International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

A Study on Granite Saw Dust & Fly Ash Blended Geopolymer Concrete Behavior with Various NaOH Molarities

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Abstract: ***This paper describes the experimental investigation carried out to develop geopolymer concrete based on alkali activated fly ash by Sodium Hydroxide with Sodium Silicate. The granite waste because of its fineness and size it can be effectively used as a replacement of sand. The strength of geopolymer 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 geopolymer concrete as it increases the alkalinity of geopolymer concrete as well as it`s grading of sand. Effects of the factors such as method of curing and concentration of NaOH on compressive strength as well as the optimum mix proportion of geopolymer concrete were investigated. It was possible to achieve compressive strength 38 N/mm^2 for the geopolymer concrete after 8 days of casting when cured for 48 hours at 95^0 C. Results indicated that the increase of water content of all three forms of geopolymer resulted in decrease of the compressive strength. Strength development of geopolymer at room temperature was also studied and found that only half of the compressive strength of the heat cured sample was achievable even after 28 days. Most of the results were very promising and showed a great potential for this material as a substitute for Ordinary Portland Cement concrete. 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: Geopolymer, Fly ash, Sodium Hydroxide, Sodium Silicate, Granite saw dust, Compressive strength, split tensile strength, flexural strength, Molarity

1. Introduction

Concrete is a widely used material in the construction industry. Ordinary Portland Cement (OPC) is generally used as the primary binder of the concrete and in addition to that coarse aggregates, fine aggregates and water are also used in concrete construction. As the requirement for development in infrastructure increases the demand for the OPC concrete also increases.

On the other hand, a major emphasis is given for the sustainable development in the construction industry. In order to comply with sustainable development concept, it is very important to minimize the negative environmental impacts of all construction works. The negative environmental impacts associated with the OPC production are much noticeable. During the manufacturing process of one ton of OPC, it releases a ton of Carbon Dioxide (CO_2) gas to the environment due to the process of calcinations of limestone and combustion of fossil fuels [1]. On the other hand, the amount of energy required for the manufacture of OPC is only second to the requirement of energy for manufacturing of steel and aluminum. In such a situation, these negative impacts will lead us to think of better alternatives and substitutes for OPC concrete.

One of the alternatives which have been discussed as a substitute for OPC concrete is the geopolymer concrete. It can be easily produced with fly ash, which is a waste product of the coal-fired power stations. The main objective of this research was to develop a fly ash based geopolymer concrete which can be used as a substitution for OPC concrete and is much more environmental friendly.

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 18.8 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 saw dust 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

2.1 Geopolymer

The term „geopolymer" was first introduced by Davidovits, to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Davidovits suggested the use of the term „Poly(sialate)" for the chemical designation of geopolymers based on silico-aluminate where sialate is an abbreviation for Silicon-oxo-Aluminate [2].

Poly(sialates) is chain and ring polymers of Si^{4+} and Al^{3+} with the empirical formula.

$$M_n [-(SiO_2)_z - AlO_2)-]_n .wH_2O \qquad .... (1)$$

Where,
z is 1, 2 or 3 or higher up to 32
M is a monovalent cation such as Potassium or Sodium
n is a degree of poly-condensation (z> n)
$w \leq 3$

To date, the exact mechanism of setting and hardening of the geopolymer material is not clear, as well as its reaction kinetics and it is believed that the chemical reaction may comprise the following steps [3].

- Dissolution of Si and Al atoms from the source material through the action of hydroxide ions.
- Transportation or orientation or condensation of precursor ions into monomers.
- Setting or polymerization of monomers into polymeric structures.

2.2. Types of Fly Ash

There are two main types of fly ash, namely Class F and Class C fly ash which are waste products of the combusted coal in thermal power plants. Fly ash is collected in electrostatic precipitators, and then transferred to large silos for shipment. When needed, fly ash is classified by precise particle size requirements, thus assuring a consistent quality product. Class F fly ash is the most commonly found type where it is generally low in lime, usually under 15 % and contains a greater combination of Silica, Aluminium and Iron (greater than 80 per cent) than class C fly ash.

Class C fly ash normally comes out of coal power plants with higher lime content generally more than 15 % often as high as 30 %. Elevated levels of Calcium Oxide (CaO) may give class C unique self-hardening characteristics.

It is also revealed that the Calcium content in fly ash plays a significant role in strength development and final compressive strength. Higher the Calcium content results in faster strength development and higher compressive strength. However, in order to obtain the optimal binding properties of the material, fly ash as a source material should have low Calcium content and other characteristics such as unburned material lower than 5%, Fe_2O_3 content not higher than 10%.It is also stated that the presence of Calcium in fly ash in significant quantities could interfere with the polymerisation setting rate and alters the microstructure [4]. Therefore, it appears that the use of low Calcium (Class F) fly ash is more preferable than high Calcium (Class C) fly ash as a source material to make geopolymers.

2.3. Alkaline Solutions

It has been identified that the type of alkaline liquid also plays an important role in the polymerisation process. The most common alkaline liquid used in geo-polymerisation is a combination of Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) along with Sodium Silicate (Na_2SiO_3) or Potassium Silicate (K_2SiO_3). Generally the NaOH causes a higher extent of dissolution of minerals than the KOH while addition of Na_2SiO_3 to the NaOH solution as the alkaline liquid enhances the reaction between the source material and the solution.

2.4 Granite Saw Dust

Felixkala T and Partheeban P (2010) examined the possibility of using granite saw dust as replacement of sandalong with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite saw dust 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 saw dust were less than those of ordinary concrete specimens.

3. Experimental Investigation

A. Materials used

Fly ash, NaOH, Na_2SiO_3

Experiments were carried out starting from fly ash based geopolymer concrete to find out the behaviour and properties of each type in order to derive an optimum mix proportion. Throughout the research, the composition of all constituents such as class „F" fly ash, NaOH,Na_2SiO_3 were kept constant (see Table1,2& 3).

Table 1: composition of the class F flyash

Component	%
SiO_3	60.41
Al_2O_3	28.98
CaO	1.60
Fe_2O_3	3.68
SO_3, chlorides, Na_2O & others	5.35

Table 2: Composition of the NaOH

Components	%
NaOH	40.00
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)	0.0005
Nickel	0.0005
Iron	0.0005
Aluminum	0.0005

Coarse Aggregates

Hard broken crushed stones were used as a coarse aggregate in concrete and 20 mm maximum size was used. The specific gravity was found to be 2.88. Finess modulus is also determined is found to be 2.95.

Fine aggregate

The used is sand obtained from Hundri River near Kurnool is used as fine aggregate in this project investigation. It is free from clay matter .silt and organic impurities etc. The sand is tested for specific gravity in accordance with IS 2386-1963 and it is 2.83, whereas fineness modulus is 2.83.The sieve analysis results printed in table no. The sand conforms to zone II.

Granite saw dust

Granite belongs to igneous rock family. The density of granite is between 2.65 to 2.85 g/cm3 and compressive strength will be greater than 200 MPa. Granite saw dust obtained from the polishing units in Kurnool District and the properties were found. Since the granite saw dust was fine, hydrometer analysis was carried out on the granite saw dust 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 8.82. The specific gravity of the granite saw dust was found to be 2.61. Table 4 gives the chemical composition of granite saw dust.

Table 4: Chemical composition of Granite saw dust

Chemical constituent	**%**
Alumina (Al_2O_3)	14.42
Magnesium Oxide (MgO)	0.81
Calcium Oxide	1.82
K_2O	4.12
Na_2O	3.69
Silica(SiO_2)	82.04
Fe_2O_3	1.22

B. Details of concrete mix

Trial tests were carried out to develop Granite-fly ash based geopolymer concrete with fly ash and alkaline solution made out of NaOH and Na_2SiO_3 along with some additional water(Figures 1 and 2). Constituent materials were thoroughly mixed using the Hobart Mixture and cubes of 10cm x 10cm x 10cm were cast.

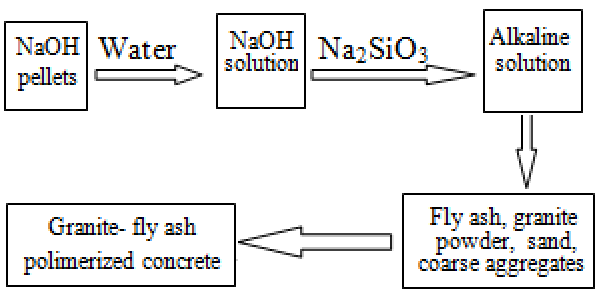

Figure 1: Process of making fly ash based geopolymer paste

Figure 2: Pan Mixer Used for Manufacturing Geopolymer Concrete

Figure 3: Casted Cubes

After pouring the concrete into the mould, any entrapped air was removed by tamping with a rod. The moulds were placed inside the oven for almost 48hours at 95^0C. A separate set of samples were kept at room temperature to observe the strength development at room temperature and the strengths was measured 8 days and 28 days.

As one of the objectives of this experimental study was to develop a High Volume Fly Ash (HVFA) product, the following trials were carried out keeping the Na_2SiO_3 mass ratio as 2.25 and fly ash to alkali liquied ratio constant as 0.8 while varying the NaOH proportions as 8M, 10M, 12M, 14M, 16M to find the optimum mix.

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.

Table 5: Concrete Mix Designation

S. No	*MIX*	*% Granite powder*	*Time period*	*No. of cubes casted*	*No.of cylinders casted*	*No.of cylinders casted*
1.	16M of NaOH	15%	8 days	3	2	1
2.	14M of NaOH	15%	8 days	3	2	1
3.	12M of NaOH	15%	8 days	3	2	1
4.	10M of NaOH	15%	8 days	3	2	1
5.	8M of NaOH	15%	8 days	3	2	1
6.	16M of NaOH	15%	28 days	3	2	1
7.	14M of NaOH	15%	28 days	3	2	1
8.	12M of NaOH	15%	28 days	3	2	1
9.	10M of NaOH	15%	28 days	3	2	1
10.	8M of NaOH	15%	28 days	3	2	1

4. Test Results

Compressive Strength

The cured specimens were allowed to dry in air. The dried specimens were centred on a compression testing machine of capacity 2000 kN. The load was applied at a uniform rate of 14 kN/mm2/min. The test setup is shown in Figure3.

Figure 3: Test setup

Split Tensile Strength test

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x300 mm were used to determine the split tensile strength. After curing, the specimens were tested for split tensile strength using a calibrated compression testing machine of 2000KN.

Flexural Strength Test

The casting procedure is same as that in compressive strength test. Beams of size 500 mm x 100 mm x 100 mm are used in present work. The mould is applied with oil for lubrication. Concrete is laid in the mould in 3 equal layers, each layer being compacted with tamping rod. The next step on vibration on vibrating machine. The above procedure is same for all mixes with different percentages of granite saw dust to fine aggregate replacement.

The values of compressive strength, split tensile strength and flexural strength are given table 6, table 8 respectively for different molarities at 8 days and 28 days.

Table 6: Test results of concrete at 8 th day

S. No	Molarity of NaOH	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural strength (N/mm^2)
1.	8M	16.5	2.06	3.84
2.	10M	21.0	2.06	4.08
3.	12M	28.1	2.23	3.92
4.	14M	38	2.54	3.82
5.	16M	36.8	2.38	3.92

Table 7: Test results of concrete at 28 th day

S. No	Molarity of NaOH	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural Strength (N/mm^2)
1.	8M	30	2.3	3.64
2.	10M	36.68	2.3	3.08
3.	12M	38.5	2.62	4.1
4.	14M	43	3.1	4.5
5.	16M	42.5	2.86	4.38

The variation in the compressive strength, split tensile strength and flexural strength of granite- fly ash polymerized concrete with respect to different molarities of NaOH are as shown in figure 4, figure 5,and figure 6 respectively.

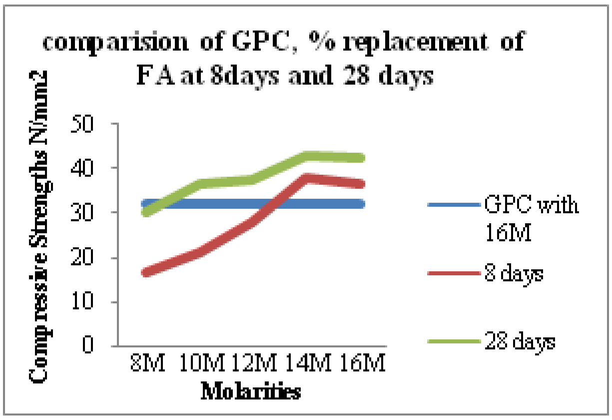

Figure 4: compressive strengths of concrete with different molarities

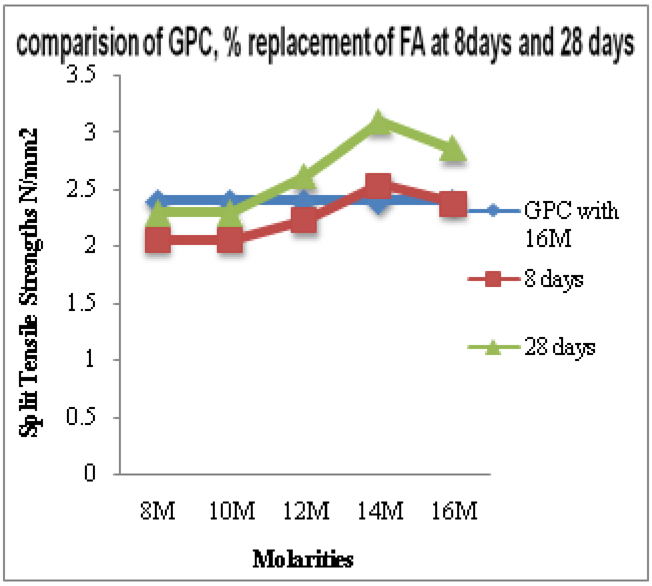

Figure 5: compressive strengths of concrete with different molarities

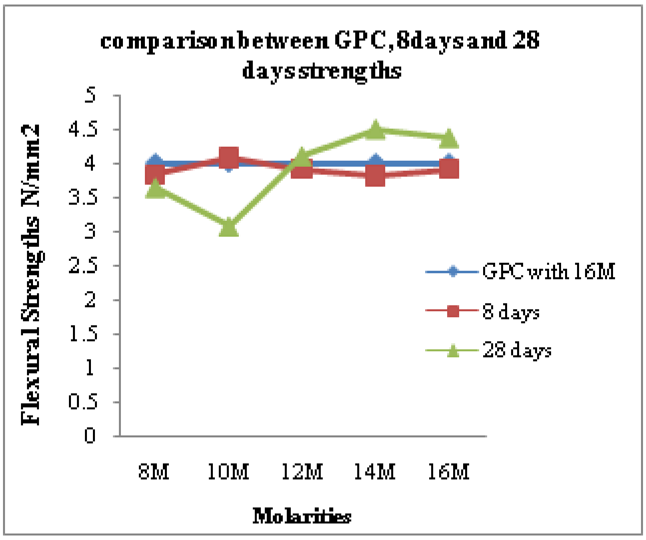

Figure 6: Flexural strengths of concrete with different molarities

From the figures, it can be seen that 16M of NaOH got higher the compressive and split tensile strengths of concrete. As the percentage replacement of sand with granite saw dust increases, the compressive and split tensile strengths increase, reach a maximum value and then decrease.

5. Concluding Remarks

According to the experimental results of geopolymer concrete, the following observations can be made.

1) The maximum strength is obtained at 14M NaOH.
2) Aggregate will Not React with Alkaline Solution. But granite saw dust having the alkali nature because it contains Na_2O and k_2O.
3) The Na_2O and k_2O content present in granite saw dust contributes alkalinity to the granite saw dust when it is polished. So contribution of excess alkalinity also reduces the strength, here the granite saw dust contributes some alkalinity to the concrete so maximum strength is obtained at 14 M of NaOH.
4) The time for the strength gain in ambient cured samples was higher than that of the heat cured samples. Approximately 14% of the strength achieved by heat curing after 28 days can be also achieved by keeping it at room temperature for the same time period. This may be due to the slow speed of polymerization at low temperatures
5) Fly ash based geopolymer concrete can be efficiently used to manufacture relatively high strength interlocking paving blocks.

References

[1] Davidovits, J. (1988). "Soft Mineralogy and Geopolymers. *Proceedings of the Geopolymer 88 International Conference, the Université de Technologie.* Compiègne, France.

[2] Davidovits, J. (1999). Chemistry of Geopolymeric Systems, Terminology. *Geopolymer '99 International Conference.* France: Geopolymer Institute.

[3] Dr.T. Felix Kala, "Effect of Granite Powder on Strength Properties of Concrete" International Journal of Engineering and Science, Vol.2, Issue 12 (May 2013), Pp 36-50.

[4] Djwantoro Hardjito, Steenie E. Wallah, Dody M.J. Sumajouw, and B.V. Rangan, "Factors Influencing the Compressive Strength of Fly Ash-Based Geopolymer Concrete", *Civil Engineering* Dimension, Vol. 6, No: 2, pp 88–93, September 2004

[5] Hamza, K.K Aizboon, "Effect of using granite slurry in concrete", Construction and building materials, 10-2013, pp 1014-1020.

[6] Mehta, P.K., *"Reducing the environmental impact of concrete"*, Concrete International, Vol 23, No: 10, pp 61-66, 2001.

[7] Visited,10http:// www.yourbuilding.org /Article /News Detail.aspx?p=83&id=1570, th October 2010

[8] XuH., Van Deventer J.S.J., (2000), The Geopolymerisation of alumino–silicate minerals, *Int. J. Miner, Process*, 59247-266.