Properties of Geopolymer Concrete using Granite Powder as Partial Replacement of Fine Aggregate

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Abstract - *The present study reports the mechanical and durability properties of Geopolymer concrete (GPC) using granite powder as fine aggregate replacement. Granite waste because of its fineness and size it can be effectively used as a replacement of fine aggregate. Granite powder sourced from local natural stone processing plants and Flyash sourced from industrial waste. In this study, granite powder was replaced at different replacement levels (0%, 20%, 40% and 60%). Class F Flyash is used as geopolymer binder. Sodium silicate (Na_2SiO_3) and sodium hydroxide (10M) has been used as a alkali activator. Compressive strength, Splitting tensile strength and Flexural strengths were studied after 7days and 28days of heat cured at 60̊C for 24hrs.From the results it is revealed that the studied mechanical properties were increased with the increasing replacement level of Granite powder up to 40% and there is a strength decrement were observed after 60% replacement level. It is concluded that the optimum percentage replacement for fine aggregate with granite powder is up to 40%.*

Key Words: **Geopolymer concrete, Granite powder, Flyash, Molarity, Thermal curing,**

1. INTRODUCTION

The consumption of concrete stands second globally after water. As the demand for concrete increases it also increases the demand for Portland cement. On the other hand, the climate change due to global warming has become a major concern. Global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2) to the atmosphere by human activities. The cement industries are held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.

Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as flyash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin as the alternative binders to Portland cement.

In this respect, the geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of global warming, the geopolymer technology could significantly reduce the CO_2 emission to the atmosphere caused by cement industries.

This "Geopolymer" was developed in the mid 1970 by Davidovits and it had geopolymericalumino-silicate gel performing the role of binder. Recently, Ragan and Hardjito (2005) also exploited silica (SiO_2) and alumina (Al_2O_3) of flyash to synthesize geopolymeric binder which was found to be useful to prepare structural grade concretes.

Granite industry generates different types of wastes such as solid waste and stone slurry. The semi liquid substance released from the polishing operations was termed as stone slurry or powder. Leaving the waste materials to the environment directly can cause environmental problems. Hence the reuse of waste materials has been emphasized.

Wastes can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste efficiently.

2. OBJECTIVES

The major objective of this project stand the use of granite powder as fine aggregate in different variations in low calcium flyash based geopolymer concrete to evaluate its mechanical properties and also studying the durability properties of it.

3. MATERIALS USED

3.1 Cement

In present studies, Zuari cement of 53 grade confirming to grade IS 12269-2013 was used and cement sample was tested as per IS 4031-1988 part 4 and IS 4031-1988 part 5. Physical properties like specific gravity, standard consistency, initial setting time and final setting time of cement were determined by using the codes (IS:4031-1988)

Table -1: Properties of cement

Property	Test results
Normal consistency	28%
Specific Gravity	3.15
Initial setting time	112 minutes
Final setting time	260 minutes

3.2 Coarse Aggregates

Crushed granite stones of size 20mm down aggregates were used as the coarse aggregates in the concrete mixtures. Properties of coarse aggregates were determined as per IS 2386-1997 part III guidelines.

Table -2: Properties of the coarse aggregates.

Characteristics	Test Results
Specific Gravity	2.68
Water Absorption	0.20%
Bulk density in loose state	1450 kg/m³
bulk density in compacted state	1670 kg/m³

3.3 Fine aggregates

In the present Work crushed stone aggregates was used as fine aggregate and test were conducted as per IS:2386-1997 Part-III and IS:383-1970.

Table -3: Properties of the fine aggregate

Characteristics	Test Results
Specific Gravity	2.69
Water Absorption	2%
fineness modulus	2.90
Bulk density in loose state	1420 kg/m³
bulk density in compacted state	1650 kg/m³
Grading zone	II

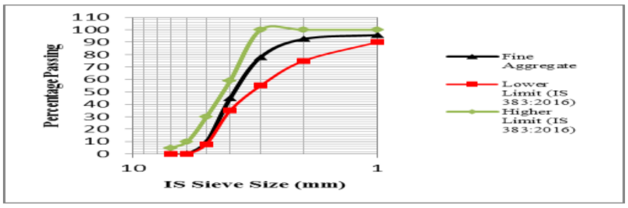

Fig -1: Sieve analysis of Fine aggregates

3.4 Granite powder

Granite belongs to igneous rock family. Granite powder is used as a secondary material for fine aggregate. Granite powder is obtained from the granite cutting industry. The semi liquid substance released from the polishing process was termed as granite slurry, which will be stored in tanks and allowed for evaporation. The material obtained after evaporation will be termed as granite powder. The specific gravity of granite powder determined is 2.5.

Fig -2: Granite powder Sample

3.5 Fly ash

Flyash of Class F grade collected from Raichur thermal power plant (RTPS) was used in the present work. From test Specific gravity of the flyash was found to be 2.33.

3.6 Alkaline Activators

Sodium hydroxide and Sodium silicate solution were combined together to form alkaline activators. Sodium hydroxide in flakes form and sodium silicate solution of industrial grades were purchased from SP enterprises, Bengaluru.

4. EXPERIMENTAL PROCEDURE

Four mix's casted were fine aggregate was replaced with 0%, 20%, 40% and 60% granite powder by weight respectively and are given below.

Table -4: Mix proportion of concrete

Ingredients (kg/m³)	0%	20%	40%	60%
Flyash	409	409	409	409
Sand	554	443.2	332.4	221.6
Coarse agg	1294	1294	1294	1294
Granite powder	0	110.8	221.6	332.4
Sodium silicate solution	102	102	102	102
Sodium hydroxide solution	41(10M)	41(10M)	41(10M)	41(10M)
Alkaline solution/flyash	0.35	0.35	0.35	0.35
Water/geopolymer solids	0.17	0.17	0.17	0.17
Extra water	100	100	100	100
$NaOH/Na_2SiO_3$	2.5	2.5	2.5	2.5

4.1 Preparation of Alkaline Liquid

Sodium hydroxide flakes were dissolved in distilled water to make a solution of 10M. Sodium silicate solution and sodium hydroxide solution of 10M were mixed together at room temperature. When both solutions were mixed together it starts to react i.e. "polymerization" takes place this liberates large amount of heat. So, it is recommended to leave it for about 24 hours.

Fig -3: Prepared Alkaline liquid before casting

4.2 Preparation of Geopolymer Concrete Mixtures

Preparation of geopolymer concrete is similar to that of cement concrete. Coarse aggregates, two types of fine aggregate like sand and granite powder and flyash were mixed in dry state. Then alkaline solution which is prepared 24hrs prior to mixing were added along with extra water based on water to geopolymer binder ratio and mixed thoroughly for 3 to 4 mins so as to obtain homogeneous mix.

4.3 Specimen Casting and Curing

For each concrete mixture, 150mm cubes, 150mm X 300mm cylinders, 100mm X 100mm X 500mm prisms, 100mm X 50mm cylinders were cast. 150mm cubes were used to determine the compressive strength, 150mm X 300mm cylinders were used to evaluate the split tensile strength, 100mm X 100mm X 500mm prisms were used to evaluate flexural strength and 100 mm X 50 mm cylinders were used to evaluate the water absorption, chloride ion permeability and sorptivity value of the concrete specimen.

The specimens were compacted using vibration table.

After 24hrs of casting all moulds were demoulded and then placed in an over for thermal curing (heating) at 60°C for 24hrs. To avoid the sudden variation in temperature the concrete specimens were allowed to cool down up to room temperature in an oven itself.

Fig -4: Casting of geopolymer concrete

Fig -5: Thermal curing of geopolymer concrete

4.4 Specimen testing

After the curing period of 7 days and 28 days, specimens are taken out for testing. Test will be conducted for compression test for cubes (150x150x150mm), split tensile test for cylinders (150mm diax300mm height) and flexural test for beams (100x100x500mm) as per IS:516-1959.Sorptivity test for durability using cylinders (150mm dia and 50mm height).

Fig -6: Compressive testing

Fig -7: Split tensile testing

Fig -8: Flexural testing

5. TEST RESULTS

5.1 Workability of concrete

Workability was measured using slump cone test. Results show that geopolymer concrete has 45mm and the degree of workability is medium.

5.2 Mechanical Properties of Concrete

Table 5 shows the compressive strength, split tensile strength and flexural strength of GPC mixes as well as normal concrete mix at different curing periods.

Table -5: Mechanical properties of GPC

	AGE	GP0	GP20	GP40	GP60
Compressive strength (MPa)	7	37.80	42.22	44.18	34.11
	28	53.10	56.00	57.08	38.91
Split tensile strength (MPa)	7	2.28	2.40	2.86	2.23
	28	3.38	3.52	3.72	3.25
Flexural strength (MPa)	7	3.95	4.20	4.80	4.95
	28	4.20	4.80	5.25	5.38

5.2.1 Compressive strength test

In the present study, 3 cubes for each mix proportion were tested and average of 3 cubes was taken as compressive strength of concrete. The compressive strength of concrete can be seen in Fig.1. Above results shows that there will be increase in compressive strength of geopolymer concrete when it is replaced with granite powder up to 40%. As the granite powder variation increases to 60% the compressive strength gets decreased.

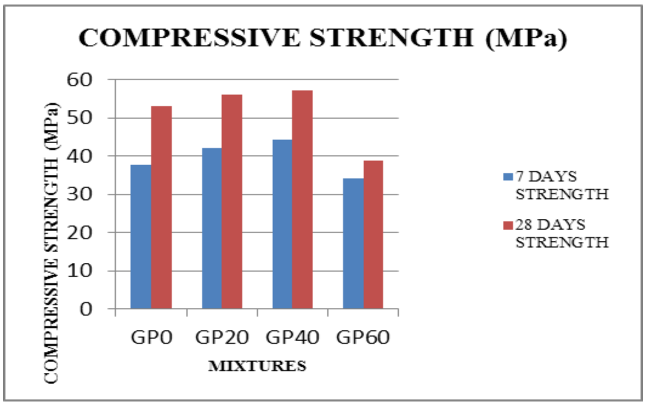

Fig -9: 7 and 28 days compressive strength of concrete

5.2.2 Split tensile strength test

Split tensile strength of concrete was tested on 150mm X 300mm cylinder at the age of 7 and 28 days. Test results are shown in the Fig.2. Splitting tensile strength of GPC mixes with granite powder increases up to 40%. But at GP60 mix the splitting tensile strength decreases.

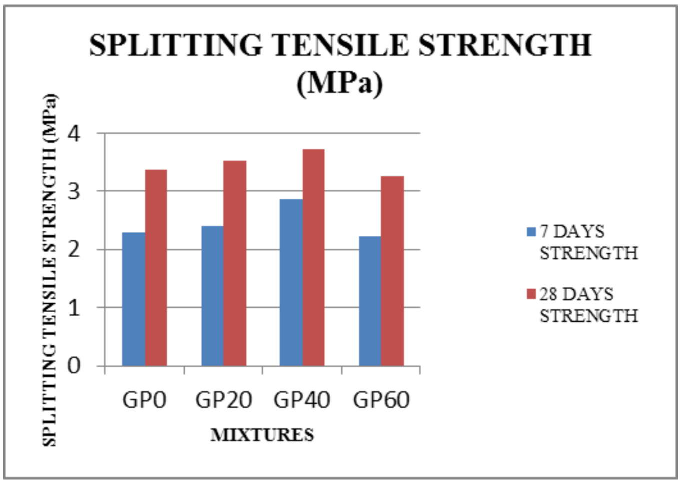

Fig -10: 7 and 28 days split tensile strength of concrete

5.2.3 Flexural strength test

Flexural strength of concrete was tested on 100mm X 100mm X 500mm prisms at the age of 7 and 28 days. Test results are shown in the Fig.9. The test results show that there will be increase in the flexural strength as the percentage of granite powder increases in geopolymer concrete at 7 and 28 days.

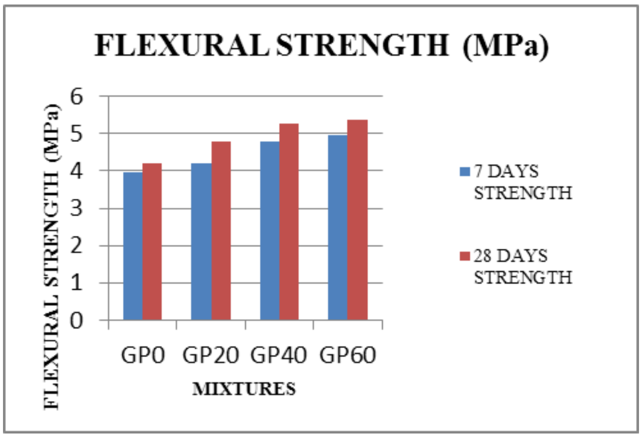

Fig -11: 7 and 28 days flexural strength of concrete

5.3 Durability properties of concrete

5.3.1 Sorptivity

Sorptivity has been tested on both geopolymer concrete with replacement of granite powder and conventional concrete. This test was conducted on 100mm X 50mm size specimen after 28 days of curing. The dry weights of the specimen are noted and its wet weights are noted at 30 min interval. Table 6 gives Sorptivity values of geopolymer concrete with different percentage of granite powder. The result shows that, in geopolymer concrete the Sorptivity will goes on decreasing when the percentage of granite powder increases.

Table -6: Sorptivity test values

Type of concrete	No. of specimen	Dry wt. W1 (kg)	Wet wt. W2 (kg)	Sorptivity values in 10^{-6}	Avg. sorptivity value
GP0	1	0.994	1.050	1.301	1.301
	2	1.024	1.078	1.255	
	3	0.986	1.044	1.348	
GP20	1	1.062	1.112	1.162	1.254
	2	0.996	1.044	1.215	
	3	0.999	1.050	1.385	
GP40	1	1.060	1.112	1.208	1.208
	2	1.024	1.078	1.255	
	3	0.990	1.040	1.162	
GP60	1	1.038	1.078	0.929	0.968
	2	1.028	1.070	0.976	
	3	0.995	1.038	0.999	

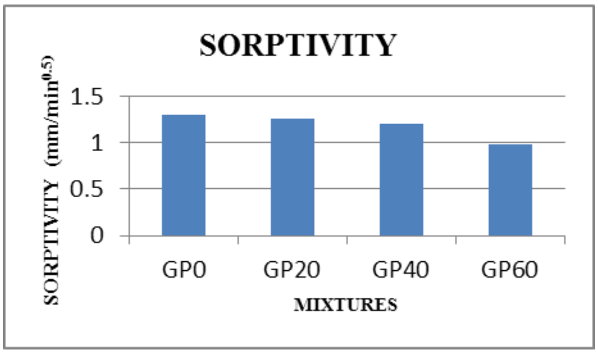

Fig -12: 28days sorptivity values

6. EFFECT OF CURING HOURS ON GPC WITH OPTIMUM PERCENTAGE REPLACEMENT OF GRANITE POWDER

The results show that at different curing hours like 3, 12 and 24 hours at 60̊C the compressive strength, splitting tensile strength and flexural strength increases as the hours of curing increases.

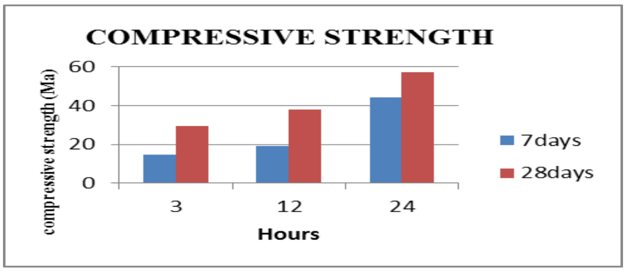

Fig -13: Compressive strength at 7days and 28days

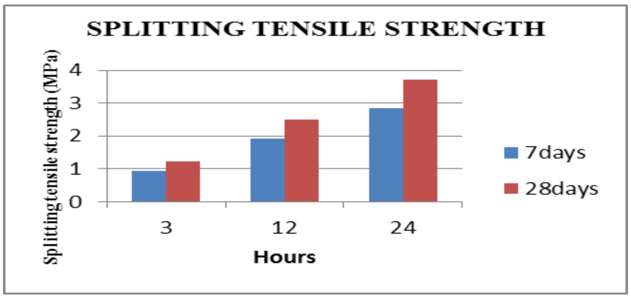

Fig -14: Split tensile strength at 7days and 28days

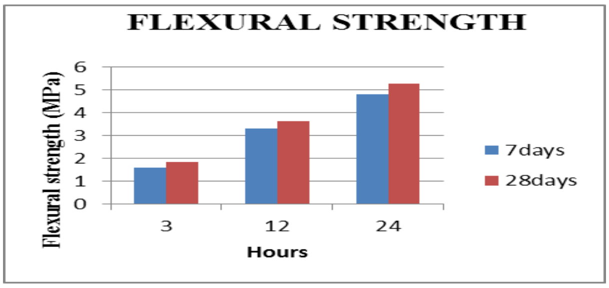

Fig -15: Flexural strength at 7days and 28days

7. CONCLUSIONS

Study upon the mechanical properties and durability properties concerning GPC when it is partially replaced with granite powder has been presented. Major conclusion derived from this study it could be compile as follows,

- Use regarding waste materials like granite powder and flyash can reduce the environmental pollution and disposal.
- Geopolymer concrete has less workability. And it can be overcome by adding suitable Superplasticizer.
- Geopolymer concrete attains its maximum strength in 7days itself. This is because polymerisation takes place within 24 hours of mixing and attains its maximum strength when it is heated at 60 for 24 hours
- It have being observed which an increasing trend has been observed in compressive strength as well as split tensile strength of GPC mixtures till 40% replacement level of granite powder. And both the properties got falling trend at 60% of replacement level of granite powder.
- Whereas the flexural strength increases as the percentage replacement of granite powder as fine aggregate in geopolymer concrete increases.
- It is concluded in order that 40% replacement of granite powder is consider as optimum replacement level. And it seems that granite powder act as filling material and makes the concrete dense.
- Sorptivity of GPC is less. That means the rate of absorption of GPC is unsubstantial.
- The effect of curing hours on the geopolymer concrete when it is replaced with optimum percentage of granite powder increase as there is increase in the curing hours.

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