Geo Polymer Concrete with the Replacement of Granite Aggregate as Fine Aggregate

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Abstract: ***Disposal of granite fines from the polishing industries is a major problem. As the granite polished powder is reactive it cannot be disposed into land. When dumped on land, these wastes adversely affect the productivity of land due to decreased porosity, water absorption, water percolation etc. They cause serious environmental and dust pollution and require vast area of land for their disposal. The production of cement concrete accounts to about 5 % of the man made pollution for global warming. During the polishing operations the amount of granite powder waste retained and passing through 150µ are 12% and 88% respectively. The granite waste because of its fineness and size it can be effectively used as a replacement of sand. The strength of geo polymer concrete increases with the increase in the alkalinity of NaOH. Previous investigations on introduction of granite fines into ordinary concrete showed positive results at an optimum replacement of sand at 15 %. An attempt was made to introduce granite aggregate into geo polymer concrete as it increases the alkalinity of geo polymer concrete as well as it`s grading of sand. The granite aggregate was replaced in percentages various tests such as split tensile strength, compressive strength and flexural strengths were tested and compared with basic mix.***

Keywords: Granite aggregate, river sand, compressive strength, split tensile strength, flexural strength, Molarity, stone slurry, Optimization.

1. Introduction

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. About 17.8 million tones of solid granite waste and out of which 12.2 million tones will be rejects at the industrial sites, 5.2 million tonnes granite slurry at processing and polishing units. Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized. Waste 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 deposits. Marble stone industry generates both solid waste and stone slurry. Solid waste results from the rejects at the mine sites or at the processing units. There are several reuse and recycling solutions for this industrial by- product, both at an experimental phase and in practical applications. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled [9] 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. Granite industry has grown significantly in the last decades with the privatization trend in the early 1990s as the flourishing construction industry in the World. Accordingly, the amount of mining and processing waste has increased. Granite reserves in India are estimated at 1200 million tonnes. Granite industries in India produce more than 3500 metric tonnes of Granite powder slurry per day as waste product. Granite tiles manufacturing industries are also producing tonnes of granite dust/slurry during the manufacturing process.

2. Literature Review

Hamza et.al (2011) introduced granite waste into concrete bricks the test results showed that the use of granite dust had a positive effect and the optimum granite content was 10 %.

Oyekan G.L and Kamiyo O.M (2008) studied the performance of hollow sand crete blocks containing cement, sharp sand and granite fines in varying propositions to determine their structural and hydrothermal properties. The percentage of granite fines by volume of the total fine aggregate was varied in steps of 5% to a maximum of 30%.Results of the tests indicated that the inclusion of granite fines in the sand-cement matrix has a very significant effect on the compressive strength of sandcrete blocks. It was also, observed that for both mix propositions, 15% granite fines content was the optimum value for improved structural performance.

Kanmalai Williams C et al (2008) examined the performance of concrete made with the granite powder as fine aggregate. Sand was replaced with granite powder in steps of 0, 25, 50, 75 and 100% and cement was replaced with 7.5%Silica fume, 10% fly ash and 10% slag. They added 1% super plasticizer to improve the workability. The effects of curing temperature at 32^0 C and 1, 7, 14, 28, 56 and 90 days compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration depth were found. Experimental results indicated that the increase in the proportions of granite powder resulted in a decrease in the compressive strength of concrete. The highest compressive strength was achieved in samples containing 25% granite powder concrete, which was 47.35 KPa after 90 days. The overall test performance revealed that granite powder can be utilized as a partial replacement of natural sand in high performance concrete.

Felixkala T and Partheeban P (2010) examined the possibility of using granite powder as replacement of sandalong with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite powder of marginal quantity as partial replacement to sand had beneficial effect on the mechanical properties such as compressive strength, split tensile strength and modulus of elasticity. They also reported that the values of plastic and drying shrinkage of concrete with granite powder were less than those of ordinary concrete specimens.

Hudson (1999) reported that, „„„concrete manufactured with a high percentage of minus 75 micron material will yield a more cohesive mix than concrete made with typical natural sand.

Mishra at PWD Research Institution, Lucknow (1984), on use of stone dust in cement mortars explains the influence of Shape and Size of fine aggregate on strength of mortars The experiments conducted by **Dr. D.S. Prakash Rao and V.Giridhar Kumar (2004)** on strength characteristics of concrete with stone dust as fine aggregate, draws the following conclusions-The concrete cubes with crusher dust developed about 17% higher strength in compression, more split tensile strength and 20% more flexural strength (Modulus of Rupture) than the Concrete cubes/beams with river sand as fine aggregate. Similarly, Reinforced Concrete Beams with crusher dust sustained about 6% more load under two point loading and developed smaller deflections and smaller strains than the beams with river sand.

3. Research Significance

The objective of the work was to replace the sand with granite aggregate and tests on structural performance of concrete was carried out at various percentages from 5 % to 30% and the results were compared with a basic mix. As the granite waste from the polishing industries is basic in nature parameters such as ratios also have to be changed to attain the strengths.

4. Materials

4.1 Fly Ash

In the present work class F fly ash was used for the Investigation and the chemical composition of fly ash is quoted in table 1.

4.2 Sodium Hydroxide

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. The role of sodium hydroxide in this study is to activate the Geopolymer concrete which is a homogeneous material. Hence it is recommended to use sodium hydroxide with cost effectiveness and purity. In this investigation, the sodium hydroxide pellets were used, whose physical and chemical properties are given by the manufacturer as shown in Table 4.2 and 4.3.

4.3 Sodium Silicate

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In the present investigation, sodium silicate 2.0 (ratio between Na2O to SiO2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. The same sodium silicate is used for the making of Geo polymer concrete. The composition of the silicates is as shown in Table 4.4

4.4 Granite Powder

Granite belongs to igneous rock family. The density of granite is between 2.65 to 2.75 g/cm3 and compressive strength will be greater than 200 MPa. Granite powder obtained from the polishing units in Kurnool District and the properties were found. Since the granite powder was fine, hydrometer analysis was carried out on the granite powder to determine the particle size distribution. From hydrometer analysis it was found that the coefficient of curvature was 1.95 and coefficient of uniformity was 7.82. The specific gravity of the granite powder was found to be 2.61. Table 4.5 gives the chemical composition of granite powder.

5. List of Tables

Table 4.1: Chemical composition requirements of fly ash as per IS: 3812-1981 and the chemical composition of the fly ash used in the mixture.

S. No.	*Chemical composition*	*Specifications as per IS: 3812-1981*	*Properties of fly ash used*
1	SiO_2+Al_2O_3+Fe_2O_3	70% (min.)	90.50%
2	SiO2	35% (min.)	58.00%
3	CaO	5% (max.)	3.60%
4	SO_3	2.75% (max.)	1.80%
5	Na_2O	1.50% (min.)	2.00%
6	MgO	5.00% (max.)	1.91%
7	LOI	12.00% (max.)	2.00%

Table 4.2: Properties of Sodium hydroxide

Colour	Colourless
Specific gravity	1.92

Table 4.3: Chemical Composition of Sodium Hydroxide (NaOH)

Components	**%**
Purity	98
Sodium carbonate	1.00
Chloride	0.005
Sulphate	0.0005
Phosphate	0.0005
Silicate	0.001
Total Nitrogen	0.003
Heavy metals(as like Pb, Nickel, Iron , Aluminium, Calcium, Potassium)	0.003

Note: NaOH gram molecular weight is 40

Table 4.3: Composition of Sodium Silicate (Na_2SiO_3)

Component	%
SiO_2-Na_2O	2.0
SiO_2 by weight	35.7
Na_2O by weight	17.8
H_2O by weight	46.5
Specific Gravity	1.7
Tolerance	+2% to -2%

Table 4.4: Chemical composition of Granite Powder

Chemical constituent	%
Alumina (Al_2O_3)	14.42
Magnesium Oxide (MgO)	0.71
Calcium Oxide	1.82
K_2O	4.12
Na_2O	3.69
Silica(SiO_2)	72.04
Fe_2O_3	1.22

***P^H test on granite powder*:**

When Granite powder comes into contact with water the P^H of water gets affected. In geo polymer concrete, water is added along with NaOH solution. The water added into geo polymer concrete also variable depending on molarities of the solution. A test was conducted on Granite powders reactivity to know the variation. At 15 % replacement of granite powder with sand as per the mix design for every 50 ml of water about 61g of granite powder was added. The reactivity of granite powder increases with decrease in the size of granite. Test was carried out separately for granite retained and passing on 150μ sieve.

Weight of water = 50g

Weight of granite powder = 61 g

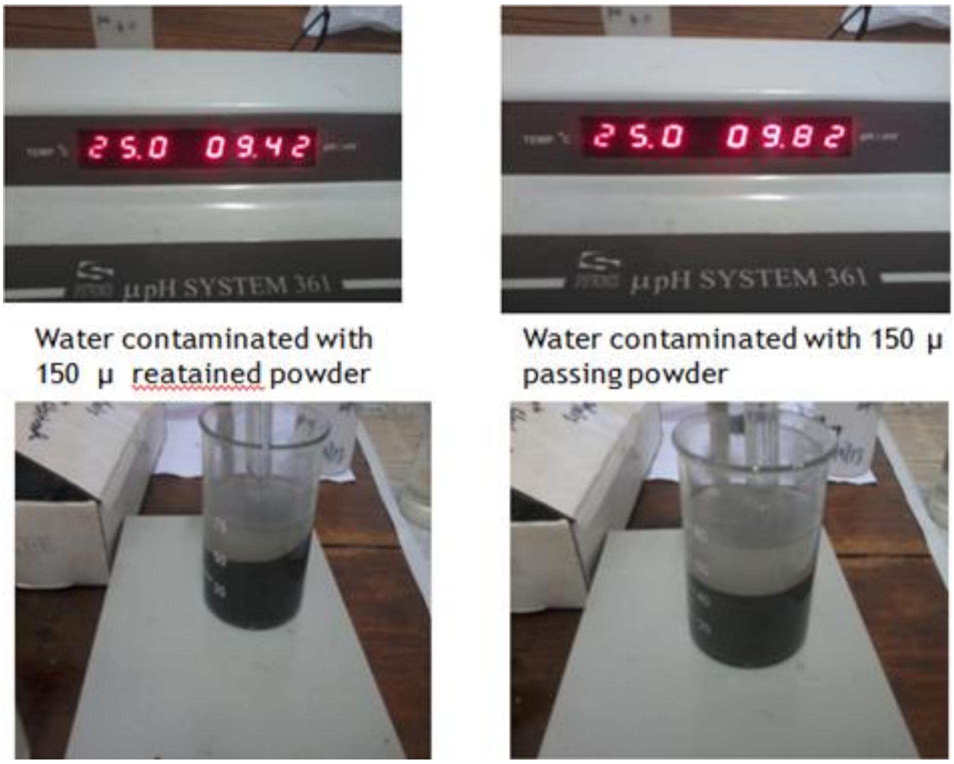


Figure 5.1

6. Experimental Procedure

Constituents of geo polymer concrete are as shown below based on mix design of B.V.Rangan.

Table 6.3: Mix Design Results for 1 M^3 for Na_2SiO_3 to NaOH ratio 2.25 and alkaline liquid to fly ash ratio as 0.7

S.No	Ingredient	Quantity (Kg)
1.	NaOH flakes	44.66
2.	Water	46.52
3.	Na_2SiO_3	211.77
4.	Fine aggregate	504
5.	Coarse aggregate	1176
6.	Fly ash	423.52

6.1 Alkaline liquid preparation

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at room temperature. When the solution mixed together both solutions start to react i.e. (polymerisation takes place) it liberates large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent.

6.2 Casting of specimens

Before casting of specimens the moulds were cleaned and oiled.

6.3 Gestation phase

During this phase the concrete along with moulds immediately after casting kept into the oven at temperature of 95^0 C. The concrete is allowed to set for 4 hours. After that the concrete is removed from oven and demoulded.

6.4 Curing of Geopolymer Concrete Specimens:

The most important operation in the manufacture of Geopolymer concrete is curing. After gestation phase the demoulded specimens are kept in oven and cured at temperature of 95^o C for 48 hours and kept open to atmosphere and testing is performed after 8 days and 28 days. Unlike OPC concrete which needs water for curing, Geopolymer concrete requires heat or temperature to activate the chemical reaction that takes place in Geopolymer matrix. Steam curing, dry curing and curing at ambient temperature are the types of curing that could be employed to cure the Geopolymer concrete.

Figure 7.1: Mixing of Geopolymer Concrete

Figure 7.2: Gestation Phase of GPC

Figure 7.3: Curing of Specimens

Tests on fresh concrete
The slump value and Compaction factor value of the given concrete mixes is 220 mm and 0.97. The values recorded for different mixes in which variation is inconsistent.

6.5 Destructive Tests on Hardened Concrete:

The following results were obtained at 8 days and 28 days

Table 9.1- Concrete Mix Designation

S.NO	*Mix*	*Designation*
1	0% Granite Powder replacement	G0
2	5% Granite Powder replacement	G5
3	10% Granite Powder replacement	G10
4	15% Granite Powder replacement	G15
5	20% Granite Powder replacement	G20
6	25% Granite Powder replacement	G25
7	30% Granite Powder replacement	G30

Table 9.8: Strength Properties for Na_2SiO_3 to NaOH ratio 2.25

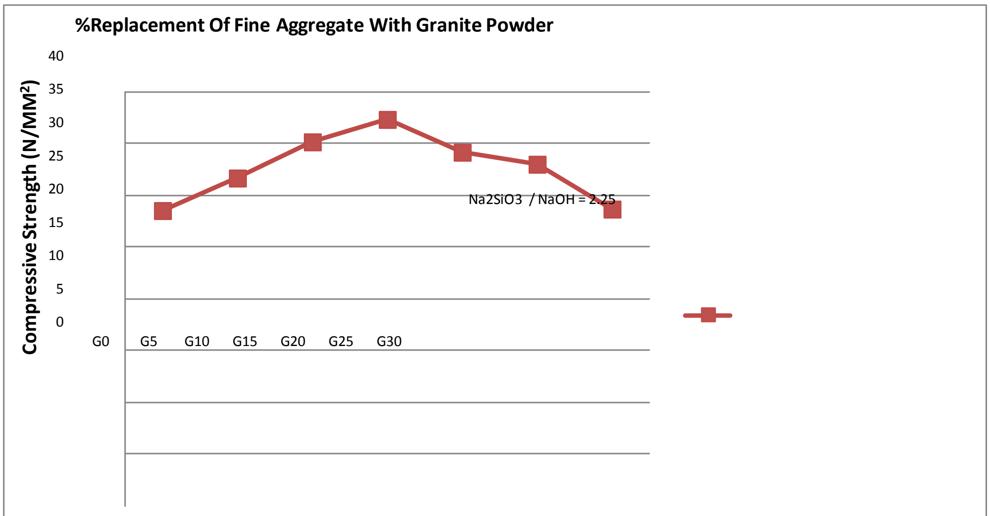
MIX Designation	*% of granite powder replaced with fine aggregate*	*Compressive strength(N/mm^2) At 8 days*	*Flexural strength(N/mm^2) At 8 days*	*Split Tensile strength(N/mm^2) At 8 days*
G0	0%	28.53	3.92	2.38
G5	5%	31.67	4.32	2.54
G10	10%	35.16	4.08	2.38
G15	15%	37.33	4.22	2.705
G20	20%	34.16	4.32	2.228
G25	25%	33	3.9	2.38
G30	30%	28.67	3.88	2.069

Table 9.13: Strength Properties for Na_2SiO_3 to NaOH ratio 2.25 at 28 days

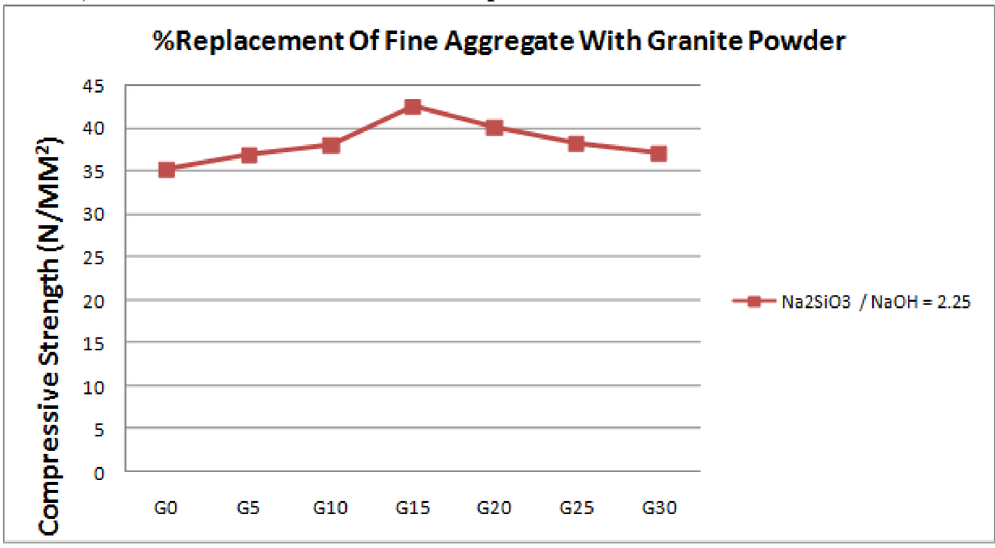
MIX Designation	*% of granite powder replaced with fine aggregate*	*Compressive strength(N/mm^2) At 28 days*	*Flexural strength(N/mm^2) At 28 days*	*Split Tensile strength(N/mm^2) At 28 days*
G0	0%	35.16	4.4	2.54
G5	5%	36.83	4.16	2.54
G10	10%	38	4.24	2.62
G15	15%	42.5	4.372	2.86
G20	20%	40	4.4	2.62
G25	25%	38.16	4.1	2.78
G30	30%	37	4.24	2.62

The graphs for 8 days compressive strength and 28 days compressive strength were shown in graphs 9.1 and 9.2 respectively.

Graph 9.1



Graph 9.2



7. Conclusions and Recommendations

- As the granite powder is replaced in place of sand it was found that at Na_2SiO_3 to NaOH ratio of 2.5. The results that were obtained were less than the basic mix.
- So by altering the Na_2SiO_3 to NaOH ratio to 2.25 the results were consistent compared to 2.5 and we obtained strength of 28.63 % increase in compressive strength, 13.6 % increase in split tensile strength at 15 % replacement of sand with granite powder.
- When 30 % sand is replaced with granite powder the compressive strength obtained is almost equivalent to that of basic mix.

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