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Effect of Addition of Granite Powder and Polypropylene Fibers on Concrete

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Abstract: *Fiber reinforcement in concrete can increase many of the engineering properties (fracture toughness, flexural strength and resistance to fatigue, impact, thermal shock and spalling) of the normal materials. River sand is the most commonly used fine aggregate in making concrete. But extensive use of this natural resource gives rise to its large scale depletion and therefore to cut down the cost of sand, granite powder shall be used as a substitution of fine aggregate. Granite powder is an industrial waste which is available in abundance. The main objective to use Granite powder in concrete is to determine alternate source of excellent quality of fine aggregates which is reducing day by day due to the fast pace of construction activities all over the world. Many additives are used for enhancing the properties of concrete, but polypropylene fibers are preferred material. PP (Polypropylene) is a thermoplastic polymer used in a extensive variety of applications which include packaging and labeling, textiles. Polypropylene fiber is mainly used for reinforcement of concrete to improve the tensile strength. Extensive research in past showed that it can also be used in order to avoid explosive spalling at elevated temperature, thus making it fire resistant. The partial substitution of fine aggregate with the granite powder along with the PP fibers in the conventional mix gives better results in terms of strength, tensile and flexural properties of concrete.*

Keywords: Granite Powder, Polypropylene, Concrete

I. INTRODUCTION

Most important part of concrete is fine aggregate and almost all construction industries in the whole world, use river sand as fine aggregate. But river sand is quite expensive because of its excessive cost of transportation from natural sources. As it is extensively used in concrete, its consumption is also quite high due to which there is a lack of availability of the required amount of sand which is adversely affecting the infrastructure industries, thus creating a void in the development and growth of many parts of the country. Different state governments are imposing ban on the sand removal from the rivers due to its unsafe effects. On the other hand granite powder is made from granite stone the treated as a waste material which is present in abundant amount and can be efficiently used as a replacement of sand. Around 17.8 million tonnes of solid granite waste is generated by the Indian granite stone industry out of which 12.2 million tonnes are rejected at the sites and 5.2 million tonnes is present as the form of undersize materials cuttings/ trimmings and there is 0.4 million tonnes of the granite slurry present at the processing and polishing units. This granite waste is dumped which in turn gives rise to the environmental issues also with the huge increment in the amount of waste requiring disposal, intense lack of dumping area, sharp increment in the transportation and dumping costs influencing the earth, and adversely affects the sustainable development.

On the other hand polypropylene fiber is used reinforcing the concrete. Basically concrete based materials are world changing man made development materials. It comprises of binding material i.e. cement, sand and total blended with water, for example, cement and mortar. Concrete has magnificent resistance to pressure or compression, yet is exceptionally poor in stretching. Its properties can be custom-made by need (strength, ductility and so on). Be that as it may it has low elasticity, low ductility and low absorption of energy. Because of its absence of tensile strength, it is fortified with reinforcement bars or mesh in structures yet this sort of reinforcement is insufficient for crack control.

Concrete is essential in nature; reinforcement gets rotted and corroded in some environment. Due to this drawback of fiber reinforcement took place as fiber have many characteristics as they can be uniformly distributed unlike the steel or bars that need to be placed at some distinct places only. Reinforcement of the randomly distributed short fibers into the concrete is a good approach to stabilize the cracks, thus making the concrete more ductile and with increased tensile strength. Polypropylene (PP) fiber reinforcement is considered as an effective method that helps in improving the toughness, characteristic shrinkage cracking, and fire resistance of concrete materials.

II. LITERATURE REVIEW

- A. V. K. R. Kodur “Effect of Strength and Fiber Reinforcement on Fire Resistance of High-Strength Concrete Columns” *Journal of Structural Engineering*, 2003 . In this study columns were fabricated using five batches of concrete. Batch 1 consisted of a concrete mix with normal strength (NSC), while the rest of the mixes for Batch 2–5 were of HSC. To Batch 4 and Batch 5 were having Steel and PP fiber reinforcements, respectively. Batch 3 had coarse aggregate of carbonate type (1040 kg/m³), while the rest of the batches were having siliceous aggregate (732 kg/m³ in batch 1 , 1040 kg/m³ in batch 2 , 900 kg/m³ in batch 4 and 5). It was found by experiments:
- 1) The fire resistance of NSC columns is greater than that of HSC columns at high temperatures.
 - 2) Carbonate aggregate in HSC leads to enhancement of fire resistance.
 - 3) Addition of Steel and polypropylene fibers in HSC improve ductility of HSC columns and also improve their fire resistance.
- B. K.SrinivasaRao M., PothaRaju,P.S.N. Raju, “A Study on Variation of Compressive Strength of High Strength Concrete at Elevated Temperatures”, Conference on ‘Our World In Concrete & Structures’, 2004. Studied the effect of elevated temperatures (up to 950°C) on the compressive strength of HSC of M60 grade using fly ash based Pozzolona Portland Cement. Cube specimens of High strength concrete were exposed to different temperatures from 50°C to 950°C in intervals of 50°C for different durations of 1,2 and 3 hours. Super plasticizer (Conplast SP430) has been used as an admixture to maintain workability having Specific Gravity: 1.220 to 1.225 at 30°C as per IS: 456 and BS: 5075. Facts concluded from this experiment were:-
- 1) Compressive strength increases gradually in the temperature range of 100°C to 250°C and is nominal in the range of 250°C to 350°C.
 - 2) The concrete retains its original strength only up to a temperature of 400°C for all durations of exposure.
 - 3) Compressive strength decreases gradually in the temperature range of 400°C to 700°C and rapid decrease is there after 700°C causing spalling of concrete.
- C. Kanmalai Williams, Partheeban P, Felix Kala T, “Mechanical properties of high-performance concrete incorporating granite powder as fine aggregate”, *International Journal on Design and Manufacturing Technologies*, vol.2, 2008. In this reported the results of an experimental study regarding the replacement of fine aggregate with granite powder and then studying various properties of this high performance concrete. Different percentages of granite powder like; 0, 25, 50, 75 and 100% were used to replace the sand in concrete mix and cement was replaced with 7.5%Silica fume, 10% fly ash, 10% slag and 1% super plasticizer. The effects on compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration of concrete were studied at curing temperature of 32°C and 0.40 water-to-binder (w/b) ratio for 1, 7, 14, 28, 56 and 90 days. Their results indicated that:-
- 1) The highest compressive strength, split tensile strength, modulus of elasticity was achieved in samples containing 25% granite powder concrete.
 - 2) The water penetration in GP25 was 5% less than that of reference mix.
 - 3) The drying shrinkages of all the five concretes were very similar with a maximum value of 420 micro strains after 90 days.
- D. B. Toumi, M. Resheidat, Z. Guemmadi and H. Chabil (*Jordan Journal of Civil Engineering*),2009 in. Studied Coupled Effect of High Temperature and Heating Time on the Residual Strength of Normal and High-Strength Concretes. A series of experiments was performed to investigate the residual strength of NSC, HSC and HSC-PP subjected to elevated temperatures ranging from 300 to 700°C for a heating duration between 1 hour and 9 hours. In this concrete, Aggregates used were of crushed limestone. Commercial Portland cement of 42.5 MPa grade, produced in Jordan as CEM I cement was employed. Silica fume (ASTM C-494 F type) and polypropylene fiber (PP fiber) were used as aggregate and make HSC and HSC-PP sample. The followings are conclusions conducted during the study:
- 1) The residual strength of concrete decreases as the exposure temperature increases, and prolonging the heating time decreases also the residual concrete strength. The strength degradation of heated concretes comes mainly from the peak temperature and the increase of exposure time.
 - 2) Adding polypropylene fibers to HSC mixtures improves their residual compressive and tensile strengths.
 - 3) The polypropylene fibers melt at high temperatures (e.g. fire) providing voids that help reduce explosive characteristics of concrete.

E. Ali Behnood, Masoud (J. Mater. Civ. Eng.), 2009 in. "Comparison of compressive and splitting tensile strength of high-strength concrete with and without polypropylene fibers heated to high temperatures" proposed a four mix of concrete i.e. Mix 1, Mix 2, Mix 3, Mix 4 are OPC-40, SF-6, OPC-30, SF-10 (NF) respectively without PP fiber. And In Mix 2 and Mix 4 a part of the cement is replaced with silica fume at two different replacement levels of 6% (SF-6) and 10% (SF-10). Mix5, Mix6, Mix7 have polypropylene fibrillated fibers, 12 mm in length, were used at dosages of 1, 2, and 3 kg/m³ respectively. From the results obtained in this study, the following conclusion can be drawn:

- 1) Relative residual compressive strengths of concretes containing PP fibers were higher than those of concretes without PP fibers.
- 2) Addition of 2 kg/m³ PP fibers can significantly promote the residual mechanical properties of HSC during heating.
- 3) The presence of PP fibers was more effective for compressive strength than splitting tensile strength above 200 C.
- 4) Rate of heating is 3 degree C/min.

III. EXPERIMENTAL PROGRAM

A. General

This unit describes the objectives and research methodology proposed to be used in achieving the objectives as underlined below:

- 1) Details of materials used, methods adopted in preparing the test specimens.
- 2) Different test procedures shall be discussed.
- 3) The methods employed in preparing the test specimens including casting, curing and conditioning shall also be described in detail.

B. Problem Statement

To study the "Effect of Granite Powder and Polypropylene Fiber on Compressive, Split Tensile and Flexure Strength of concrete at high temperature".

C. Objectives of Study

The main objectives of this study are listed below:

- 1) To design concrete mix of grade M45 as reference concrete by replacing sand with Granite Powder, and fixed proportion of polypropylene fiber having high fire resistance properties.
- 2) To compare the different strength parameters of plain and impregnated M45 grades at 7, 14, 28 days at 300° Celsius at elevated temperature.
- 3) To optimize the replacement of granite powder and polypropylene fibers for M45 grade of concrete.

IV. METHODOLOGY

A. Cement

OPC 43 grade Ambuja cement conforming to IS: 8112 was used.

All tests related to the ingredients of concrete and the entire research/study were performed at Laboratory.

B. Fine Aggregate

Crushed sand was used as fine aggregate. Source of aggregate was BurjKotiyan. Sieve analysis would be done to determine the zone of sand as per IS: 383-1970. Physical properties of sand like specific gravity, fineness modulus were determined.

The concrete mix design was done by using IS 10262:2009 for M-20 grade of concrete.

C. Coarse Aggregate

Crushed aggregates, angular in shape have been used in experimental work. Grading of coarse aggregate was done according to IS: 383-1970. Aggregate of nominal size 20 mm and 10 mm are combined to obtain graded aggregates with gradation ratio of 2:1. Specific gravity and water absorption of coarse aggregate were determined as per IS 2386 (PART -3)-1963.

D. Water

Potable water available in the laboratory for mixing and curing was used for this project specification conforming to BIS: 456- 2000

E. Granite Powder

Granite belongs to igneous rock family. Granite powder was obtained from the polishing units and the properties were found. Physical properties of granite powder shown in Table 3.8.



Fig.1 Granite Powder

Table 1: Physical Properties of Granite Powder

| Properties | Test Results |
|----------------------|--------------------------------|
| Specific Gravity | 2.93 |
| Density | 2.65 to 2.75 g/cm ³ |
| Compressive Strength | 200 MPA |

F. Polypropylene Fiber

The fiber used was fine polypropylene. The fibers used were from Reliance Industry by name RECRON. It is available in various different sizes i.e. 6mm, 12mm, 18mm and 24 mm. The one that is used in this research is 18mm. Specific gravity of polypropylene was 0.90 as conveyed by the manufacture.



Fig.2 Polypropylene Fiber

G. Super Plasticizer

The super plasticizer used in the study was “Aura mix 400” of Fosroc Company. Aura mix 400 is a unique combination of the latest generation super plasticizer, based on a polycarboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. This mechanism considerably reduces the water demand in flowable concrete.

Following properties can be imparted to concrete as per claim made by the Fosroc Company on using Aura mix 400:

- 1) Low viscosity suitable for pumping of different grades of concrete to higher floors
- 2) Improved adhesion to reinforcing and Pre- stressing steel
- 3) Better resistance to carbonation
- 4) Lower permeability
- 5) Better resistance to aggressive atmospheric conditions
- 6) Reduced shrinkage and creep
- 7) Increased durability



Fig.3 Aura Mix 400

H. Mix Design Method

Concrete mix design is the method of correct proportioning of ingredients of concrete as per the site requirements, in order to obtain desirable properties of concrete in plastic as well as hardened stage. The objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed as concrete mix design.

M45 grade of concrete were used in this project work and designed as per BIS method.

1) Design mix data of M45 Grade of concrete using OPC.

Specific gravity of coarse aggregate = 2.76

Specific gravity of fine aggregate = 2.63

Grading ratio of 12.5mm and 20mm aggregate = 2:1

Specific gravity of cement (OPC) = 3.15

2) Mix design as per BIS method for M45 grade of concrete.

Exposure condition = Extreme

Minimum cement content = 450 kg

Maximum free water cement ratio = 0.38

Slump required = 75 to 100 mm

a) Target mean strength = 53.25 N/mm²

b) Water cement ratio = 0.38 < 0.40

c) Cement = 450 > 360 kg

d) Water content = 171 kg

e) Volume of coarse aggregate corresponding to unit volume of total aggregate for different zones of fine aggregate for different zones of fine aggregates = 0.62 + 0.024 = 0.644 m³

f) Volume of fine aggregate = 1 - 0.644 = 0.356 m³

g) Volume of cement = (450/3.15) × (1/1000) = 0.142 m³

h) Volume of water = (171/1) × (1/1000) = 0.171 m³

i) Volume of super plasticizer = (6.75/1.11) × (1/1000) = 0.0061 m³

j) Total aggregate = 1 - (0.142 + 0.171 + 0.0061) = 0.6809 m³

k) Mass of coarse aggregate = 0.6809 × 2.76 × 1000 × 0.644 = 1210.66 kg/m³

l) Mass of fine aggregate = 0.6809 × 2.63 × 1000 × 0.356 = 637.61 kg/m³

Table 2: Final mix proportion of M45 grade per cubic meter concrete using OPC

| Cement (kg) | F.A (kg) | C.A (kg) | Water (m ³) | Super plasticizer (m ³) |
|-------------|----------|----------|-------------------------|-------------------------------------|
| 450 | 637.61 | 1210.66 | 0.38 | 1.2% |
| 1 | 1.42 | 2.69 | 0.171 | 0.0061 |

V. RESULTS AND DISCUSSION

A. General

In this chapter, the findings of experimental investigations are presented. Various tests were conducted to evaluate the effect of granite powder and Polypropylene fiber on compressive, splitting tensile and flexural strength test. Granite powder was used as a partial replacement of fine aggregate at the percentage of 10 %, 20%, 30% and fixed proportion of polypropylene fiber which is 0.25% by weight of cement. After this same procedure was adopted for testing cubes heated at 300°C temperature for compressive strength. Design of different concrete mix and procedure of various tests are described in chapter 3

B. Compressive Strength

Now plain concrete and granite powder with fix proportion of polypropylene fiber concrete was taken. The specimens of size 150×150×150 mm were cast and tested for its compressive strength at 3 different curing periods which is 7, 14 and 28 days as given in the Table 4.1. The results obtained from the tests are represented as under in tabular and graphical form.

Table: 3. Compressive Strength for Cube 150x150x150 mm

| Mix Sample | Compressive Strength (N/mm ²) | | |
|----------------|---|--------|--------|
| | 7 days | 14days | 28days |
| Plain concrete | 38.50 | 46.25 | 54 |
| GP10 | 41.55 | 47 | 52.25 |
| GP20 | 44.60 | 49.63 | 54.66 |
| GP30 | 43.85 | 48.8 | 53.25 |

The comparison was done only between plain concrete and granite powder with fix proportion of polypropylene fiber concrete for its compressive strength. The values of compressive strength at 7 days are represented in Fig.4.1, compressive strength at 14 days is shown in Fig.4.2 and compressive strength at 28 days is shown in Fig.4.3. Concrete made with GP20 showed maximum compressive strength among all other concrete samples i.e. Plain concrete, GP10, GP30

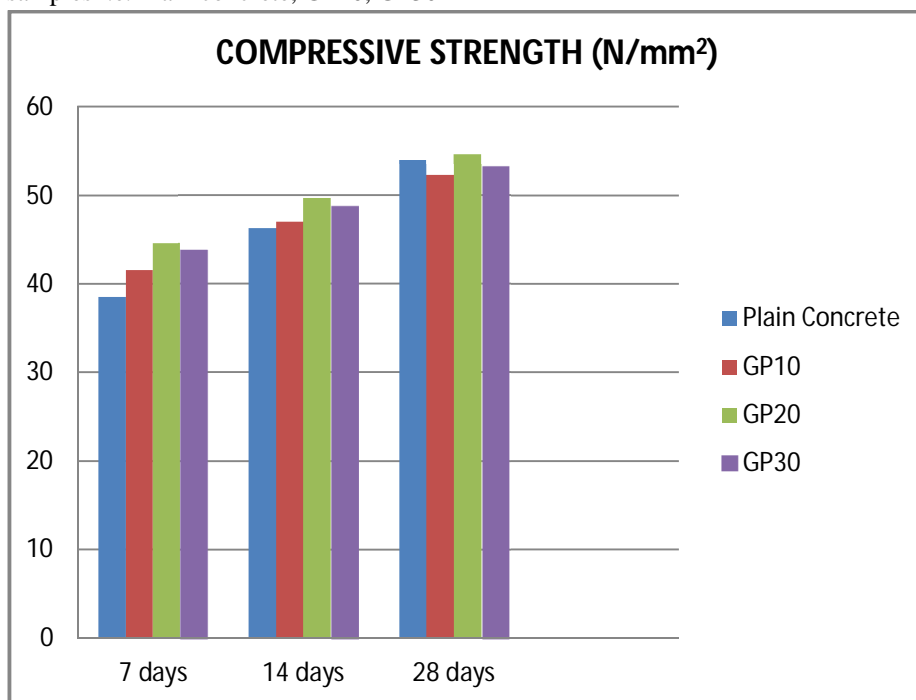


Fig.4. Comparison of Compressive Strength at various testing stages

C. Split Tensile Strength

The split tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder specimen (100x200mm) is a method to determine the tensile strength of concrete. Concrete being a weak material in tension due to its brittle nature does not resist the direct tension. Test results of split tensile strength test at the age of 7 days, 14 days and 28 days are given in the Table4.2. These values are graphically presented in Fig 4.5, Fig 4.6 and Fig 4.7 which shows the variation in split tensile strength of plain concrete and granite powder with fix proportion of polypropylene fiber concrete. Concrete made with GP20 showed maximum split tensile strength among all other concrete samples i.e. Plain concrete, GP10, GP30.

Table: 4. Split Tensile Strength

| Mix Sample | Split Tensile Strength (N/mm ²) | | |
|----------------|---|---------|---------|
| | 7 days | 14 days | 28 days |
| Plain concrete | 3.26 | 3.38 | 3.50 |
| GP10 | 4.27 | 4.60 | 4.96 |
| GP20 | 5.28 | 5.46 | 5.65 |
| GP30 | 4.89 | 5.09 | 5.29 |

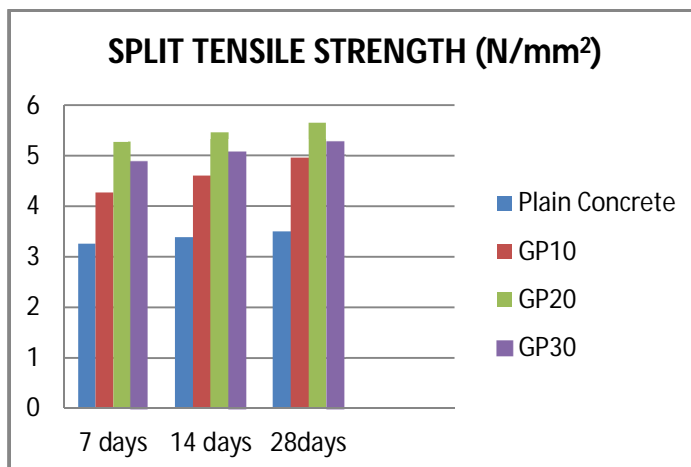


Fig.5. Comparison of Split Tensile Strength at different testing stages

D. Flexure Strength Test

Flexural strength is a measure of the tensile strength of concrete. It is a measure of an un-reinforced concrete beam or slab to resist failure in bending. Test results of Flexural strength test at the age of 7 days, 14 days and 28 days are given in the Table 4.3. These values are graphically presented in Fig 4.9, Fig 4.10 and Fig 4.11 which show the variation in Flexural strength of plain concrete and granite powder with fix proportion of polypropylene fiber concrete. Concrete made with GP20 showed maximum flexure strength among all other concrete samples i.e. Plain concrete, GP10, GP30.

Table: 5.Flexure Strength

| Mix Sample | Flexure Strength (N/mm ²) | | |
|----------------|---------------------------------------|---------|---------|
| | 7 days | 14 days | 28 days |
| Plain concrete | 4.44 | 5.20 | 5.97 |
| GP10 | 5.12 | 6.05 | 6.99 |
| GP20 | 6.06 | 6.95 | 7.84 |
| GP30 | 5.46 | 6.35 | 7.24 |

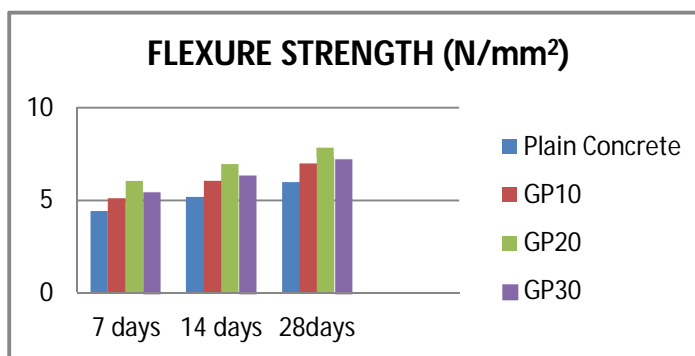


Fig.6. Comparison of Flexure Strength at different testing stages

VI. CONCLUSIONS

The experimental study was carried out by designing a mix of grade M45 and then, adding fixed proportion of PP fiber (0.25% of weight of cement) and replacing sand with Granite powder having proportions of 10%, 20% & 30%. After performing this study and comparison of the results, the inferences that are made from the study are mentioned below:

- 1) As PP fiber is light in weight it results in more bulk density which has more positive effect on concrete strength parameter at high temperature of 300°C as it improves their restriction against widening of concrete micro cracks.
- 2) Granite powder, being the waste material, can be easily found and when added to concrete enhances various strength parameter even at high temperature.

- 3) Among the various mixes, GP20 (20% of granite powder in concrete by replacing sand) was found to be the most superior one as all the strength parameters (i.e. compressive, split tensile and flexure strength) of GP20 was higher than the plain conventional concrete at elevated temperature of 300°C.

The present experimental study shows that the strength and fire resistance of concrete could be enhanced by using PP fiber and granite powder which is a waste material obtained from granite industries.

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