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Fresh and Hardened Properties of Geopolymer Concrete Using Demolition Waste

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Abstract: *Concrete is the world's most utilized versatile and durable construction material. Portland's cement production industry is the major generator of carbon dioxide, which was a global threat to the environment. Researchers recognized geopolymer process reduces the use of OPC in concrete and resulted in a reduction of carbon dioxide emission and impact on the environment. Similarly, the disposal of demolition waste also harms the environment. In the current study, an attempt was made to study the fresh and hardened properties of geopolymer concrete using recycled aggregate.*

Keywords: *Fly Ash, GGBS, Geopolymer concrete, Compressive strength.*

1. Introduction

Concrete is the material broadly utilized everywhere over the world. For the preparation of concrete Ordinary Portland cement is used as a binding material. According to the Bureau of Energy Efficiency total of 298 Million Tonnes of cement is produced per annum with an installed capacity of 500 MTPA. Because of the drastic increase in infrastructure demand for concrete would increase and the expected production of cement will be 800 MTPA by 2030. During the production of one-ton ordinary Portland cement, one ton of carbon dioxide is released into the atmosphere. Also, contribute 7% of the carbon dioxide emission by the cement manufacturing process. To reduce carbon footprint alternative binding materials are required.

Many types of research were conducted to replace Ordinary Portland cement, In that Ground Granulated blast furnace slag, Flyash, Silica fume, Rice husk, and Metakaolin are partially replaced. These pozzolanic materials contain more percentage silicon (Si) and aluminum (Al). Industrial by-product used as alkali-activated binders having silicate material is one of the alternative materials. Ground granulated blast furnace slag (GGBS), Fly ash (FA) is the most common industrial by-product used as binder materials. Because of latent hydraulic properties, GGBS has been widely used as a cement replace material and Fly ash has used as a pozzolonic material.

Research has shown that Fly ash and Slag is possible to use as a sole binder in mortar by activating them with an alkali component, such as silicate salt, non-silicate salts of weak acids and caustic alkalise. There are two model of alkali activation, Low to mild alkali activation materials primarily silicate and calcium will produce calcium silicate hydrate gel (C-S-H), with lower Ca/Si ratio similar to that formed in Portland cement. The next mechanism materials containing primarily aluminates and silicate using a high alkaline solution involved in activation. Through a polymerization process an inorganic reaction takes place. The name Geo-polymer is used to characterize this reaction from previous and the name Geopolymer has been adopted for this type of binder.

In geo-polymerisation most common alkaline liquid combination are sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate. To produce Geopolymer concrete Geopolymer binder are used together with aggregate which are ideal for repairing infrastructure and for pre-cast unit.

Due to the fast production and utilization of concrete, which result in increased the consumption of natural aggregate as the major concrete component. Effective utilization of the recycled aggregate is the possible solution for replacing natural aggregate which produce alternative aggregate for structural concrete. In recent year the utilization of recycled aggregate has gained remarkable movement in construction project. In this project demolition concrete is used as a coarse aggregate for preparing geo-polymer concrete. It involves breaking, crushing, and removing contaminated materials from existing concrete and utilized for preparing geo-polymer concrete.

2. LITERATURE REVIEW

***Thomas et al* (2015)** suggested that the sodium Silicate (Na_2SiO_3) and Sodium hydroxide (NaOH) are used as an alkaline liquid in geopolymerisation. This study talks about the replacement of natural aggregate with demolition waste recycled coarse aggregate in the Geopolymer concrete and structural characteristic of Geopolymer concrete when complete replacement of recycled coarse aggregate. Distinctive molar of sodium hydroxide (NaOH) which are 8M, 10M and 12M were embraced. Different outcome of Compressive strength, split tensile strength, flexural strength of Geopolymer concrete of oven curing at 80C age 3 and 7day curing period.

***Anuar et al* (2011)** have an experimental investigation of Geopolymer concrete incorporating with demolition waste aggregate. Alkali liquid and sludge ash are utilized as a binder to find alternate for Portland cement to create Geopolymer concrete. Sodium silicate & sodium hydroxide mixture is used in geopolymerisation.

Harish K (2009) carried out the investigation work to find effect of GGBS along with flyash as base material for geo-polymer concrete. He has worked with different type of curing regimes like ambient, sundry and oven dry condition. Sundry curing showed encouraging results by using GGBS as partial replacement to fly ash.

T. Bakharev (2005) carried out work on the effect of elevated temperature on Geopolymeric materials preparing Class F fly-ash. Sodium silicate and sodium hydroxide were utilized as alkaline liquid. Different three regimes of curing were taken. In the first case samples were cured at ambient temperature for two hours and then cured at 75^0C for one month.

Swanepoel and Strydom (2002) conducted a study on geoolymer concrete by mixing Sodium silicate, sodium hydroxide, flyash, kaolinite and water. It shows that compressive strength depends on curing temperature and obtain optimum compressive strength in oven dry curing at 60ºC.

Ramamurthy and Gumster (1998), study that strength of the recycled aggregate reduces the strength of concrete and also strength difference depends on the strength of the parent concrete from the obtained aggregate.

VanJaarsveld, et al (1997), carried out the investigation on the properties of Geopolymer concrete which affects the certain parameter. They said that incomplete dissolution of the materials involved in geopolymerisation which influence the property of Geopolymer. Curing regime, curing period and water content also effects the strength and properties of Geopolymer concrete. When the sample were oven cured at temperature 70ºC for 24hour increase in strength observed and also oven cured for long period also reduced the compressive strength.

Davidovits (1988), introduced the term geo-polymer in 1978 to represent the mineral polymer as consequence of geochemistry. Geo-polymer is an inorganic alumina silicate polymer, is synthesized from predominantly silicon (Si) and aluminum (Al) materials of geological origin or by product materials. The chemical composition of geo-polymer material is similar to zeolite, but they reveal an amorphous microstructure. Silicon and aluminium atom are combined to form the building block during the synthesized process they are structurally and chemically comparable to binding the natural rocks.

3. MATERIALS AND METHODOLOGY

Materials

Fly Ash

In this present experimental study Low calcium Fly ash used was from Raichur Thermal power station. This Conforms to Grade 1 as per IS: 3812-2003. Physical and chemical properties of this fly ash as described below in Table 1 and 2.

Table 1. *Physical properties of Fly ash*

Particulars	Properties
Residue on 45µ sieve	32%
Specific gravity	1.96
Finess (Blain's air permeability)	341 m^2/kg

Table 2. *Chemical properties of Fly ash*

Test Conducted	Results	Requirement as per I S:3812-2003
SiO_2+Al_2O_3+Fe_2O_3 minimum (% by mass)	94.42	70.00(min)
SiO_2 minimum (% by mass)	60.28	35.00(min)
AlO_3 (% by mass)	29.96	50(max)
MgO max (% by mass)	1.14	3.0(max)
Total sulhar as sulphur trioxide (SO_3) % by mass, max	0.24	5.0(max)
LOI (1 Hour) max (%)	0.57	5.0(max)

Ground Granulated Blast Furnace Slag

GGBS was obtained from Jindal Steel plant Bellary, Karnataka. The physical and chemical properties are shown in Table 3 and 4.

Table 3. *Physical properties of GGBS*

Properties	Values
Specific Gravity	2.87
Fineness by Blaine's air permeability (m^2/kg)	368
Wet sieve analysis % retained on (45µ)	2.8

Table 4. *Chemical Properties of GGBS*

Chemical Component	Result
SiO_2	33.78%
Al_2O_2	17.08%
CaO	39.87%

Sodium Hydroxide (NaOH)

In market sodium hydroxide is available in pallet or flakes form with purity of 96% to 98%, Depending on the purity cost of the material increased. The Sodium hydroxide solid in solution effect on the concentration of solution expressed in terms of molar, denoted by M. For example, to prepare 8M sodium hydroxide solution concentration take 8x40=320 grams of solid NaOH pallets or flakes in one liter of water.

Sodium Silicate

Sodium silicate available in gel form in the market and it is also called as water glass. Strength of geo-polymer concrete depends on the ratio of Na_2O and SiO_2 in sodium silicate. In the solution various chemical composition was SiO_2 47.32% by mass and Na_2O 14.0% by mass and remaining are water and specific gravity of sodium silicate was 1.639.The chemical composition of sodium silicate is presented in Table 5.

Table 5. *Chemical composition of Sodium Silicate solution*

Chemical Component	Percentage by mass
Na_2O	14.0%
SiO_2	47.32%
Water	38.68%
Specific gravity	1.639

Fine Aggregate

The aggregate size less than 4.75mm and confirming to zone II according to IS 383-1970 (RA2007) is used. The properties of material are listed in Table 6.

Table 6. *Properties of fine aggregate*

Test	Fine Aggregate
Fineness modulus	2.74
Dry rodded bulk density kg/m^3	1581
Specific Gravity	2.64

Coarse Aggregate

In this work locally available coarse aggregate and recycled demolished Concrete having maximum of 20mm were used. Recycled aggregates are composed of natural aggregates as well as cement paste which is hydrated. The materials used are represented in Fig 1 & 2.

Water

In this project portable water is used to prepare sodium hydroxide solution which is used in Geopolymer concrete, water used is free from organic materials salts and acids. Because of polymerization process water is not required for curing.

Figure 1. *Materials used for preparing Geo-polymer concrete*

Figure 2. *Natural aggregate and Recycled aggregate*

Mix Design

The mix design is prepared based the literature study. In the above-mentioned investigations, the mix proportioning is mainly based on the performance criteria of the concrete and, absolute volume method had been adopted to obtain the proportioning of materials. One of the major assumptions in both this research work is the wet density of Geopolymer concrete which is taken as a constant of 2400kg/m^3.

Mix Proportions

Mix-1: Mix proportion of GPC for 140 litres water content and Fly Ash: GGBS=90:10 Using natural aggregate, Mix Proportion 1:1.89:1.90:0.193:0.4832 (Cementitious Martial: FA: CA: NaOH: Na_2SiO_3)

Mix-2: Mix proportion of GPC for 140 litres water content and Fly Ash: GGBS=60:40 Using natural aggregate, Mix Proportion 1:1.992:2.01:0.179:0.448 (Cementitious Martial: FA: CA: NaOH: $Na_2SiO_{3)}$

Mix-3: Mix proportion of GPC for 140 litres water content and Fly Ash: GGBS=90:10 using recycled aggregate, Mix Proportion 1:1.89:1.90:0.193:0.4832 (Cementitious Martial: FA: CA: NaOH: Na_2SiO_3)

Mix-4: Mix proportion of GPC for 140 litres water content and Fly Ash: GGBS=60:40 using recycled aggregate, Mix Proportion 1:1.99:2.01:0.179:0.448 (Cementitious Martial: FA: CA: NaOH: Na_2SiO_3)

Curing of the Specimens

In the present study, three types of curing conditions are chosen. They are ambient condition or laboratory condition, Exposed to Sundry, Cured in oven at a temperature 60 ^{0}C for 24 hours. Tests are conducted at different durations such as 7 days and 28 days for the above curing conditions.

The fresh and hardened properties of concrete is studied as per code provisions.

Result and Discussion

Mix-1: Properties of GPC ratio Flyash 90% and GGBS 10% using Natural Coarse Aggregate.

Workability is measured in terms of slump. For the above mix slump obtained was 220 mm. Higher the water content higher will be the workability.

The compressive strength of mix obtained is presented in Fig 3. The average compressive strength of 23.34 N/mm^2 and 25.66 N/mm^2 were obtained for the period of 7 days and 28 days respectively when the concrete is cured in ambient (laboratory) condition. Further, the concrete cured in sundry condition showed slightly higher compressive strength of 27.23 N/mm^2 and 30.25 N/mm^{2}for the period of 7 days and 28 days respectively. And also, the concrete is cured in oven at a temperature of 60 ^{0}C for duration of 24 hours showed compressive strength of 30.92 N/mm^2 and 32.78 N/mm^2 for the testing period of 7 days and 28 days respectively.

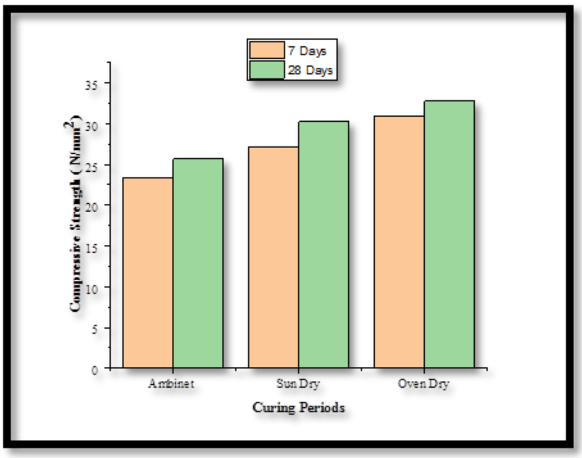

Figure 3. *Compresive strength of GPC mix-1 for different Curing regime.*

Mix-2: Properties of GPC ratio Fly ash 60% and GGBS 40% using Natural Coarse Aggregate

Workability is measured in terms of slump. For the above mix slump obtained was 160 mm. Higher the water content higher will be the workability.

Fly ash and GGBS ratio of 60:40 and water content of the 140 litres/m^3. The average compressive strength of 26.54 N/mm^2 and 31.34 N/mm^2 were obtained for the period of 7 days and 28 days respectively when the concrete is cured in ambient (laboratory) condition. Further, the concrete cured in sundry condition showed slightly higher compressive strength of 31.69 N/mm^2 and 34.36 N/$mm^2$for the period of7 days and 28 days respectively. And also the concrete cured in oven dry at the temperature of 60ºC for duration of 24 hours showed compressive strength of 34.83 N/mm^2 and 36.22 N/mm^2 for the testing period of 7 days and 28 days respectively. The Fig 5 give the details of the compressive strength of GPC cured at different condition like ambient, sundry and oven dry for the Geopolymer concrete with 140 litres of water content and Fly- Ash:GGBS = 60:40. The compressive strength of mix obtained is presented in Fig 4.

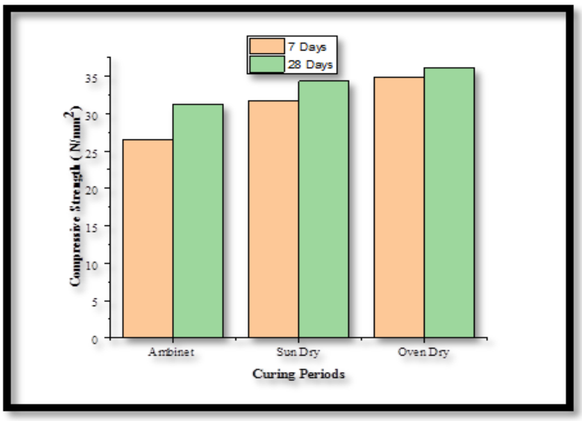

Figure 4. *Compresive strength of GPC mix-2 for different Curing regime*.

Mix-3: Properties of GPC ratio Fly ash 90% and GGBS 10% Using Recycled Coarse Aggregate

Workability is measured in terms of slump. For the above mix slump obtained was 220 mm. Higher the water content higher will be the workability.

The average compressive strength of 22.34 N/mm^2 and 24.46 N/mm^2 were obtained for the period of 7 days and 28 days respectively when the concrete is cured in ambient (laboratory) condition. Further, the concrete cured in sundry condition showed slightly higher compressive strength of 26.18 N/mm^2 and 29.32 N/$mm^2$for the period of 7 days and 28 days respectively. And also the concrete is cured in oven at the temperature of 60 ^{0}C for duration 24 hours showed compressive strength of 29.57 N/mm^2 and 31.46 N/mm^2 for the testing period of 7 days and 28 days respectively.

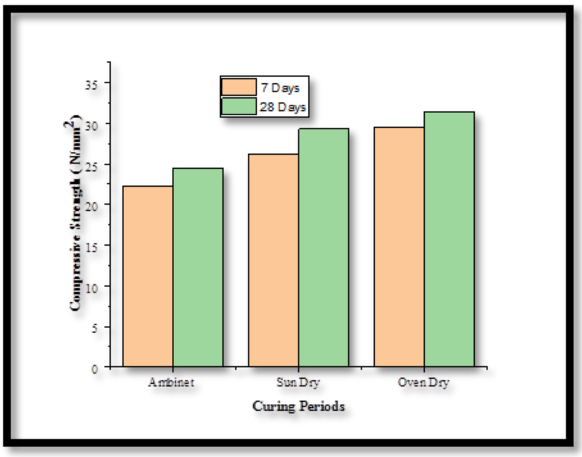

Figure 5. *Compresive strength of GPC mix-3 for different Curing regime.*

Mix-4: Properties of GPC ratio Fly ash 60% and GGBS 40% Using Recycled Coarse Aggregate.

Workability is measured in terms of slump. For the above mix slump obtained was 165 mm. It is noticed that increased in concentration of GGBS leads to decrease workability. Also, concrete sets rapidly in short duration.

The second mix is with Fly ash and GGBS ratio of 60:40 and water content of the 140 litres/m^3. The average compressive strength of 25.23 N/mm^2 and 30.88 N/mm^2 were obtained for the period of 7 days and 28 days respectively when the concrete is cured in ambient (laboratory) condition. Further, the concrete cured in sundry condition showed slightly higher compressive strength of 30.44 N/mm^2 and 33.26 N/mm^{2}for the period of 7 days and 28 days respectively. And also the concrete cured in oven at a temperature of 60ºC for duration of 24 hours showed compressive strength of 33.52 N/mm^2 and 35.15 N/mm^2 for the testing period of 7 days and 28 days respectively. The Fig 6 gives the details of the compressive strength of the GPC cured at different like ambient, sundry and oven dry for the Geopolymer concrete with 140 liters of water content and Fly- Ash: GGBS = 60:40.

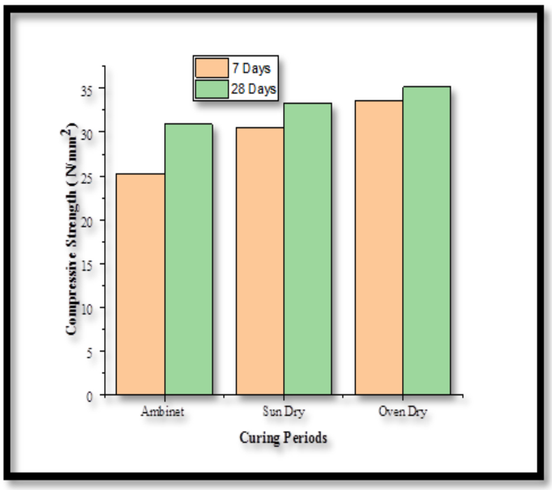

Figure 6. *Compresive strength of GPC mix-4 for different Curing regime.*

4. CONCLUSION

Based on the experimental work following conclusions are drawn, It is possible to cast geopolymer concrete using natural and recycled coarse aggregate. The better workability is obtained with natural aggregate with mix 1 of 90 % fly ash and 10 % GGBS. Better fresh property is observed in Mix 1 in compression with all the mix. Whereas higher compressive strength was observed in Mix-2.Mix-2 given higher strength due to increase in percentage of GGBS. Through experiment it is observed that reduction in strength in recycled aggregate concrete. Increase in use of GGBS resulted in gain of early strength in Mix-3 & Mix-4. But it resulted in slump loss due to early setting time.

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