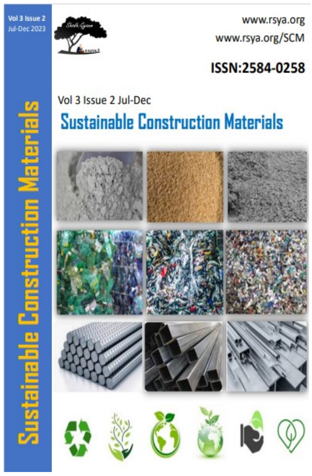

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An Examination of The Mechanical Properties of Geopolymer Concrete Materials

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Abstract

The proliferation of environmental pollution has become a significant concern within our culture. Carbon dioxide plays a significant impact in global pollution. Conventional construction techniques depend on the utilisation of cement, which generates a substantial amount of carbon dioxide (CO2). As a result, geopolymer concrete, a novel material, was created and is currently extensively employed in construction to recycle industrial waste and reduce CO2 emissions. Several studies have employed various curing temperatures and materials, including fly ash, GGBS, sodium hydroxide, sodium silicate, as well as superplasticizers and admixtures like polypropylene and jute fibres. By examining this information, we may ascertain the optimal quantity of material, the most effective strategy, and the highest level of strength that can be achieved through the research.

Keywords: Geopolymer concrete, Carbon dioxide, Fly Ash, Mechanical Behavior, Fibers

Introduction

Geopolymer Concrete, an environmentally friendly alternative to Portland cement concrete, is being used in the construction industry to reduce the negative impact of concrete on CO2 emissions. The C-S-H gel in normal Portland cement undergoes degradation at elevated temperatures. (2) This is a cementless concrete material that is becoming increasingly popular worldwide. This chemical is being utilised in both domestic and international contexts. Precast geopolymer concrete structures are employed in the transportation industry, offshore buildings, maritime constructions, railway sleepers and sewage funnels in Brisbane, Australia. Geopolymer concrete structures are increasingly used in fire-resistant constructions. The authors' research mostly revolves around geopolymer concrete. The manufacturing of GPC involves the utilisation of ground granulated blast furnace slag and flyash, along with alkali activators for curing (such as oven curing, steam curing, and ambient curing), in addition to super plasticizers and different conditions. The material underwent testing for flexural strength, compressive strength, split tensile strength, specific gravity, and fineness modulus. The ratios of various materials and the effects of time and curing temperature were also taken into account. The GPC grades exhibit a wide range of variations, and the objective of the article is to determine the ideal amount of GGBS for each grade of GPC. The compressive strength of concrete at 7 days is approximately 60-70% of the compressive strength of concrete at 28 days. The project's 30 cubes, 30 cylinders, and 15 prism beams were cast using a combination of super plasticizer and M20 to M60 grade concrete. The outcomes of concrete utilised and normal concrete show a 28-day enhancement in compressive strength compared to IS 456-2000. The experiment's findings indicate that heat curing accelerates the attainment of the desired strength in geopolymer concrete compared to ambient curing. A second-order polynomial model is recommended to optimise the utilisation of concrete. A numerical technique was developed using the response optimizer approach to accurately determine the minimum geopolymer concrete mix fraction. The split tensile strength of cubes and cylinders at 14, 28, and 56 days was measured using low calcium flyash. The delay durations of 0, 24 hours, 48 hours, and 72 hours were considered. Antonella Petrillo and her colleagues conducted a comparison between ordinary Portland cement blocks and geopolymeric blocks that were made using reclaimed clay as a fine aggregate, which is commonly utilised in both types of blocks. **2**

Material used

Fly Ash

Large volumes of fly ash can be found ubiquitously. It is a derivative of the numerous thermal power plants in India, which are abundant in quantity. The quantity of fly ash and CO2 emissions is measured in quintals. Fly ash class C, class F, and pond ash are distinct variations of fly ash generated by a power station. A particle can be found within a diameter range of 0.5 to 300 microns. The chemical composition of fly ash can vary significantly depending on the type of coal utilised. The normal chemical compositions of Class C and Class F flyash are as follows.

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

Chemical Composition	Class F	Class C
SiO_2	52	35
Al_2O_3	23	18
Fe_2O_3	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 utilises fly ash that has a low calcium concentration. The decrease in the hardening time of geopolymer concrete is directly proportional to the increase in the fineness of fly ash. The relationship between compressive strength and curing temperature, molarity, and activator/fly ash ratio has been demonstrated to be linear. GPC samples produced using flyash class F exhibit high thermal shock resistance, whereas GPC samples fabricated using 11 other samples of flyash from various countries exhibit fractures and expansion. When using GPC at high temperatures, it is crucial to consider material features such as particle size distribution and chemical composition. The presence of zeolitic phases, including sodalite, analcime, and anapheline, as well as the general pore structure of GPC and the geopolymerization process, are crucial factors to consider. Utilising Fly ash in concrete diminishes drying shrinkage, whether used independently or in combination. Low-calcium fly ash is more desirable than high-calcium fly ash due to its accelerated setting time.

Curing Time and Temperature

As a result of the polymerization process, GPC undergoes hardening when subjected to heat. Steam curing or hot air curing is used for a minimum duration of 24 hours. To achieve strength during curing under normal conditions, it is recommended to use silica fume and slag in proportions of up to 30-40% [7]. The curing process of fly ash-based geopolymer mortar is accelerated at higher curing temperatures [9]. Initially, the samples underwent a three-day curing process at a temperature of 80°C. Subsequently, they were subjected to a one-hour immersion at a temperature of 1093°C. In this investigation, the curing process involved exposing the mixture to a temperature of 60oC for either 24 or 48 hours, with a ratio of 1 part to 2.5 parts. After this first curing, the mixture was then subjected to air curing. An attempt was made to decrease the duration of the strength increase from 48 hours to 24 hours in order to conserve energy [3]. The dehydration and significant reduction in size of geopolymer concrete are caused by the contraction of the gel during the curing process at high temperatures, resulting in the deterioration of the microstructure of fly ash [1].

Coarse Aggregate

A 5mm-diameter fused alumina was used as a whole. Aggregate mix has a dual impact on flowability and compressive strength after a week. As the aggregate content increased, the flowability decreased and the 7-day compressive strength increased. It was demonstrated that aggregates in the saturated surface dry (SSD) state did not provide more water to the mixture nor absorb chemical solutions. If the GPC size remains below 10 mm, the aggregate will disintegrate into fragments when exposed to temperatures ranging from 420°C to 505°C. Aggregates with sizes ranging from 10 to 14 mm and 20 mm experience a reduction in strength of 61.8 percent. Concrete that has been mixed with uniformly graded coarse aggregate has greater tolerance to higher temperatures. The fine aggregate utilised is an aggregate with a fineness of 2.36mm.The production of an amorphous zone of N-A-S-H at higher temperatures is advantageous for enhancing the binder's durability, heat resistance, and mechanical performance [2].

GGBS

The compressive strength of the concrete is significantly affected by changes in slag concentration, ranging from 0% to 40%, resulting in an increase of more than 228% in both the 7-day and 28-day compressive strength [3]. The use of ground-granulated blast furnace slag enhances the strength of fly ash. Initially, the substance has an off-white hue and possesses a relative density of 2.92. Its bulk density ranges from 1.2 to 1.3 ton/m3. The chemical composition comprises 40% calcium oxide, 35% aluminium oxide, 10% silicon dioxide, and 8% magnesia dioxide [12]. Within the GPC process, varying amounts of slag, specifically between 10% and 40%, are mixed with CWP and subjected to a 24-hour curing period at a temperature of 60°C. This is the impact on flowability as a consequence [4].

Compressive Strength

The compressive strength of Polymer Portland cement concrete (GPC) was superior to that of Plain Portland cement concrete (PCC) and Lightweight Modified concrete (LMC), but inferior to that of Polymer Portland cement concrete (PPCC). The concrete fractures were caused by the disintegration of the binder matrix and the separation of the interfacial transition zone (ITZ). The strength and slump of concrete were tested using IS: 10262-2009, with the substitution of cement by fly ash and alkaline solutions [7]. The use of polypropylene fibres enhances both the compressive strength and ductility of the geopolymer.The compressive strength of GPC is enhanced by including polypropylene fibres at a weight percentage of 0.05 and 0.15 percent. The compressive strength values remained unchanged after seven days of ambient curing. To attain the maximum compressive strength of geopolymer concrete, it is necessary to enable the specimens to undergo oven curing for a significant period of time at temperatures ranging from 80 to 90 LC. This low-strength concrete can be poured in place as it achieves the majority of its compressive strength during a period of 21 to 28 days, regardless of the method used for curing. Therefore, it exhibits significant potential as a material like concrete. Fly ash containing a larger proportion of calcium oxide (CaO) is reported to exhibit increased compressive strength due to the development of calcium-aluminate-hydrate and other calcium compounds. The presence of a higher concentration of calcium oxide (CaO) in fly ash enables the formation of calcium-aluminate-hydrate and other calcium compounds through synthesis.

Flexural Strength

LMC and PCC exhibit varying levels of strength, with PPCC being stronger than GPC. The failures in GPC, PCC, and PPCC were primarily caused by debonding in the interfacial transition zone (ITZ), as indicated by the observations made on the failed specimens [12]. The flexural strength of self-compacting concrete decreases with an increase in the molarity of NaOH.

Splitting Tensile Strength

The strength of PCC and LMC is lower than that of GPC, whereas GPC's strength surpasses that of PPCC. The failure of GPC, PCC, and PPCC was mostly caused by debonding in the interfacial transition zone (ITZ) [4]. The deflection in flexure of jute fibres integrating blast furnace slag as a composite met the required standards both initially and ultimately.

Alkaline Activator

The Si-O-Al-O bond in Si-Al minerals forms a three-dimensional polymeric chain and ring structure. To attain structural strength, substantial levels of alkali content and the poly-condensation of silica and alumina are employed. Na2SiO3 functions as a catalyst to accelerate the chemical reaction when combined with fly ash [5]. This paste comprises aluminium and silicon, both of which are present in fly ash. Solutions of NaOH and Na2SiO3 were employed to consolidate the aggregates and steel fibres in GPC. Alkali metal silicate solutions and solid aluminosilicate oxides undergo a heterogeneous chemical reaction at moderate temperatures, leading to the formation of amorphous to semi-crystalline polymeric structures. These structures include Si–O–Si and Si-O–Al links and are formed under very alkaline conditions [11]. The substrates and the solution undergo a series of chemical reactions. The introduction of NaOH to the alkaline activators solution expedited the reaction, leading to a gel with a more coarse texture and an increased reaction rate. The activator solution binds the flyash and aggregate together. The interaction between silica and alumina is conducted using a blend of potassium hydroxide (KOH) and potassium silicate (K2SiO3). Potassium hydroxide (KOH) and sodium hydroxide (NaOH) are dissolved in water to form a fine powder. The viscosity of NaOH solutions is 12 times higher than that of KOH. Sodium silicate (Na2SiO3) is employed as an activator in this reaction, using a 14 M solution of NaOH. SiO2 and Na20 were mixed in a weight ratio of 2:1 to yield Na2SiO3.

Material Testing

Following each cycle, the samples were subjected to a performance evaluation to ascertain the presence of significant or minor cracks, expansion, or complete failure. After each cycle was finished, a thorough visual inspection was conducted, and digital micrographs of each sample were captured. The chemical composition of the GPC specimens was determined using the Energy Dispersive-X-Ray fluorescence (XRF) spectroscopy technique. To comprehend the microstructure characterization, we conducted scanning electron microscopy (SEM) and X-ray diffraction investigations using a D8 Advanced Bruker AXS spectrometer. The pore structure of the geopolymer concrete was determined using X-ray micro tomography following exposure to heat stress [2]. The Sulphate Resistance test conducted in a Na2SO4 solution revealed a decrease in the compressive strength of Geopolymer Concrete. The concrete underwent an acid resistance test in an H2SO4 solution for a duration of 60 days. The results showed an increase in both mass and compressive strength [7].

Conclusion

The aim of geopolymer concrete is to possess identical characteristics to those of Portland cement concrete. The majority of geopolymer concrete consists of a combination of large and small particles, making up approximately 75-80 percent of the total composition. The potency of the GPC will decrease if the proportion of superplasticizer in the mixture exceeds 2 percent. The durability of geopolymers remains largely unaffected by the passage of time. Substituting CWP with 40 percent slag resulted in enhancements in both the bulk electrical resistivity and the material's strength. Superplasticizer enhances the fluidity of mixtures. Curing enhanced the strength of the GPC.

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