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Geopolymer Concrete Materials: An Overview of their Mechanical Behavior

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ABSTRACT

Environmental contamination has emerged as a big issue in our society. When it comes to global pollution, carbon dioxide has a huge role to play. Traditional building methods rely on the use of cement, which produces a significant quantity of CO2. Consequently, a new substance called geopolymer concrete was developed and is now widely utilised in construction as a means of repurposing industrial waste and decreasing CO2 emissions. Many research have used different curing temperatures and materials such as flyash, GGBS, sodium hydroxide, sodium silicate, and superplasticizers and admixtures such as polyproplene and jute fibres. As a result, we can determine the best quantity of material, the best approach, and the best strength that can be produced from the research by evaluating this information.

Keywords: *Geopolymer concrete; Carbon dioxide; Fly Ash; Mechanical Behavior; Fibers.*

1.0 Introduction

Compared to Portland cement concrete, a new environmentally friendly substance called Geopolymer Concrete is being utilised in the building industry to lessen concrete's impact on CO2 emissions. At high temperatures, the C-S-H gel in regular Portland cement is destroyed. (2) It is a cement-free concrete substance that is gaining popularity across the globe. This substance is being used both domestically and internationally. Precast geopolymer concrete structures are utilised in the transportation industry, offshore buildings, maritime structures, railroad sleepers, and sewage funnels in Brisbane, Australia. In fire-resistant constructions, geopolymer concrete structures are becoming more widespread. Geopolymer concrete is the focus of much of the authors' research. Material used in GPC production includes ground granulated blast furnace slag and flyash, alkali activators curing (oven curing, steam curing, and ambient curing), coupled with super plasticizers and various conditions. Flexural strength, compressive strength, split tensile strength, specific garvity, and fineness modulus were some of the metrics the material was tested on, and the ratios of different materials, as well as changes in time and curing temperature, were all factors considered.

Bhikshma and Kumar shows that GPC grades are diverse, and the paper's goal is to indicate the optimal quantity GGBS for each grade of GPC. 7-day concrete's compressive strength is 60-70 percent of 28-day concrete's. Super plasticizer and M20 to M60 grade concrete were used to cast the project's 30 cubes, 30 cylinders, and 15 prism beams. A 28-day improvement in compressive strength compared to IS 456-2000 is seen in the findings of concrete utilised and typical concrete.

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Geopolymer concrete achieves its desired strength quicker with heat curing than with ambient curing, according to the findings of the experiment. To maximise the amount of concrete, a second-order polynomial model is suggested. The MINITAB response optimizer approach was used to construct a numerical algorithm for determining the smallest possible geopolymer concrete mix fraction. With low calcium flyash, the split tensile strength of cubes and cylinders at 14, 28, and 56 days has been determined for delay periods of 0, 24 hr., 48 hr., and 72 hours (Baboo Rai and Manoj Rajjak).

Antonella Petrillo et al compared regular Portland cement blocks with geopolymeric blocks recycled clay as fine aggreagte typically used in both blocks. Two methods are employed in the Life Cycle Assessment of OPC and geopolymer blocks: the Eco Indicator 99 (EI 99) and the CML (CML 99). Among the resources used to gauge potential negative consequences on the environment were Simapro 7.1 and the Eco Invent 2.1 database, both from 2009 versions.

2.0 Material Used

2.1 Fly ash

Fly ash in huge quantities may be found everywhere. It is a byproduct of India's many thermal power plants, of which there are a large number. Fly ash and CO2 emissions amount to quintals. Fly ash class C, class F, and pond ash are all types of fly ash that are produced by a power station. Between 0.5 and 300 microns in diameter, a particle may be found. Based on the kind of coal used, fly ash's chemical makeup might vary widely. Class C and Class F flyash have the following standard chemical compositions.

Table 1: Standard Chemical Analysis of Class C and Class F Flyash

Chemical Composition	Class F	Class C
SiO2	52	35
Al2O3	23	18
Fe2O3	11	6
CaO	5	21
SO3	0.8	4.1
Na2O	1	5.8
K2O	2	0.7
Total Na,Alk,%	2.2	6.3
Loss on ignition	2.8	0.5

Geopolymer concrete uses fly ash with low calcium content. As the fineness of fly ash increases, the amount of time it takes for geopolymer concrete to harden decreases. Compressive strength has been shown to be linearly related to curing temperature, molarity, and activator/fly ash ratio. GPC samples generated with flyash class F demonstrate thermal shock resistance, but GPC samples made with 11 samples of flyash from various nations show fractures and expansion. Material properties such as particle size distribution and chemical composition are critical when GPC is to be employed at high temperatures. Zeolitic phases such as sodalite, analcime and anapheline, the overall pore structure of GPC and geopolymerization process are also important. The use of Fly ash to concrete reduces drying shrinkage (either separately or together). Compared to high-calcium fly ash, low-calcium fly ash is preferable because of its rapid setting time.

2.2 Curing time and temperature

Due of the polymerization process, GPC hardens when it is heated. For a minimum of 24 hours, steam curing or hot air curing is employed. Silica fume and slag up to 30-40% should be used during curing under ambient circumstances in order to produce strength [7]. At higher curing temperatures, the curing process of fly ash-based geopolymer mortar is quicker [9]. Initially, samples were cured for three days at 80°C, then held at 1093°C for an hour while submerged. Curing for 24 and 48 hours at 60oC, with a mix ratio of 1:2.5, followed by air curing, were used in this study [2]. Efforts were made to reduce the strength increase from 48 hours to 24 hours in order to preserve energy [3]. Dehydration and excessive shrinkage of geopolymer concrete occur as a consequence of gel contraction during the curing process at extreme temperatures, which degrades flyash's microstructure [1].

2.3 Coarse aggregate

As an aggregate, 5mm-diameter fused alumina was employed. There are two ways aggregate composition affects flowability and compressive strength after seven days. The flowability reduced and the 7-day compressive strength rose as the aggregate content increased. It was shown that aggregates in the saturated surface dry (SSD) state did neither contribute more water to the mix nor absorbed chemical solutions. As long as the GPC size is below 10 mm, the aggregate will shatter into fragement when heated to temperatures between 420°C and 505°C. Sizes 10–14 mm and 20 mm aggragates have a 61.8 percent decrease in strength. Higher temperatures are more tolerable for concrete that has been mixed with uniformly graded coarse aggregate. Aggregate of 2.36mm fineness is used as fine aggregate.To increase the binder's durability, heat resistance, and mechanical performance, an amorphous zone of N-A-S-H produced at increased temperatures is beneficial [2].

2.4 GGBS

More than 228 percent of the 7-day and 28-day compressive strength is influenced by slag concentration changes from 0% to 40% [3]. By adding ground-granulated blast furnace slag, Fly ash's strength is boosted. To begin with, it's an off-white colour, with a relative density of 2.92, bulk density of 1.2-1.3 ton/m3, and a chemical composition that includes 40% calcium oxide, 35% aluminium oxide, 10% silicon dioxide, and 8% magnesia dioxide [12]. In GPC, slag concentrations ranging from 10% to 40% are combined with CWP and cured for 24 hours at 60°C. This is how flowability is affected as a result [4].

2.5 Compressive strength

The strength of Polymer Portland cement concrete GPC was better than that of PCC and LMC, but lower than that of Polymer Portland cement concrete PPCC. The breakdown of the binder matrix and debonding at ITZ were to blame for the concrete fissures. For testing concrete's strength and slump, IS: 10262-2009 was utilised using fly ash and alkaline solutions in lieu of cement [7]. Polypropylene fibres increase the geopolymer's compressive strength and ductility.GPC's compressive strength is increased by adding 0.05 and 0.15 percent polypropylene fibres (by weight). Compressive strength values were unaffected by ambient curing after seven days.

The ultimate compressive strength of geopolymer concrete may be achieved in a short amount of time if specimens are allowed to oven cure for a substantial duration of time at temperatures between 80 and 90 LC. This low-strength concrete may be cast in situ since it gains the bulk of its compressive strength in 21 to 28 days, regardless of the curing technique. So it has a lot of promise for a concrete like that. Due to the formation of calcium-aluminate-hydrate and other calcium

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compounds, fly ash with a greater percentage of calcium oxide (CaO) is said to have a higher compressive strength. The synthesis of calcium-aluminate-hydrate and other calcium compounds is made possible by the flyash's increased amount of calcium oxide (CaO).

2.6 Flexural strength

There is a difference in the strength of LMC and PCC, although PPCC is stronger than GPC. According to the observations made on the failed specimens, debonding at ITZ was the primary cause of the failures in GPC, PCC, and PPCC [12]. The flexural strength of self-compacting concrete diminishes as the molarity of NaOH increases.

2.7 Splitting tensile strength

PCC and LMC's strength is inferior than GPC's, while GPC's was greater than PPCC's. Debonding at ITZ was the primary cause of the failure of GPC, PCC, and PPCC [4]. First and final deflection in flexure were satisfactory for jute fibres incorporating blast furnace slag as a composite.

2.8 Alkaline activator

The -Si-O-Al-O bond in Si-Al minerals creates a three-dimensional polymeric chain and ring structure. In order to achieve structural strength, a high alkali content and poly-condensation of silica and alumina are used. When mixed with fly ash, Na2SiO3 acts as a catalyst to speed up the chemical process [5]. This paste is made of aluminium and silicon, which are both found in the fly ash. NaOH and Na2SiO3solutions were used to bind the aggregates and steel fibres together in GPC. Alkali metal silicate solutions and solid aluminosilicate oxides react in a heterogeneous chemical reaction at moderate temperatures, resulting in amorphous to semi-crystalline polymeric structures, such as Si–O–Si and Si-O–Al linkages, under extremely alkaline circumstances [11]. There is a progression of chemical reactions between the substrates and the solution. The addition of NaOH to the alkaline activators solution accelerated the reaction, resulting in a gel with a rougher texture and a quicker reaction rate. Flyash and aggregate are held together by the activator solution. The reaction of silica and alumina content is carried out using a mixture of KOH and K2SiO3. KOH and NaOH dissolved in water to make a powdery component. NaOH solutions have a viscosity that is 12 times greater than that of KOH. (14 M NaOH) Sodium silicate (Na2SiO3) is utilised as an activator in this reaction. SiO2 and Na20 were combined in a weight ratio of 2:1 to produce Na2SiO3.

3.0 Material Testing

After each cycle, the samples underwent a performance examination to determine whether or not they had large or small cracks, expanded, or completely failed. Following the completion of each cycle, a visual examination was carried out, and digital micrographs of each sample were taken. The Energy Dispersive-X-Ray fluorescence (XRF) spectroscopy method was used in order to determine the GPC specimens' chemical composition. In order to get an understanding of the microstructure characterisation, scanning electron microscopy (SEM) and X-ray diffraction analyses were carried out using a D8 Advanced Bruker AXS spectrometer. Using X-ray micro tomography, it was possible to determine the pore structure of the geopolymer concrete after it had been subjected to thermal stress [2]. Sulphate Resistance test in Na2SO4 solution done show reduction in compressive strength on Geopolymer Concrete. Acid resistance test in H2SO4 solution for 60 days performed this indicates rise in mass and compressive strength on concrete [7].

4.0 Conclusion

The combinations of geopolymer concrete are intended to have the same properties as Portland cement concrete. The bulk of geopolymer concrete is comprised of coarse and fine particles to the extent of about 75–80 percent. The strength of the GPC will diminish if the percentage of superplasticizer in the mixture is increased over 2 percent. The strength of geopolymers is not significantly affected by the passage of time. The addition of 40 percent slag in place of CWP led to improvements in both the bulk electrical resistivity and the strength of the material. The use of superplasticizer improves the flowability of mixes. The process of curing increased the strength of the GPC.

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