrete for all operating conditions. Hence the following conclusions are made based on a comparison of GP25 with the control concrete, CC.

The mechanical properties like the compressive strength, split tensile strength, modulus of elasticity and flexural strength particularly for all ages higher than that of the reference mix, CC as mentioned below. There was an increase in strength as the days of curing increased.

- Compressive strength is 6.12 to 22.14 % greater than that of CC.
- Split tensile strength is 14.88 to 21.95 % higher than that of CC.
- Modulus of elasticity is 8.85 to 18.89 % higher than that of CC.
- Flexural strength is 12.5 to 22.22 % higher than that of CC.

Thus the present experimental investigation indicates that the strength properties of the concrete could enhance the effect of utilization of granite powder obtained from the crusher units in place of river sand in concrete. In general, the behavior of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand.

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