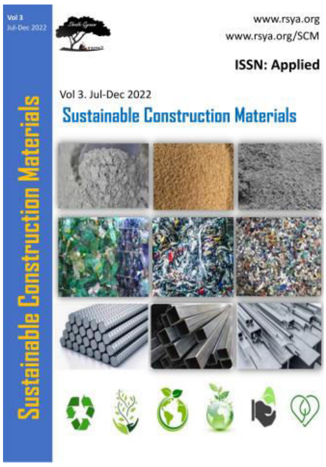

www.rsya.org

Sustainable Construction Materials

Vol 1, Issue 1, Jul-Dec 2021

www.rsya.org/scm

Review of the Mechanical Behavior of Geopolymer Concrete

Pooja Khatri[*], Bhagmant Singh, Sapna Katara

CHANDIGARH UNIVERSITY, NH-05, Ludhiana - Chandigarh State
Hwy, Punjab 140413, India

[*]Corresponding Author: pooja92khatri8@gmail.com

Abstract: In contemporary society, environmental contamination has become a major problem. Carbon dioxide is a major contributor to global pollution. Traditional construction techniques rely on cement, which generates a lot of CO2. As a result, a novel material known as geopolymer concrete was created and is now frequently used in construction as a way to reuse industrial waste and reduce CO2 emissions. Different curing temperatures and materials, including flyash, GGBS, sodium hydroxide, sodium silicate, and superplasticizers and admixtures such polyproplene and jute fibres, have been utilised in numerous studies. By analysing this data, we may ascertain the ideal amount of material, the ideal strategy, and the ideal strength that can be generated from the research.

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

Introduction

To reduce concrete's effect on CO2 emissions compared to Portland cement concrete, the building industry is now using Geopolymer Concrete, a new environmentally friendly material. The C-S-H gel in ordinary Portland cement is destroyed at high temperatures. (2) It is a type of cement-free concrete that is becoming more and more well-liked all over the world. Internationally and domestically, this drug is used. In Brisbane, Australia, sewage funnels, offshore buildings, maritime constructions, and the transportation sector all use precast geopolymer concrete structures. Geopolymer concrete constructions are becoming more common in buildings designed to withstand fire. The majority of the writers' research is focused on geopolymer concrete. Ground granulated blast furnace slag and flyash, alkali activators curing (oven, steam, and ambient curing), together with super plasticizers, are materials used in the production of GPC. Some of the metrics the material was evaluated on included flexural strength, compressive strength, split tensile strength, specific gravity, and fineness modulus. The ratios of the various materials, as well as variations in time and curing temperature, were all taken into account. The purpose of the paper is to specify the ideal quantity of GGBS for each grade of GPC, as demonstrated by Bhikshma and Kumar who also show that GPC grades are varied. The compressive strength of 7-day concrete is 60–70% that of 28-day concrete. 30 cubes, 30 cylinders, and 15 prism beams were cast for the project using super plasticizer and M20 to M60 grade concrete. The results of the concrete used and normal concrete show a 28-day increase in compressive strength compared to IS 456-2000. According to the results of the investigation, heat curing geopolymer concrete makes it stronger more quickly than ambient curing. A second-order polynomial model is recommended in order to maximise the amount of concrete. The minimum feasible geopolymer concrete mix fraction was calculated using a numerical method built using the MINITAB response optimizer approach. The split tensile strength of cubes and cylinders with low calcium flyash has been determined for delay times of 0 hours, 24 hours, 48 hours, and 72 hours (Baboo Rai and Manoj Rajjak). Recycled clay, a common fine aggregate used in both types of blocks, was compared by Antonella Petrillo et al. to conventional Portland cement blocks and geopolymeric blocks. The Eco Indicator 99 (EI 99) and the CML are two techniques used in the Life Cycle Assessment of OPC and geopolymer blocks (CML 99). Simapro 7.1 and the Eco Invent 2.1 database, both from 2009 releases, were two tools used to estimate potential environmental harm.

Material used

Fly Ash

There may be enormous amounts of fly ash everywhere. It is a byproduct of the numerous thermal power facilities that are located throughout India. Quintals are the amount of fly ash and CO2 emissions. A power plant will create different forms of fly ash, including class C, class F, and pond ash. A particle can range in size from 0.5 to 300 microns. The chemical composition of fly ash may differ 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

Low calcium fly ash is used in geopolymer concrete. The length of time it takes for geopolymer concrete to harden decreases as fly ash fineness rises. Compressive strength has been demonstrated to be linearly proportional to curing temperature, molarity, and activator/fly ash ratio. GPC samples generated with flyash class F showed thermal shock tolerance, however GPC samples made with 11 samples of flyash from diverse nations show fractures and expansion. When using GPC at high temperatures, material characteristics like particle size distribution and chemical composition are crucial. The geopolymerization process, the general pore structure of GPC, and zeolitic phases like sodalite, analcime, and anapheline are also significant. Concrete drying shrinkage is reduced when fly ash is used (either separately or together). Compared to high-calcium fly ash, low-calcium fly ash is desirable because of its short setting time.

Curing Time and Temperature

The polymerization process causes GPC to harden when heated. Steam curing or hot air curing is used for a minimum of 24 hours. To provide strength, silica fume and slag up to 30–40% should be employed during ambient curing conditions [7]. Fly ash-based geopolymer mortar cures more quickly at higher curing temperatures [9]. Samples were initially cured at 80°C for three days, and then kept at 1093°C for an hour while submerged. In this investigation, curing for 24 and 48 hours at 60 oC with a mix ratio of 1:2.5 was used, followed by air curing [2]. In an effort to conserve energy, the strength increase was lowered from 48 to 24 hours [3]. Due to gel contraction during the curing process at extremely high temperatures, which destroys the fly ash microstructure, geopolymer concrete dehydrates and shrinks excessively [1].

GGBS

Changes in slag concentration from 0% to 40% have an impact on more than 228 percent of the 7-day and 28-day compressive strength [3]. Blast furnace slag that has been crushed into small granules is used to strengthen fly ash. It is initially an off-white colour, has a bulk density of 1.2–1.3 tons/m3, a relative density of 2.92, and a chemical makeup of 40% calcium oxide, 35% aluminium oxide, 10% silicon dioxide, and 8% magnesia dioxide [12]. Slag concentrations between 10% and 40% are blended with CWP in GPC, and the mixture is then heated to 60°C for 24 hours to cure it. As a result, flowability is impacted in this way [4].

Coarse Aggregate

5mm-diameter fused alumina was used as the aggregate. After seven days, there are two ways aggregate composition can impact flowability and compressive strength. 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 absorb chemical solutions or add extra water to the mixture. When heated at temperatures between 420°C and 505°C, the aggregate will fragment as long as the GPC size is less than 10 mm. Aggregates in the 10-14 mm and 20 mm sizes have a 61.8 percent reduction in strength. Concrete that has been blended with uniformly graded coarse aggregate may withstand higher temperatures. As fine aggregate, 2.36 mm fine aggregate is employed. An amorphous zone of N-A-S-H generated at higher temperatures is advantageous for improving the binder's toughness, heat resistance, and mechanical performance [2].

Compressive Strength

Although less than that of Polymer Portland cement concrete PPCC, the strength of Polymer Portland cement concrete GPC was superior to that of PCC and LMC. The concrete cracks were caused by the debonding and breakdown of the binder matrix at ITZ. Using fly ash and alkaline solutions in place of cement, IS: 10262-2009 was used to test the strength and slump of concrete [7]. The compressive strength and ductility of the geopolymer are improved by the polypropylene fibres. By including between 0.05 and 0.15 percent of polypropylene fibres, GPC's compressive strength is raised (by weight). After seven days, the effects of ambient curing on compression strength values were negligible. If specimens are allowed to oven cure for a significant amount of time at temperatures between 80 and 90 LC, the final compressive strength of geopolymer concrete may be attained quickly. Regardless of the curing method, this low-strength concrete can be put in place because it gains the majority of its compressive strength in 21 to 28 days. Therefore, it shows great promise for a concrete of that nature. Fly ash with a higher concentration of calcium oxide (CaO) is thought to have a higher compressive strength due to the synthesis of calcium-aluminate-hydrate and other calcium compounds. The enhanced calcium oxide content of the flyash enables the formation of calcium-aluminate-hydrate and other calcium compounds (CaO).Although less than that of Polymer Portland cement concrete PPCC, the strength of Polymer Portland cement concrete GPC was superior to that of PCC and LMC. The concrete cracks were caused by the debonding and breakdown of the binder matrix at ITZ. Using fly ash and alkaline solutions in place of cement, IS: 10262-2009 was used to test the strength and slump of concrete [7]. The compressive strength and ductility of the geopolymer are improved by the polypropylene fibres. By including between 0.05 and 0.15 percent of polypropylene fibres, GPC's compressive strength is raised (by weight). After seven days, the effects of ambient curing on compression strength values were negligible. If specimens are allowed to oven cure for a significant amount of time at temperatures between 80 and 90 LC, the final compressive strength of geopolymer concrete may be attained quickly. Regardless of the curing method, this low-strength concrete can be put in place because it gains the majority of its compressive strength in 21 to 28 days. Therefore, it shows great promise for a concrete of that nature. Fly ash with a higher concentration of calcium oxide (CaO) is thought to have a higher compressive strength due to the synthesis of calcium-aluminate-hydrate and other calcium compounds. The enhanced calcium oxide content of the flyash enables the formation of calcium-aluminate-hydrate and other calcium compounds (CaO).

Flexural Strength

LMC and PCC have different strengths, though PPCC is more powerful than GPC. Debonding at ITZ was the main reason for the failures in GPC, PCC, and PPCC, based on observations obtained on the failed specimens [12]. As the molarity of NaOH rises, self-compacting concrete's flexural strength decreases.

Splitting Tensile Strength

Strength-wise, GPC is stronger than PCC and LMC, and PPCC is stronger than GPC. The key factor in GPC, PCC, and PPCC failure was debonding at ITZ [4]. For jute fibres including blast furnace slag as a composite, the first and last deflection in flexure were adequate.

Alkaline Activator

In Si-Al minerals, the -Si-O-Al-O bond results in a three-dimensional polymeric chain and ring structure. High alkali concentration and poly-condensation of silica and alumina are employed to achieve structural strength. Na2SiO3 functions as a catalyst to quicken the chemical reaction when combined with fly ash [5]. Aluminium and silicon, both of which are present in fly ash, are used to make this paste. The aggregates and steel fibres were joined together in the GPC using NaOH and Na2SiO3 solutions. Under very alkaline conditions, a heterogeneous chemical reaction between solid aluminosilicate oxides and alkali metal silicate solutions produces amorphous to semi-crystalline polymeric structures, such as Si-O-Si and Si-O-Al connections [11]. The substrates and the solution go through a series of chemical reactions. The reaction was sped up by adding NaOH to the alkaline activators solution, producing a gel with a rougher texture and a quicker reaction time. The activator solution holds the flyash and aggregate together. Utilizing a combination of KOH and K2SiO3, the reaction between the silica and alumina content is carried out. To create the powdered component, KOH and NaOH were dissolved in water. The viscosity of NaOH solutions is 12 times larger than that of KOH solutions. Sodium silicate (Na2SiO3) is used as an activator in this synthesis, which uses (14 M NaOH). Na2SiO3 was created by combining SiO2 and Na20 in a weight ratio of 2:1.

Material Testing

The samples received a performance evaluation following each cycle to evaluate whether or not they had large or small cracks, expanded, or failed entirely. Each cycle was finished off with a visual inspection and digital micrographs of each sample being taken. The chemical composition of the GPC specimens was determined by Energy Dispersive-X-Ray Fluorescence (XRF) spectroscopy. Using a D8 Advanced Bruker AXS spectrometer, scanning electron microscopy (SEM) and X-ray diffraction investigations were done to investigate the microstructure characterization. After the geopolymer concrete had been subjected to thermal stress, the pore structure could be identified using X-ray micro tomography [2]. Geopolymer Concrete's compressive strength is reduced as a result of a sulphate resistance test conducted in a Na2SO4 solution. Concrete's mass and compressive strength increased as a result of an acid resistance test that was conducted in H2SO4 solution for 60 days [7].

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.

References

1. Baboo Rai ,L.B.Roy ,Manoj Rajjak “A Statistical Investigation of Different Parameters Influencing Compressive Strength of Fly ash induced Geopolymer Concrete” WILEY fib ,Structral Concrete,2018,pp.1-12 .

2. Kunal Kupwade-Patil, Md. Sufian Badar, Milap Dhakal and Erez N. Allouche” Evaluation of Geopolymer Concretes at Elevated Temperature” Developments in Strategic Materials and Computational Design IV. The American Ceramic Society,(2014),pp. 79-95

3. Sama T. Aly, Dima M. Kanaan, Amr S. El-Dieb, and Samir I. Abu-Eishah “Properties of Ceramic Waste Powder-Based Geopolymer Concrete” International Congress on Polymers in Concrete (ICPIC 2018),chapter 54,pp429-435.

4. Sulaem Musaddiq Laskar, Ruhul Amin Mozumder and Biswajit Roy “Behaviour of Geopolymer Concrete Under Static and Cyclic Loads” ,Advances in Structural Engineering,(2015),pp 1643-1652.

5. J. T. Gourley, “Geo polymers; opportunities for environmentally friendly construction materials,” Paper presented at the Materials 2003, Conference on Adaptive Materials for a Modern Society, Sydney,(2003).

6. S. V. Joshi and M. S. Kadu, “Role of Alkaline Activator in Development of Eco-friendly Fly Ash Based Geo Polymer Concrete” International Journal of Environmental Science and Development, Vol. 3, No. 5,(2012),pp 417-421

7. C. Antony JeyaseharDr. M. SalahuddiDr. S.Thirugnanasambandam “Development of Flyash based Geopolymer Concrete Precast Elements” a project report submitted in combination of Government of India Ministry of Environment and Forest and Annamalai University(2013)Tamilnadu.

8. Mark Reed, Weena Lokuge, Warna Karunasena ,”Fibre-reinforced geopolymer concrete with ambient curing for in situ applications” Springer Science Business Media New York 2014.

9. Memon FA, Nuruddin MF, Demie S, Shafiq N, “Effect of curing conditions on strength of fly ash-based self- compacting geopolymer concrete”, World Acad Sci Eng Technol 80:860–863(2011).

10. Daniel L.Y. Kong a, Jay G. Sanjayan “Effect of elevated temperatures on geopolymer paste, mortar and concrete” Cement and Concrete Research 40, (2010),pp 334–339

11. M M A B Abdullah, M F M Tahir, M A F M A Tajudin, J J Ekaputri, R Bayuaji and N A M Khatim1 “Study on The Geopolymer Concrete Properties reinforced with steel fibre” IOP Conf. Series: Materials Science and Engineering 267 (2017),pp1-7

12. J.S. Kalyana Rama, N. Reshmi, M.V.N. Sivakumar and A. Vasan, “ Experimental Investigation and Numerical Validation on the Effect of NaOH Concentration on GGBS Based Self-compacting Geopolymer Concrete”, Advances in Structural Engineering Springer India (2015),pp1673-1686

13. Ana Carolina , Pontifícia,Rio de Janeiro, “Mechanical Properties of Jute fiber reinforced geopolymers” ,Advances in Materials Science for Environmental and Energy Technologies VI: Ceramic , Transactions, Volume 262 (2017),pp 85-96