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An Experimental Study on Flyash Based Geopolymer Concrete With A Partial Replacement Of Flyash By Waste Granite Powder

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Abstract: The demand of concrete is increasing day by day for satisfying the need of development of infrastructure facilities. It is well established fact that the production of OPC not only consumes significant amount of natural resources and releases substantial quantity of carbon dioxide to the atmosphere. Therefore, it is essential to find alternatives to make the concrete environment friendly. Geopolymer is an inorganic alumino-silicate compound, synthesized from fly ash. The fly ash, one of the source materials for geopolymer binders. Hence it is essential to make the efforts to utilize this by-product in concrete manufacturing in order to make the concrete more environmental friendly. This paper studied the use of granite waste as partial replacement to fly ash in geopolymer concrete. The fly ash is replaced with granite powder in the percentages of 0%, 5%, 10%, 15% and 20% in M35 grade geopolymer concrete. The tests are carried out for the determination of Strength studies at the age of 7, 14 and 28 days. As the result, the maximum compressive strength obtained with 15% replacement of granite powder to fly ash.

Keywords: Geopolymer concrete, fly ash, granite powder, alkaline solution, durability, replacement, strength test.

I. Introduction

Portland cement contributes to about 5–6% of global CO_2 emission. Geopolymer are emerging as a green alternative to Portland cement as they exhibit comparable mechanical properties and have significantly lower CO_2 emission. The damage that this level of pollution is doing to the atmosphere is unsustainable and as such we need to create a substitute for OPC. And also, the production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere which leads to global warming conditions. This substitute comes in the form of Geo-polymer Concrete (GPC).

Davidovits (1993) introduced the term "Geo-polymers" to the chemical world and in so during a new field of research and technology was created. . Geo-polymers were thus viewed as mineral polymers resulting from geochemistry or geosynthesis.

Geopolymer is a type of amorphous alumino-silicate material. Geopolymer can be synthesized by polycondensation of geopolymer precursor, and alkali polysilicates. Geopolymer is used as binder, instead of cement paste, to produce concrete binds the loose coarse and fine aggregates and other un-reacted materials together to form geopolymer concrete. Geopolymer are inorganic materials of cementitious nature. Derived from the alkaline activation of alumino-silicate materials which can be either readily available natural material such as kaolinitic clay or industrial by-products such as fly ash and iron slag. Fly ash (class F) obtained from Mettur thermal power station was used as source material.

II. Literature Review

B. Vijaya Rangan et al., [1] examined that the Fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The salient factors that influence the properties of the fresh concrete and the hardened concrete have been identified. The paper has identified several economic benefits of using fly ash based geopolymer concrete.

Nguyen Van Chanh et al., [2] presents the results of studying materials, mixture composite, microstructure of Geopolymer, and parameters affecting properties of

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geopolymer concrete. on vacuum saturated specimens, indicating that the influences of increased hydration and denser bulk and ITZ microstructures overwhelm those of the increased water-filled porosity of the vacuum-saturated LWA.

T.S.Ng and S.J.Foster [3] developed the equation for elastic modulus of conventional concrete cannot be applied that of GPC, the density and poisson's ratio of geopolymer concrete are similar to those of OPC concrete.

J.Temuujin et al., [4] found the Compressive strength of fly ash based geopolymer mortar was found to depend on the strength of the geopolymer binder and excellent bonding between the geopolymer binder and aggregate. It is proposed that compressive strength of geopolymer mortars with high levels of aggregate can be increased by optimizing the amount of alkali.

Allam M. E. et al., [5] in this paper the behaviour of green concrete, having partial replacement of cement or sand with granite waste was studied. The study revealed that by comparing the mechanical properties of the control mix to the green concrete mixes containing 5% of fine granite waste as a partial replacement of cement was 20% higher than the control mix.

Shehdeh Ghannama et al., [6] made an experimental investigation has been carried out to explore the possibility of using the granite powder and iron powder as a partial replacement of sand in concrete. It was observed that substitution of 10% of sand by weight with granite powder in concrete was the most effective in increasing the compressive and flexural strength compared to other ratios. For 20% (GP) in concrete the split tensile strength was actually lower than that of the control mix.

L.N. Tchadjié et al., [7] studied the Potential of using granite waste as raw material for geopolymer synthesis. The main objective of this work was to investigate the potential of using granite waste (GW) as raw material for geopolymer synthesis. The results showed that the Compressive strength results of geopolymer mortars are varying between 6.25 and40.5 MPa depending on the amount of Na2O used during the alkali fusion process.

C Ying Li et al., [8] presents the results of an experimental investigation on compressive strength of granite waste fly ash magnesium oxychloride cement (GFMOC). The results demonstrated that the water absorption and filling role of the fine particles of granite waste in GFMOC slurry are favorable for 5 Mg(OH)2_MgCl2_8H2O (P5) and dense microstructure, respectively.

Dige S.S and Prof G. N. Shete [9] examined the strength of granite fines concrete. Concrete is prepared with granite fines as a replacement of fine aggregate in 5 different proportions namely 0%,10%,15%,20%and 25%various tests such as compressive strength, tensile strength and Flexural strength are investigated and these values are compared with the conventional concrete without granite fines. We conclude that we can replace fine aggregate with granite fines upto 25%.but maximum strength is obtained at 15% replacement of granite fines. The flexural strength of beam is increased by 29.8% at 7 days and 33.57% at 28 day scuring with 20% replacement of fine aggregate with granite fines. Further increases in percentage there is decreases in strength but that value is greater than conventional concrete up to 25% replacement.

Sarbjeet Singh et al., [10] studied the Sustainable Concrete's Investigation experimentally made with granite industry by-product. At a 0.50 water-to-cement ratio (w/c), feasibility studies were performed and analyses were done for 10, 25, 40, 55, and 70% sand replacement by GIB in the manufacturing of concrete. Optimal replacement level of river sand by GIB was found to be 25%.

Divakar. Y et al., [11] made an attempt experimentally to investigate the Strength Behavior of Concrete with the use of Granite Fines as an additive. Concrete is prepared with granite fines as a replacement of fine aggregate in 5 different proportions namely 5%, 15%, 25%, 35% and 50% and various tests such as compressive strength, Split tensile strength and Flexural strength are investigated and these values are compared with the conventional concrete without granite fines. It is concluded that an overall increase in strength with 35% replacement of fine aggregates with granite fines.

Y.Yaswanth Kumar et al., [12] studied the use of granite waste as partial replacement to cement in concrete. In this investigation Granite Slurry (GS) was used as partial substitute in proportions varying from 5% to 20% by weight to cement in concrete and tested for compressive strength, tensile strength and flexure strength. It was observed that substitution of 10% of cement by weight with GS in concrete resulted in an increase in compressive strength to 48 N/mm^2 compared to 35 N/mm^2 of conventional concrete. Further investigations revealed that to attain the same strength of conventional concrete a 20% substitution with GS is effective.

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III. RESEARCH SIGNIFICANCE

The objective of the work was to replace the fly ash with granite powder and tests on structural performance of concrete was carried out at various percentages from 0 % to 20% 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.

IV. MATERIALS

4.1FLY ASH

In the present work class F fly ash was used for the Investigation and their properties are tabulated as quoted in table 4.1 & 4.2.

Table 4.1.Chemical Properties Of Fly Ash (Class F)

S.No	Components	(%)
1.	Silicon dioxide(SiO_2)	60.54
2.	Alumina(Al_2O_3)	23.87
3.	Iron oxide(Fe_2O_3)	9.64
4.	Magnesium oxide(Mgo)	1.52
5.	Calcium oxide(CaO)	1.07

Table 4.2.Physical Properties Of Fly Ash (Class F)

S.NO	Types of Test	Fly Ash – Class F
1.	Specific gravity	1.90
2.	Fineness	7%
3.	Normal Consistency	33%
4.	Initial setting time	45 min
5.	Bulk density	1.077 g/cm^2
6.	Specific surface area	4205.72 cm^2/gm

Figure 4.1 Fly ash

4.2 GRANITE POWDER

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 fly ash in geopolymer concrete. Granite belongs to igneous rock family .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 GPC, with 28 days strength.

4.2 Chemical Properties Of Granite Powder

S.No	Components	(%)
1.	SiO_2	72.02
2.	Al_2O_3	14.42
3.	Fe_2O_3	1.22
4.	CaO	1.82
5.	K_2O	4.12
6.	MgO	0.72
7.	Na_2O	3.69

4.3 Physical Properties of Granite Powder

S.No	Types of Test	Values Obtained
1.	Specific gravity	2.66
2.	Fineness	6% (IS sieve 90μ)
3.	Consistency	33%
4.	Specific surface area	4628.2 cm^2/gm

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Figure 4.2 Granite powder

4.3 COARSE AGGREGATE

In this present investigation, locally available crushed granite aggregate was used, as per IS 383-1970, coarse aggregate in sieve size 20mm passing and 4.75mm retaining in saturated surface dry (SSD) condition were used.

Figure 4.3 Coarse Aggregate

4.4 FINE AGGREGATE

The locally available river sand was used as fine aggregate in the present investigation. The sand was screened at site to remove deleterious material and tested as per procedure given in IS: 383-1970.

Figure 4.4 Fine Aggregate

4.5 ALKALINE LIQUID

Alkaline Activated Solution (AAS) used here was a mixture of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH). Sodium hydroxide was available in flakes form, dissolved in distilled water to get solution with 12 Molarity.

Figure 4.5 Alkaline liquid

The ratio of sodium silicate to sodium hydroxide solution is **2.50**. The mass of NaOH solids in a solution varies depending on the concentration of the solution expressed in terms of molar, M. More amount of heat was generated during the mixing of water with NaOH flakes. For this reason, It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state. Sodium silicate solution is then mixed with the NaOH solution prior to batching. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions.

V. EXPERIMENTAL PROCEDURE

5.1.1Batching

In batching concrete, the quantity of fly ash, fine aggregate and coarse aggregate shall be determined by mass and sodium silicate and sodium hydroxide solution measured in volume or mass.

5.1.2Mixing

Mixing can be done by following two process in geopolymer concrete using pan mixer.

Dry Mixing

The fly ash, coarse aggregate and fine aggregate were mix together. The mixing time shall be at least 3 minutes.

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Wet Mixing

Then the sodium silicate and sodium hydroxide solution was mixed with dry solid for 3minutes water would be added if any necessity (3% of water).

5.1.3 Moulding , Compaction and Surface finishing

- After the wet mixing the moulding process was done by following two methods
- Geopolymer concrete was compacted in mould of three layers with 25 manual strokes.
- For each layer mould was placed on mechanical vibrator table for compaction.The Compacted mould surface was finished by trowel.

5.1.4 Curing of specimens

- After 24 hours, the specimens were demoulded and the specimen was kept at respective curing condition.
- Curing is the process of preventing the loss of moisture from the concrete while maintaining a satisfactory temperature regime.
- The Casted moulds are being in the hot air oven at the temperature of about 70ºC for curing.

VI. RESULTS

A strength test were conducted for geopolymer concrete such as

(i) Compressive strength test for 7,14 and 28 days
(ii) Split tensile test for 28 days
(iii) Flexural strength test for 28 days
(iv) Bond strength test for 28 days

(i) Compressive Strength

It was found that the compressive strength for control mix is 43.80 MPa at 28 days. The maximum compressive strength of 53.12 MPa was obtained from the 15% replacement of granite powder to fly ash at 28 days.

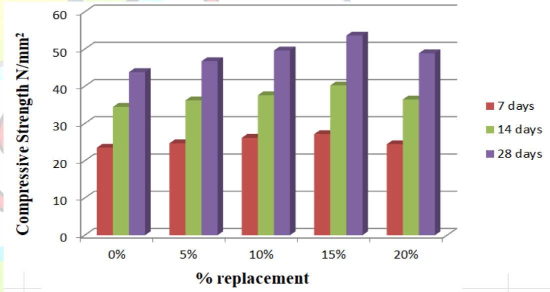

Fig 6.1 Avg. Compressive strength of geopolymer concrete with different % replacement

(ii) Split tensile test

Split tensile test was carried out for control mix and optimum percentage for the age of 28 days.

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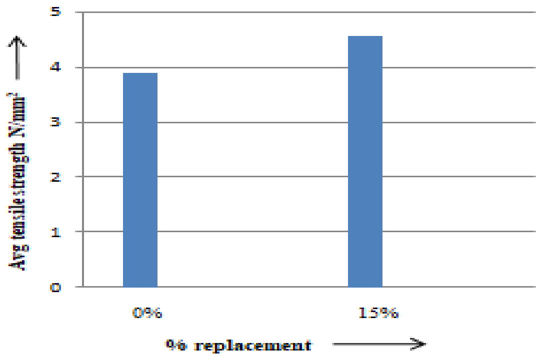

Fig 6.2 Average Split tensile strength of geopolymer concrete

(iii) Flexural strength test

A Flexural strength test was carried out for control mix and optimum percentage for the age of 28 days.

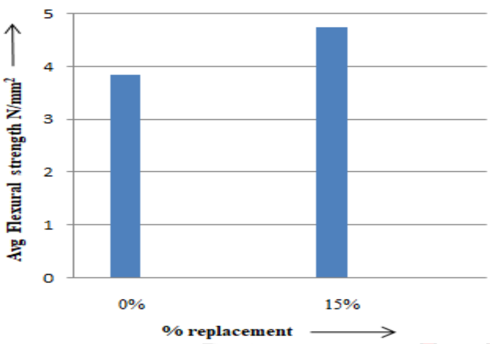

Fig 6.3 Average Flexural strength of geopolymer concrete

(iv) Bond strength test

A Bond strength test was carried out for control mix and optimum percentage for the age of 28 days.

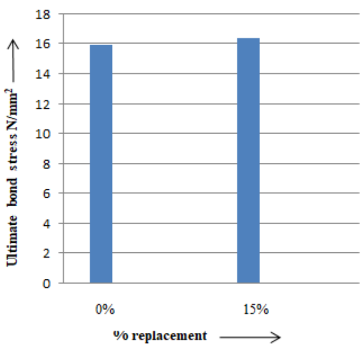

Fig 6.4 Average Bond strength of geopolymer concrete

VII. CONCLUSIONS

- Increase in compressive strength was found to be 21.27% for 15% replacement of fly ash by granite powder as compared to control mix.
- From the various percentages of granite powder replacements, 15% replacement was found to be optimum value.
- Similarly the split tensile, flexural strength and bond stress were obtained for control mix which was compared with optimum percentage.
- Using granite waste in concrete mix proved to be very useful to solve environmental problems and produce green concrete.
- Therefore, it is recommended to re-use these wastes in concrete to move towards sustainable development in So it can be concluded that, the compressive strength increases up to 15% of granite waste powder addition in concrete mix, because the granite powder waste of small dosages works as a filler material which can decrease the voids in concrete mix (form an intensive material) and to act as a workability agent, after which it is considered as a fine material without any bond characteristic and low strength.

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