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Effect of Granite Powder on Strength Properties of Concrete

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Abstract : *This paper focuses on the experimental study of using locally available granite powder as fine aggregate and partial replacement of cement with admixtures in the production of HPC with 28 days strength to the maximum of 60 MPa. The influence of water cement ratio and curing days on mechanical properties for the new concrete mixes were premeditated. 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 test results show clearly that granite powder of marginal quantity, as partial sand replacement has beneficial effect on the above properties. The highest strength has been achieved in samples containing 25% granite powder together with admixtures. Based on the results presented in this paper, it can be concluded that concrete mixture can be prepared with granite powder as an additive together with admixtures to improve the strength of concrete structure.*

Keywords : *concrete properties, fly ash, granite powder, HPC, silica fume, slag*

I. INTRODUCTION

Fine aggregate 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. In order to reduce the dependence on natural aggregates as the main source of aggregates in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry [1]. 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 [2]. Hence the assumption is granite powder aggregate could be an alternative to natural sand in preparation of concrete. Granite powder, one of the byproducts 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 granite waste generated by the stone crushing industry has accumulated over the years. Only insignificant quantities have been utilized and the rest has been unscrupulously dumped resulting in environmental problems. Presently, all the processing units are disposing this industrial waste by dumping it in open yards, that nearly occupying 25% of the total area of the industry.

The reduction in waste generation by manufacturing value-added products from the granite stone waste will boost up the economy of the granite stone industry. 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. Mineral admixtures such as fly ash and slag have the inherent ability to contribute to the continued strength development and very high durability, the latter through pore refinement and reduced sorptivity. 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 [1]. 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 one of the major construction materials being utilized worldwide. 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.

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

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, and the results are presented in Fig. 1.

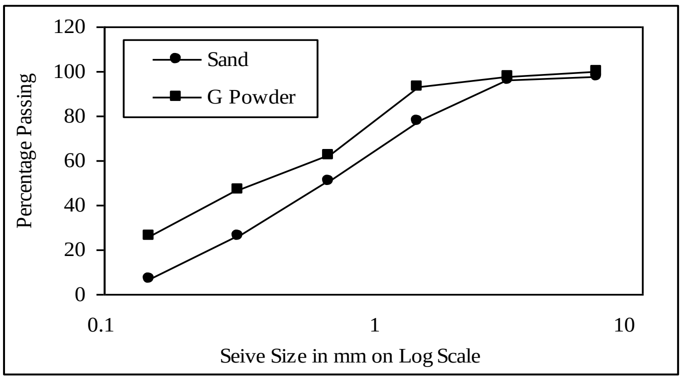

Figure 1 Sieve analysis of fine aggregates for different sieve sizes

It is shown that the amount of fine particles present in granite powder is considerably higher when compared to the river sand. The constituent materials used for the preparation of the concrete in this study have been tested and the details are given in Table 2. 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.

Table 2 Physical properties of constituent materials

Sl. No.	Materials	Description
1	Cement	Type - OPC 43 Grade Specific Gravity - 3.15 Standard Consistency - 32% Initial Setting Time - 70 Minutes Final Setting Time - 300 Minutes Fineness - 2 % Compressive Strength - 7^{th} day - 41 N/mm^2 - 28^{th} day -62 N/mm^2
2	Blue Metal	Specific Gravity - 2.68
3	River Sand	Specific Gravity - 2.63 Fineness Modulus - 2.33
4	Granite Powder	Specific Gravity - 2.58 Fineness Modulus - 2.43

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 byproduct 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. The main characteristics of admixtures are given in Table 3.

Table 3 Chemical compositions and physical properties of silica fume, fly ash and slag (%)

Properties	Silica Fume	Fly Ash	Slag
Specific gravity	2.25	2.15	2.95
Bulk density, kg/m^3	1000-10000	190-265	1100-11000
Specific surface area, m^2/kg	-	601	607
S_iO_2	95	58.9	33.67
Al_2O_3	0.13	40.1	20.56
Fe_2O_3	4.0	5.2	1.01
CaO	0.39	0.89	32.49
MgO	0.21	0.27	9.63
SO_3	-	1.01	0.10
Na_2O	0.15	0.47	1.22
K_2O	0.11	0.39	0.48
LOl	-	1.09	1.19

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 ground granulated blast furnace 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. Ground granulated blast furnace 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. The properties of superplasticiser as per the manufacturer's literature are given in the Table 4.

Table 4 Properties of superplasticiser

Sl.No.	Properties		
1	Specific gravity	:	1.220 - 1.225
2	Chloride content	:	Nil
3	Recommended dosage	:	2 - 4% of cement
4	Approximate additional Air Entrainment	:	1% at normal dosage
5	Solid content	:	40%
6	Compatibility	:	All types of cement except high alumina cement
7	Operating temperature	:	10 - 40%

III. EXPERIMENTATION

This experimental investigation was aimed to introduce high performance concrete by adding the granite powder together with three 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 mechanical 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, flexural strength test, modulus of elasticity test and water absorption 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.

3.1 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.

3.2 Split Tensile Strength Test

Knowledge of tensile strength of concrete is of great importance [10]. 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.

3.3 Flexural Strength Test

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.

3.4 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 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.

3.5 Water Absorption Test

The study of the water absorption, which is closely related to durability of concrete, is very important because deterioration of porous materials like concrete is affected by migration of water. The effect of a combination of granite powder and admixtures on water penetration of concrete was investigated in the absorption test. The absorption test was conducted using 500 mm × 500 mm × 100 mm slabs that were cured at 26^{o}C and 38^{o}C water ponding temperatures for 28 days. The slabs were air dried then for 2 days and placed into a water tank with their bottom 10 mm soaking in water. The water level was monitored in the tank to maintain the water minimum of 10 mm height. The test involved keeping the slabs into the water for the period of 1 to 2 hours and then removed. Measurements were taken using an ordinary inch tape over a cross section of the slab to determine the depth of water rise. This test measures the rate of absorption of water by capillary suction of unsaturated concrete placed in contact with water. The photographic view of the measurements of water absorption in slab specimen is shown in Fig. 2.

Figure 2 Measurements of water absorption in slab specimen

3.6 Details of Concrete Mix

The dosages of different admixtures used in the experimentation were based on the review of previous researchers ([4], [5], and [6]). Accordingly, performances of concrete specimens made with 0, 25, 50, 75 and 100% granite powder as a replacement of sand with 10% of fly ash, 10% of ground granulated blast furnace slag, 7.5% of silica fume as a replacement of cement, and 1% of superplasticiser were evaluated. 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 ([9] 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°C (±2°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

3.7 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. The various specimens such as cube, cylinder and slab were cast for studying the variation in strength properties due to the replacement of sand with granite powder. 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°C (±2°C). The temperature was manually noted every hour to find out any variations in 35°C water ponding temperatures. On an average ±2°C variation was observed in the 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

<table>
<tr><th>Material Properties</th><th>Shape</th><th>Dimensions of the Specimens (mm)</th></tr>
<tr><td>Compressive Strength
(1, 3, 7, 14, 28, 56 and 90 days)</td><td>Cube</td><td>150 × 150 × 150</td></tr>
<tr><td>Flexural Strength
(1, 7, 28 and 90 days)</td><td>Prism</td><td>500 × 150 × 100</td></tr>
<tr><td>Split Tensile Strength
(1, 28 and 90 days)</td><td rowspan="2">Cylinder</td><td>100 × 200</td></tr>
<tr><td>Modulus of Elasticity
(7 and 28 days)</td><td>100 × 300</td></tr>
<tr><td>Water Absorption
(1 and 2 hr)</td><td>Slab</td><td>100 × 500 × 500</td></tr>
</table>

IV. TEST RESULTS AND DISCUSSION

As per the procedure explained above, tests were conducted in various experimental setups to find the mechanical properties of new concrete mixture in which granite powder were 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 for M60 grade concrete.

4.1 Workability of Concrete

The workability of concrete for seven mixes was studied and the slump values are furnished in Table 7. The variation in slump values for different concrete mixes was found to be nominal when compared to the concrete mix with no admixtures (NA100). It is also shown that the slump value increases with the increase in percentage of granite powder in the concrete mix. However, concrete mixes with granite powder produced higher slump when compared to the mix with river sand. This improved workability for the mix might be due to the presence of the more quantity of fine granite powder particles along with admixtures.

Table 7 Workability of concrete

Concrete mix	Slump in mm
GP0	72
GP25	75
GP50	78
GP75	80
GP100	80
NA100	70
CC	70

4.2 Compressive Strength

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 Figs. 3 to 5. The data presented show that the compressive strength of granite powder concretes was higher than that of reference mix (CC) for all the days of curing. Concrete mixes with admixtures showed increase in compressive strength in all the mixes because of better compatibility than concrete mixes without admixtures. In the present study, a significant increase has been observed in the concrete mix with 25% granite powder (GP25) together with admixtures (fly ash 10%, slag 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 well as the 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 8 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.

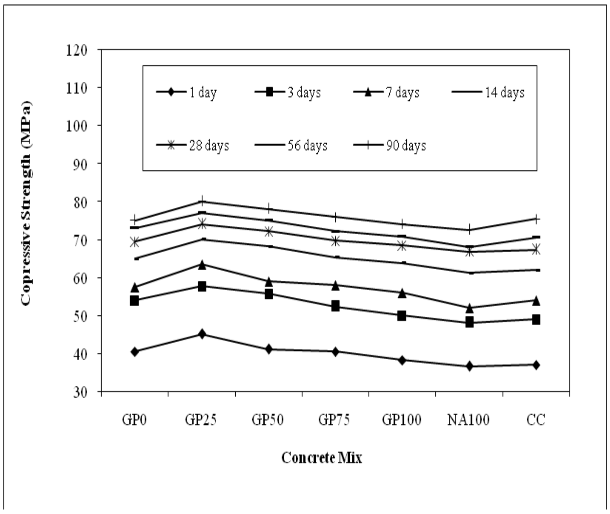

Figure 3 Compressive strength of 0.25 w/c ratio (Variation of concrete mix)

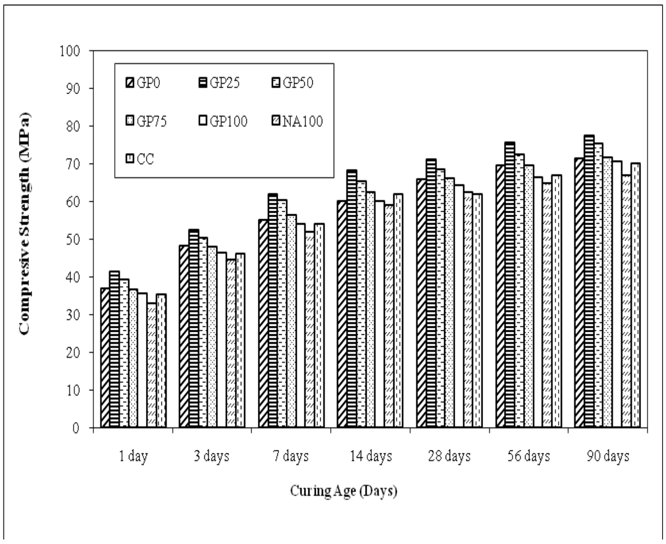

Figure 4 Compressive strength of 0.30 w/c ratio (Variation of days of curing)

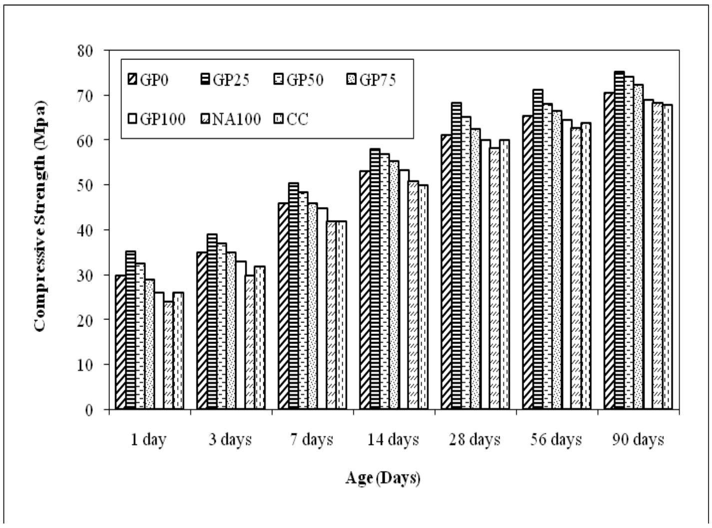

Figure 5 Compressive strength of 0.35 w/c ratio (Variation of days of curing)

Table 8 Comparison of compressive strength (MPa) for GP25 and CC

W/C	Mix	Compressive Strength (MPa)						
		Testing Age						
		1 Day	3 Days	7 Days	14 days	28 Days	56 Days	90 Days
0.25	GP25	45.12	57.75	63.50	70.00	74.00	77.00	80.00
	CC	36.94	49.00	54.00	62.00	67.30	70.50	75.38
0.30	GP25	41.28	52.34	62.00	68.20	71.00	75.60	77.54
	CC	35.25	46.00	54.00	62.00	62.00	66.85	70.00
0.35	GP25	34.52	42.56	54.25	62.50	66.00	70.50	72.65
	CC	28.55	36.20	45.10	54.00	58.00	60.00	67.20

4.3 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 Figs. 6 to 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 Figures 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.

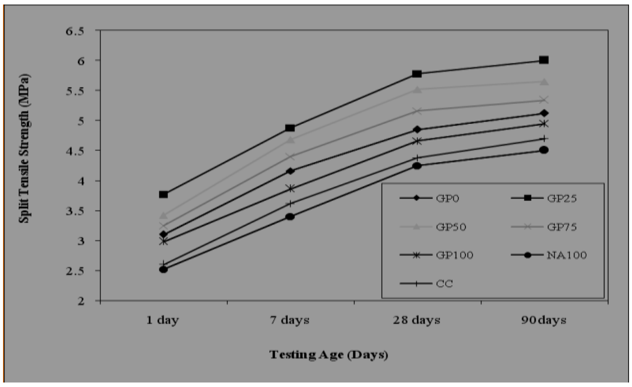

Figure 6 Split tensile strength of 0. 25 w/c ratio (Variation of days of curing)

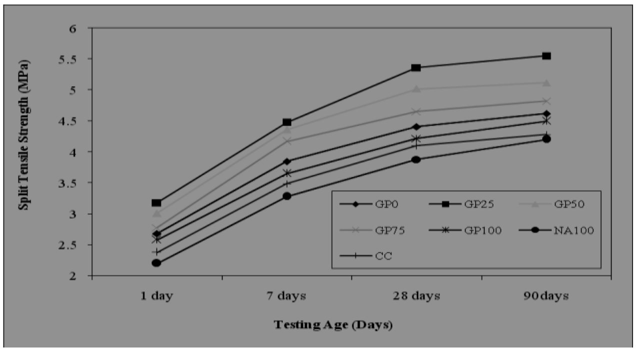

Figure 7 Split tensile strength of 0. 30 w/c ratio (Variation of days of curing)

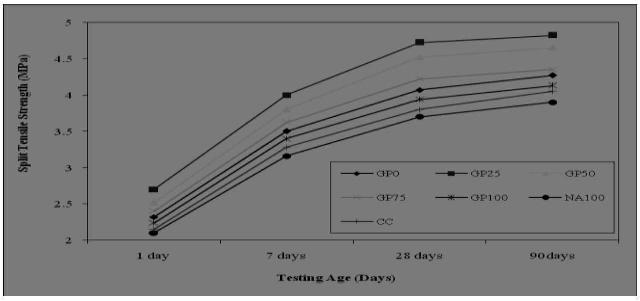

Figure 8 Split tensile strength of 0. 35 w/c ratio (Variation of days of curing)

It is to be noted that the split tensile strength of GP25 is 14.88 to 21.95 % higher than that of CC as presented in Table 9. The strength improvement for GP25 shows the effect of admixtures in conjunction with granite powder in concrete mixture. Similar to compressive strength, the trend of decrease in split tensile strength for increase in w/c ratio also was observed for the concrete mixes.

Table 9 Comparison of split tensile strength (MPa) for GP25 and CC

W/C	Mix	Split Tensile Strength (MPa)			
		Testing Age			
		1 Day	7 Days	28 Days	90 Days
0.25	GP25	3.45	4.62	5. 55	5.88
	CC	2.90	3.80	4.68	5.00
0.30	GP25	2.95	4.35	5.16	5.25
	CC	2.46	3.56	4.25	4.38
0.35	GP25	2.70	4.00	4.64	4.82
	CC	2.27	3.28	3.88	4.05

4.4 Modulus of Elasticity

The investigation on the effect of granite powder replacement on modulus of elasticity is illustrated in Fig. 9 and presented in the Table 10 and 11. 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 10. 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 11. This could be attributed to the cohesiveness of GP25 mix than other concrete mixes.

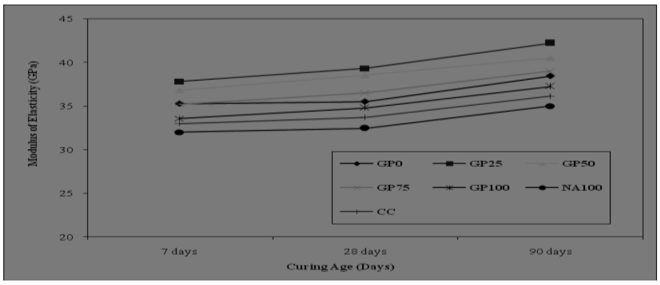

Figure 9 Modulus of elasticity of 0. 35 w/c ratio (Variation of days of curing)

Table 10 Modulus of elasticity of concrete mixes at varies curing age

Curing Age	W/C Ratio	Modulus of Elasticity (GPa) 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	45.00	43.82	41.50	40.14	40.74
7 Days	0.30	38.12	41.25	40.00	39.10	37.25	35.32	36.56
28 days		38.62	41.56	40.20	39.78	37.52	35.72	36.60
90 Days		40.45	42.80	42.12	41.25	39.15	38.20	38.85
7 Days	0.35	35.16	39.12	37.40	35.22	33.56	32.00	33.00
28 days		35.5	39.32	38.52	36.5	34.78	32.45	33.72
90 Days		38.42	42.20	40.52	39.00	37.24	35.00	36.14

Table 11 Modulus of elasticity development of GP25 compared with CC (%)

W/C	Modulus of Elasticity Development of GP25 (%) Testing Age		
	7 Days	28 Days	90 Days
0.25	13.08	13.20	13.64
0.30	12.82	13.52	10.16
0.35	18.54	16.60	16.76

4.5 Flexural Strength

The effect of granite powder and the performance of admixtures on flexural strength for all concrete mixes are presented in Tables 12 and 13, and Figures 10 to 12. 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 12 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.

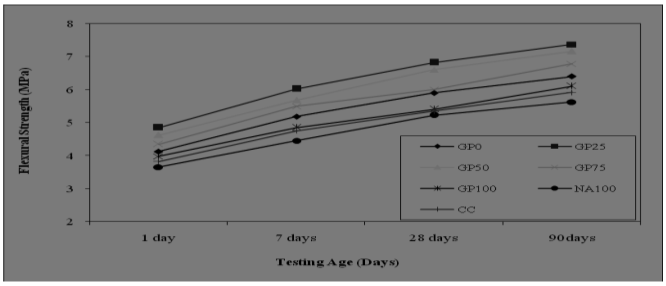

Figure 10 Flexural strength of 0. 25 w/c ratio (Variation of days of curing)

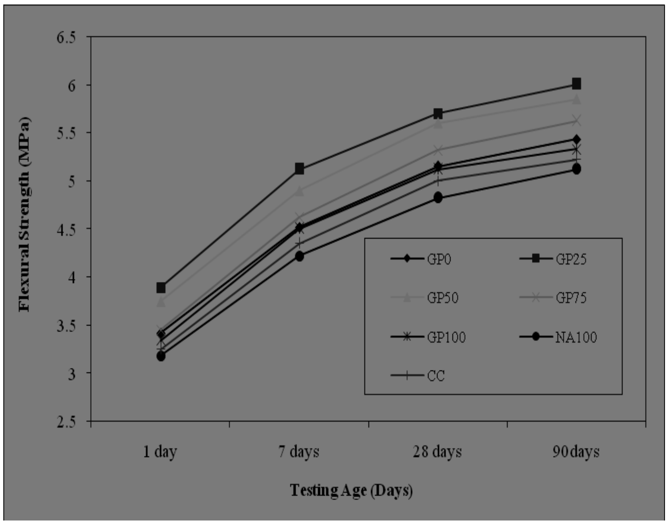

Figure 11 Flexural strength of 0. 30 w/c ratio (Variation of days of curing)

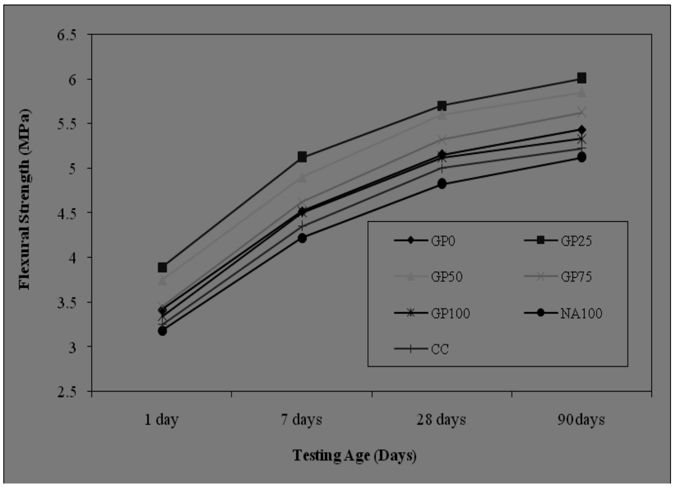

Figure 12 Flexural strength of 0. 35 w/c ratio (Variation of days of curing)

Table 12 Flexural strength development of GP25 compared with CC (%)

W/C	Flexural Strength Development of GP25 (%)			
	Testing Age			
	1 Day	7 Days	28 Days	90 Days
0.25	19.88	16.78	14.80	16.29
0.30	17.71	16.88	13.27	14.72
0.35	19.88	19.20	12.50	17.48

It can also be seen from the results that the significant improvement in the flexural strength was observed due to the inclusion of admixtures in the concrete mixes similar to other strength properties. The range of flexural strength increases in 3 to 8.73 %, 14 to 21.69 %, 11.43 to 18.34 %, 6.15 to 12.22 % and 0.65 to 4.78 % for GP0, GP25, GP50, GP75 and GP100, respectively, for all ages and different w/c ratios as presented in Tables 13.

Table 13 Effect of admixtures on flexural strength

Curing Age	W/C Ratio	Increase in Flexural Strength Compared to the case without Admixtures Mix, CC (%)				
		Mix Designation				
		GP0	GP25	GP50	GP75	GP100
1 Day	0.25	5.64	18.46	16.66	11.28	2.05
7 Days		6.14	15.57	13.11	12.50	8.19
28 days		5.35	16.96	14.64	7.14	2.14
90 Days		4.57	14.37	11.43	7.51	6.52
1 Day	0.30	8.16	21.69	15.49	7.60	4.78
7 Days		8.73	21.17	18.34	12.22	2.62
28 days		6.32	19.54	14.94	9.19	2.29
90 Days		6.49	17.32	11.91	8.30	3.61
1 Day	0.35	5.23	19.69	15.38	6.15	2.76
7 Days		3.90	17.70	12.64	6.20	3.44
28 days		3.00	14.00	14.00	6.40	2.40
90 Days		4.02	14.94	12.06	7.66	2.10

4.6 Water Absorption

In general, water absorption in the concrete causes serious problems, which may affect the strength of the concrete. In the experimental investigation, the measurements of water rise in the slabs were performed at the age of 1 and 2 hours. The test results of absorption are presented in Tables 14 and 15. The absorption of the slabs 100 mm × 500 mm × 500 mm containing granite powder together with admixtures are lower than that of CC for the tested ages. In the case of concrete mix GP25 the absorption for 1 and 2 hours 14.7 mm and 20.2 mm, respectively. It is observed that the reduction in water absorption for GP25 is 8 to 14.2 % compared to the conventional concrete mix CC as presented in Table 14. It could be noted that the variation in absorption for different concrete mixes was found to be nominal for 2 hours of curing when compared to the 1 hour of curing. However, in the case of mix with no admixtures, higher absorption was observed.

Table 14 Effect of granite powder on water absorption

Hours of Curing	W/C Ratio	Water Penetration (mm) at 38^{o}C Water Ponding Temperature						
		Mix Designation						
		GP0	GP25	GP50	GP75	GP100	NA100	CC
1 hr	0.25	13.0	13.0	13.5	14.0	14.5	15.0	14.5
2 hrs		17.8	17.6	17.8	18.2	19.0	20.0	19.2
1 hr	0.30	13.6	13.6	14.2	14.5	15.0	15.0	14.8
2 hrs		17.9	17.5	19.2	20.4	20.4	20.6	20.4
1 hr	0.35	14.2	14.2	14.8	14.6	15.2	15.5	15.0
2 hrs		19.3	19.0	19.8	20.2	20.8	21.6	21.0

Table 15 Comparison of water absorption (mm) for GP25 and CC

Concrete Mix	Water Absorption (mm) for Hours of Curing					
	w/c = 0.25		w/c = 0.30		w/c = 0.35	
	1hr	2hrs	1hr	2hrs	1hr	2hrs
GP25	13.8	18.0	14.5	20.0	14.8	20.6
CC	15.0	20.5	15.6	21.5	17.5	22.6
GP25	13.0	17.6	13.6	17.5	14.2	19.0
CC	14.5	19.2	14.8	20.4	15.0	21.0

From the above observations it can be recognized that the new concrete mixture containing 25% granite powder as a replacement of sand together with 27.5% admixtures (7.5% silica fume, 10% fly ash, 10% slag) as a replacement of cement giving maximum performance. Thus GP25 is the best choice among the concrete mixtures. Therefore, further study was carried out for GPO, GP25 and compared with control concrete (CC)

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.
- The water absorption was about 8 to 14.2 % less than that of conventional concrete mixture.

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.

REFERENCES

[1] S. Khalifa Al-Jabri, Makoto Hisada, K. Salem Al-Oraimi and H. Abdullah Al-Saidy, Copper slag as sand replacement for high performance concrete, *Cement &Concrete Composites, 31,* 2009, 483-488.

[2] Md. Safiuddin, S.N. Raman and M.F.M. Zain, Utilization of quarry waste fine aggregate in concrete mixtures, *Journal of Applied Science Research, 3 (3),* 2007, 202-208.

[3] Kefeng Tan and Xincheng PU, Strengthening effects of finely ground fly ash, granulated blast furnace slag and their combination, *Cement and Concrete Research, 28 (12),* 1998, 1819 -1825.

[4] Adam Neville and Pierre-Claude Aitcin, High performance concrete – an overview, *Materials and Structures, 31*, 1998, 111 – 117.

[5] M.N. Haque and O. Kayali, Properties of high-strength concrete using a fine fly ash, *Cement and Concrete Research, 28,* 1998, 1445 – 1452.

[6] Mladenka Saric-Coric and Pierre-Claude Aitcin, Influence of curing conditions on shrinkage of blended cements containing various amounts of slag, *ACI Materials Journal, 100*, 2003, pp.477-481.

[7] V.S. Ramachandran and V. M. Malhotra, *Superplasticisers in concrete admixtures handbook* (Park Ridge, N.J.: Noyes Publications, 1984) 211 – 268.

[8] M.S. Shetty, *Concrete Technology-Theory and Practice* (S.Chand and Company Ltd, New Delhi, Reprint with corrections, 2007) 458 – 503.

[9] BIS (Bureau of Indian Standards), Methods of Tests for Strength of Concrete, *BIS*: 516-1959 (c), New Delhi, India.

[10] A. Camoes, P. Rocha, S. Jalali, De Aguiar, and R. Delgado, High performance concrete using fly ash, *Proc. on 3rd International Conf. Concrete Technology*, Bracil Act SP-207, 2002, 15-31.
[11] BIS (Bureau of Indian Standards), Plain and reinforcement concrete code of practice, *BIS*: 456:2000, New Delhi, India.