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Geopolymer Concrete Incorporated with Quarry Dust as Fine Aggregate

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ABSTRACT: The production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO₂ to the atmosphere. The cement industry is held responsible for some of the CO₂ emissions, because the production of one tonne of Portland cement emits approximately one tonne of CO₂ into the atmosphere. This leads to the utilization of supplementary cementing materials such as fly ash and ground granulated blast furnace slag. Geopolymer concrete is a potential alternative to conventional Portland cement concrete. Alkaline solution such as sodium hydroxide and sodium silicate were used to initiate the polymerization reaction. The compressive strength of Geopolymer concrete specimens were studied by varying the molarity of sodium hydroxide concentration. The experiments were conducted for the mixed prepared with the Molarities of 6M, 8M and 10M. The curing adopted and the tests were compared with the ambient curing.

KEYWORDS: Flyash, Ground granulated blast furnace slag, Alkaline solution, Compressive strength.

I. INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The production of cement is increasing about 3% annually. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one tonne for every tonne of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. The production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO₂ to the atmosphere. The cement industry is held responsible for some of the CO₂ emissions, because the production of one ton of Portland cement emits approximately one ton of CO₂ into the atmosphere. However, Portland cement is still the main binder in concrete construction prompting a search for more environmental friendly materials. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. Furthermore, it has been reported that the durability of ordinary Portland cement concrete is under examination, as many concrete structures especially those built in corrosive environments start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life. Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in concrete. 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 fly ash, silica fume, granulated blast furnace slag, rice-husk ash and met kaolin, and the development of alternative binders to Portland cement. One possible alternative is the use of alkali-activated binder using industrial by-products containing silicate materials. In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash, GGBS and rice husk ash. He termed these binders as geopolymer. The most common industrial by-products used as binder materials are fly ash (FA) and ground granulated blast furnace slag (GGBS).

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II. LITERATURE REVIEW

Sashidhar C It is an advanced concreting that does not require both cement and compaction. In this research SCGC mixes were prepared using Class F Fly ash and GGBS in 50:50 proportion with artificial sand as fine aggregate. According to EFNARC guidelines mix design prepared with 8M, 10M, 12M of NaOH. After successful evolution of various fresh properties like slump flow, V funnel, L box. The present experimental investigation was carried out on mechanical properties like compressive and flexural strength after 28 and 56 days of ambient and room temperature curing. Result shows that increase in NaOH Molarity decreased the fresh properties but however enhanced the mechanical properties SCGC.

Arun B R The combined effect of flyash and GGBS with different molarities of self-compacting geopolymer concrete on working properties like slump flow, T50 slump flow, J-ring, V-funnel, L-box and mechanical properties such as compressive strength, split tensile strength, and flexural strength. the mix proportion of self-compacting geopolymer concrete was arrived by trial and error method. Here flyash was replaced with GGBS by 0%, 30%, 50%, and 70% by mass for a constant binder content of 400kg/m³ for all the molarities. The fluid to binder (F/B) ratio of 0.47 by mass and a SP dosage of 3% was kept constant for all the molarities and extra water content was varied accordingly. The result showed that the workability parameters for all the molarities like 8M, 10M, 12M were within the range as prescribed by EFNARC guidelines. As the % of GGBS increased and as well it increased with increase in molarity. All the specimens were oven cured at 70°C for 24 hours followed by ambient curing till the respective date of testing.

Habeeb lateef muttashar The engineering properties of the waste garnets offer the opportunity to get efficient construction materials via their appropriate recycling. The capacity of spent garnets as sand replacement for achieving SCGC. this SCGC specimens are prepared using GGBS where in the river sand is replaced by spent garnet at varying contents (0-100%) under constant liquid/binder mass ratio of 0.4. performance evaluations of the developed SCGC samples are made using several tests including durability, workability, flexural, compressive, split tensile strength conforming the EFNARC standard. test results revealed an enhancement in the workability of the proposed SCGC specimen with the increase of spent garnet contents. it is established that the spent garnet is prospective candidate for sand replacement up to 25% in terms of environmental amiability, cost effective and conservation of natural resources.

Parveen Mechanical and microstructural properties of fly ash based geo polymer concrete incorporating alccofine at ambient curing. In this study the finding of properties of fly ash based ambient temperature using 100% raw waste material as a binder have been reported. The Fresh and hardened properties of alccofine activated geo polymer concrete like workability, water absorption, compressive, split tensile and flexural strength have been studied as per Indian Standard. The prepared sample were investigated through X- ray diffraction and SEM for the determination of their phase. Result shows that maximum compressive splitting and flexure strength at ambient temperature was obtained with 16M NaOH concentration and at 400 kg/cubic meter fly ash content.

Jumah musdif Investigated the properties of self- compacting concrete prepared by adding fly ash (FA). FA was used as a replacement for Portland Cement (PC). PC was replaced 0-80% by fly ash. For all the mixes water binder ratio was maintained as 0.36. Strength properties as well as the workability, shrinkage, absorption and ultrasonic pulse velocity were studied in this research. From the observations it was concluded that 40% replacement of FA resulted in strength of more than 65 N/mm² at 56 days. On increasing the amount of fly ash the high absorption values were obtained and absorption of less than 2% was exhibited.

Fareed ahmed menon Fresh properties and compressive strength of the self compacting geopolymer concrete was found by the addition of varying molarity of sodium hydroxide concentration for laboratory tests. curing temperature and concentration of sodium hydroxide are important kind in SCGC. the concentration of sodium hydroxide varying from 8 M to 14 M. oven curing are used for two days upto 70 degree C and then it was kept in room temperature up to testing. According to this tests the concrete samples with sodium hydroxide concentration of 12 M produced maximum compressive strength.

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III. MATERIALS USED

Fly ash: Fly ash used for the present study is collected from Tuticorin thermal power plant. Fly ash is defined as the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system". Fly ash is removed from the combustion gases by the dust collection system, either mechanically or by using electrostatic precipitators, before they are discharged to the atmosphere. Fly ash particles are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1 μm to no more than 150 μm .

The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash.

Class F fly ash was used in this study.

Specific gravity of Fly ash = 2.08

Chemicals	% Composition
SiO ₂	50.18
Al ₂ O ₃	26.31
Fe ₂ O ₃	13.68
MgO	1.29
SO ₃	0.02
Na ₂ O	0.32
K ₂ O	0.53
TiO	1.66
SrO	0.30
P ₂ O ₅	1.55
Mn ₂ O ₃	0.09

Table 3.1 Chemical composition of Class F fly ash

Ground granulated blast furnace slag (GGBS): GGBS is obtained by quenching molten iron slag from a blast furnace in water or steam to produce glassy, granular product that is then dried and ground into fine powder. The replacement of cement with GGBS reduces the unit water content needed for the concrete and thereby increasing the durability of the structure. It also reduces the temperature rise and helps to avoid early age cracking, improved workability, increased resistance to chemical attack, and corrosion resistant.

Specific gravity = Weight of GGBS / Volume of GGBS

The specific gravity test result of GGBS = 2.96

Alkaline solution: The sodium hydroxide solution was prepared by dissolving the pellets in water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molarity (M). For instance, NaOH solution with a concentration of 1M consisted of $1 \times 40 = 400$ grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The NaOH solution was prepared before 24 hours of sample preparation to ensure proper dissolution of the sodium hydroxide flakes. The concentrations of the sodium hydroxide solution used were 6M, 8M and 10M. Alkaline solutions are added to initiate polymerization reaction.

Quarry dust: Quarry dust is a by – product from crushing process during quarrying activities is good alternative during construction projects. It can be used as substitute to sand wholly or partly. It offers a comparatively good strength compared to sand with or without concrete admixtures. In the construction industry there is a high demand for natural river sand, especially in the production of concrete, which create a major sustainability issues. The best way to deal with these demand is to use waste or recycled material as a substitute of natural river sand.

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Property	Values
Specific gravity	2.76
Grading Zone	II
Fineness modulus	2.41
Total water absorption	0.4%
Minimum Density	1578.6kg/m ³
Maximum Density	1758.8 kg/m ³

Table 3.2 Physical properties of quarry dust

Natural Coarse Aggregate: The coarse aggregate is according to IS: 383-1970 was used. Locally available aggregate from quarries in Tirunelveli were used in this study. Single size aggregate of 20 mm size was used for the entire investigation.

Property	Values
Specific gravity	2.76
Fineness Modulus	6.81
Type	Crushed
Total water absorption	0.5%
Moisture content	Nil

Table 3.3 Physical properties of coarse aggregate

Mixing and casting: Unlike conventional cement concretes GPCs are a new class of construction materials and therefore no standard mix design approaches are yet available for GPC. GPC involves more constituents in its binder (viz., FA, GGBS, sodium silicate, sodium hydroxide and water). In the design of geopolymer concrete mix, assume the unit-weight of concrete is 2400 kg/m³. Take the mass of combined aggregates as 74% of the mass of concrete, i.e. $0.74 \times 2400 = 1776 \text{ kg/m}^3$. Knowing the density of concrete, the combined mass of alkaline liquid and fly ash can be arrived at By assuming the ratio of alkaline liquid to fly ash as 0.4, mass of fly ash and mass of alkaline liquid was found out. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. In the present investigation, concentration of NaOH solution is taken as 6M, 8M and 10M. The required mass of coarse aggregate, fine aggregate, GGBS, fly ash are weighed prior to mixing. The solids constituents of the fly ash-GGBS based geopolymer concrete, i.e. the aggregates and the fly ash, GGBS were dry mixed in the polythene sheet for about three minutes. The liquid part of the mixture, i.e. the sodium silicate solution, the sodium hydroxide solution, added water, and the super plasticizer, were premixed then added to the solids. The wet mixing usually continued for another four minutes. The fresh fly ash, GGBS-based geopolymer concrete was dark in colour and shiny in appearance. The mixtures were usually cohesive. The workability of the fresh concrete was measured by means of the conventional slump test. Compaction of fresh concrete in the cube moulds was achieved by applying twenty five manual strokes per layer in three equal layers.



Fig3.1 Casting of GPC specimens

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Curing : Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability. Unlike Conventional concrete, GPC members requires special type of curing. Oven curing is adopted for GPC specimens. The temperature for curing ranges from 60°C-90°C. Temperature adopted for present investigation is 75°C. The GPC specimens are cured for about 24 hours. The main polymerization process or the chemical reaction of geopolymer concrete takes place with the temperature imposed to it during the curing. After removing the specimen from the oven the specimens were maintained at ambient temperature 26°C. For ambient curing conditions, specimens were placed in the shade outside the laboratory. Meanwhile, the specimens cured at heat condition for 24 hours and ready to be released at ambient condition and allowed to room temperature until test day. The rate of increase of strength is rapid in the initial 24 hours of curing beyond that the gain of strength was moderate so the specimens should be cured for 24 hours only which will sufficient enough.

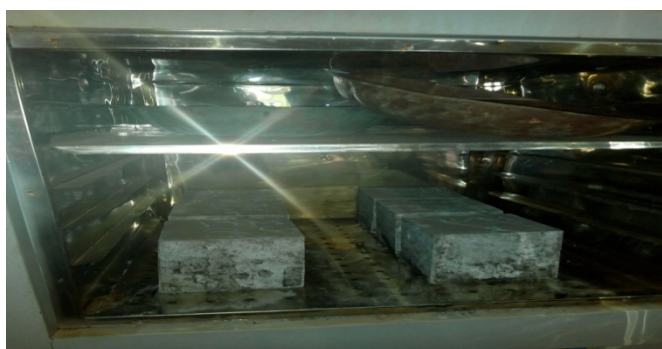


Fig3.2 oven curing for the GPC specimens

IV. EXPERIMENTAL INVESTIGATION AND RESULT ANALYSIS

Compressive strength test: The unconfined compressive strength tests of the specimens were conducted to determine the compressive strength of binder. For each mix proportion and each curing period, three identical specimens were prepared and the average of the strengths was reported as the compressive strength of the mix. Specimens are tested to determine the average compressive strength at the ages of 7 and 28 days. Steel mould of 150x150x150 mm is cleaned, well tightened and oiled thoroughly. After resting period the concrete cube is heat cured for a period of 24 hours. After curing period the specimens are taken out and tested at the age of 7, 28 days using 400 tone capacity HEICO compression testing machine. Loading was continued till the dial gauge needle just reverses its direction of motion. The reversal in the direction of motion of the needle indicates that the specimen has failed.



Fig4.1 Compressive Strength test for GPC Cubes

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Molarities	Compressive strength (mpa)			
	7 days		28 days	
	Ambient curing	Oven curing	Ambient curing	Oven curing
6M	33.77	37.33	35.84	38.4
	36.44	40.88	38.26	42.1
	37.33	39.11	39.12	41.5
Avg	35.84	39.10	37.71	40.66
8M	36.44	45.33	38.86	47.32
	31.11	43.55	33.52	45.86
	32.00	48.00	34.60	50.23
Avg	33.18	45.62	35.66	47.80
10M	44.90	51.40	49.00	58.30
	45.00	47.30	47.70	49.20
	43.90	59.70	45.10	60.20
Avg	44.60	52.80	47.26	55.9

Table 4.1 Compressive strength of GPC specimens

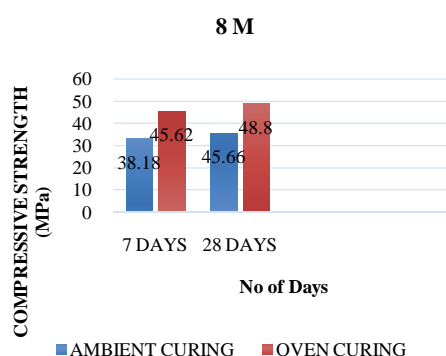


Fig4.1 compressive strength of cube for 8M

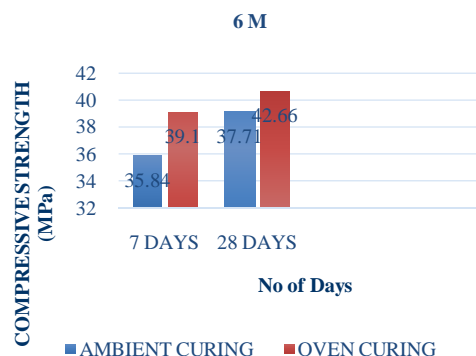


Fig4.2 compressive strength of cube for 6M

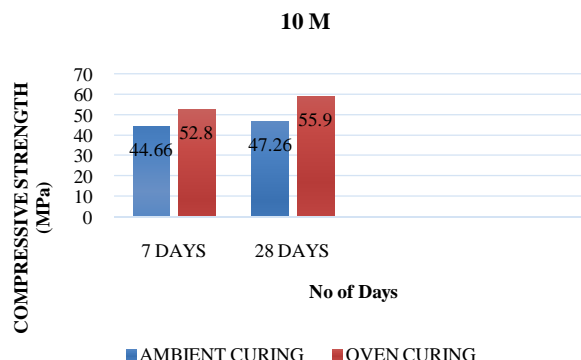


Fig4.3 compressive strength of cube for 10M

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Durability studies: Durability of the concrete is defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Factors affecting durability of concrete are cement content, compaction, curing, cover, Permeability.

Water absorption test: This test was performed on hardened GPC cubic specimens (BS 1881: part 122,1983) each of dimension 100mm X 100mm X100mm cured for 28 days. Then, the cured specimens were first oven dried at (70-80)°C for 72 hrs and subsequently cooled down to room temperature in a dry airtight chamber for 24 hrs before being weighed. The cooled GPC specimens were submerged for 30 min inside a tank filled with portable water. Afterward, every GPC specimens was isolated shaken thoroughly, and free water was removed by wiping with cloth. Again, it was weighed to determine the percentage (W) of water absorption via the expression:

$$W = (W_w - W_d) / W_d \times 100\%$$

Where,

W_w- wet weight of specimen

W_d-dry weight of specimen

Specimen	Dry weight (k.g)	Wet weight (k.g)	% of water absorption
6M (ambient curing)	1.457	1.544	6.01
6M (oven curing)	1.418	1.495	5.57
8M (ambient curing)	1.457	1.544	6.01
8M (oven curing)	1.448	1.527	5.51
10M(ambientcuring)	1.486	1.560	5.07
10M (oven curing)	1.478	1.563	5.81

Table 4.2 water absorption test results

Acid resistance: Acid resistance test was performed on Concrete cubes of size 100mm × 100mm × 100mm were cast and stored in a place at room temperature for 28 days before being immersed in 5% H₂SO₄ solution. Before immersion these cubic specimens were dried at room temperature for 48 hours and weighed. Specimen were taken out placed in room temperature and weight was taken as (w₁). After 28 days of curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken as (w₂). The percentage of weight loss were calculated.

$$(w_1 - w_2) / w_1 \times 100$$

specimens	weight (w ₁) in kg	weight (w ₂) in kg	% loss in weight
6M (A.C)	1.522	1.436	5.98
6M (O.C)	1.495	1.418	5.57
8M (A.C)	1.544	1.423	6.01
8M (O.C)	1.527	1.457	5.51
10M (A.C)	1.560	1.448	5.07
10M (O.C)	1.563	1.452	5.81

Table 4.2 Acid resistance test results

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V. CONCLUSION

The samples of Geopolymer concrete for 50% GGBS and 50% Fly ash were casted and evaluation of fresh concrete properties as well as mechanical properties of hardened concrete was studied. The compressive strength test were conducted for the test specimens. By the keen observation of test results the following conclusion were arrived. From this project the strength of Geopolymer concrete made with quarry dust with sand replacement has achieved the target strength of M_{30} grade for 6M, 8M has achieved the target strength of M_{40} grade and 10M has achieved the target strength of M_{50} . 5% amount of Lime powder was added to the concrete for avoid the oven curing for the specimens and it is also gives 85% of oven curing strength to the specimens.

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