STRUCTURAL BEHAVIOUR OF THE RC BEAM COLUMN JOINT CAST USING GEOPOLYMER CONCRETE

S. MOHANRAJ, SHAHIDHA BEGAM.N
Assistant Professor, Department of Civil Engineering, AVS Engineering College, Salem, 636 003
Email: ersmohanraj@gmail.com & shahidha.cv@gmail.com

Abstract

Efforts are urgently underway all over the world to develop environmentally friendly construction materials, which make minimum utility of fast dwindling natural resources and help to reduce greenhouse gas emissions. In this connection, Geopolymers are showing great potential and several researchers have critically examined the various aspects of their viability as binder system. Geopolymer concretes (GPCs) are new class of building materials that have emerged as an alternative to Ordinary Portland cement concrete (OPCC) and possess the potential to revolutionize the building construction industry. Geopolymer is obtained by mixing the ingredient such as sodium hydroxide solution, sodium silicate solution, fly ash, fine aggregate and coarse aggregate and cured suitably. A few studies have been reported on the use of such GPCs for structural applications. In reinforced concrete framed structure, the beam-column joints are critical regions and the joints has a very significant role in design and construction. The purpose of the present study is to investigate the behaviour of room temperature cured reinforced Geopolymer concrete. For comparing the strength of GPC and OPCC, specimens of cubes, cylinders, prisms and beam column joints were casted both in GPC and OPCC. The specimens then tested for Compression Strength, Split Tensile strength and Flexural Strength. After testing, the results of GPC casted specimens and OPCC casted specimens were analyzed. In all the tests, GPC casted specimens had more strength and durability compared to OPCC casted specimens.

***Keywords:** Geopolymer, Beam column joint, Ambient curing*

1. 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 amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel.

In 1978, Davidovits proposed that a binder could be produced by a polymerisation process involving a reaction between alkaline liquids and compounds containing alumina and silica.The binders created were termed "geopolymers".

Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium-silicate-hydrates (CSHs) for matrix formation and strength, but the aluminosilicate gel formed by geo-polymerization binds the aggregates and provides the strength to geopolymer concrete. Source materials and alkaline liquids are the two main constituents of geopolymers, the strengths of which depend on the nature of the materials and the types of liquids. Materials containing silicon (Si) and aluminium (Al) in amorphous form, which come from natural minerals or by-product materials, could be used as source materials for geopolymers. Kaolinite, clays, etc., are included in the natural minerals group whereas fly ash, silica fume, slag, rice-husk ash, red mud, etc., are by-product materials. Among the available raw materials, fly ash has attracted more attention due to its ability in improving geopolymer physical properties and its availability in large quantities. However high compressive strength geopolymer composite was obtained at elevated temperatures curing which restricts its application to precast elements.

2. Previous Project Overview

These are the project that has been already conducted on Geopolymer in 2016 & 2017.

Praveen Kumar, et al., (2017) Experimental Study on Structural Behaviour of Beam Column Joint Using Geo-Polymer Concrete Geo-polymer concrete is a good alternative for normal concrete. Geo-polymer can improve all the properties of hardened concrete and the major influence was in the improvement of structural behavior. • Geo-polymer concrete increases the compressive strength by 30% compared to conventional concrete. In cyclic loading the increase in first crack load in geo-polymer by addition of 12M, 14M and 16M of concentration are corresponding increase in conventional. • The load deflection characteristics of geo-polymer reinforced beam column joint were better than conventional concrete. The geo-polymer specimens showed better performance under cyclic loading. The ultimate load of geo-polymer increases by 32% compare to conventional concrete. • In conventional method, specimens were subjected to cyclic loading. On comparing the ductility factor increases, in addition with concentration of various molarities of NaOH. Geopolymer concrete increases the ductility factor to 1.6 times of the conventional mix. • Under cyclic loading geo-polymer shows 3.17 times higher energy absorption capacity of conventional specimen. The geo-polymer concrete beam column joint shows higher stiffness.

S.Deepa Raj, et al., (2016), Behavior of geopolymer and conventional concrete beam column joints under reverse cyclic loading. The load deflection characteristics, energy dissipation, ductility and stiffness degradation of plain and fiber reinforced beam column joints subjected to reverse cyclic loading were investigated in this study. The results indicated that the use of fibers could enhance the strength and ductility of beam column joints marginally. The experimental results lead to the following conclusions. Behavior of plain and fiber reinforced geopolymer beam column joints are almost similar to that of conventional concrete beam column joints. First crack load and ultimate load carrying capacity of GBJ and CCJ are almost the same. Energy absorption capacity of GBJ and CCJ are almost the same in forward and backward loading cycles and increase in energy absorption capacity after each cycle showed a similar trend. Energy absorption capacity of GBJ is 39% higher than that of CCJ. The load deflection characteristics, energy dissipation, ductility and stiffness degradation of plain and fiber reinforced beam column joints subjected to reverse cyclic loading were investigated in this study. The results indicated that the use of fibers could enhance the strength and ductility of beam column joints marginally. The experimental results lead to the following conclusions. Behavior of plain and fiber reinforced geopolymer beam column joints are almost similar to that of conventional concrete beam column joints. First crack load and ultimate load carrying capacity of GBJ and CCJ are almost the same. Energy absorption capacity of GBJ and CCJ are almost the same in forward and backward loading cycles and increase in energy absorption capacity after each cycle showed a similar trend. Energy absorption capacity of GBJ is 39% higher than that of CCJ.

3. Experimental program

3.1Material used: Fly ash used in this study is (class F) dry fly ash from Mettur thermal power station(MTPS) as per IS 1489 (Part 1) – 1991.Locally available river sand of fineness modulus of 2.7 was used as fine aggregate Crushed blue granite as per IS:383-1970 passing through 16mm sieve and retained on 12.5 mm sieve was used as coarse aggregate Locally available sodium silicate salt and sodium hydroxide pellets Distilled water as per IS:456-2000 was used for the concrete preparation

Fly ash: Fly ash is the By Product coming from the burning of coal it is collected on electro static precipitators from Thermal power stations.fly ash particles are spherical and in shape due this it absorbed less water. For this Experimental investigation we collected low calcium fly ash from local fly ash brick factory in erode. Specific gravity of fly ash is 2.2.

Alkaline Liquid: A combination of sodium silicate solution and sodium hydroxide solution is chosen as the alkaline liquid. Sodium-based solutions are chosen because they are cheaper than Potassium-based solutions. The sodium hydroxide solids are either a technical grade in flakes form (3 mm), with a specific gravity of 2.130, 98% purity, and obtained from Erode scientific lab, Erode. The sodium hydroxide (NaOH) solution was prepared by dissolving the flakes in water. The Sodium silicate solution, a gel like white substance, obtained from Erode scientific lab.

Fine aggregates: Fine aggregates used for concrete was well graded locally available river sand passing through 4.75mm and retained on 300 microns, to achieve minimum void ratio and the physical properties like fineness modulus, specific gravity. Bulk density were studied as per IS; 383-1978.

Coarse aggregate: Locally available blue granite was used. Crushed granite stones of size passing through 20mm sieve and retained on 4.75mm sieve as per IS:383-1970 was used for experimental purposes. The physical properties of coarse aggregates like fineness modulus, specific gravity, bulk density, impact test and crushing strength test were performed as per IS: 383-1978.The aggregate crushing and impact values were found to be within in the limits i.e. the percentage of those values were less than the 45 %. The aggregates were found to be good sounding and angular in shape. It's well fit to be used in concrete.

3.2 Mix proportions

Design mix

Mix design for M30 cement concrete as per IS 10262:2009 was prepared as control mix with ratio of 1:1.5:2.5 and 0.4 w/c ratio. The control specimens were water cured for 28 days.

Geopolymer mix

For comparing geopolymer concrete with control mix, geopolymer concrete with mix proportion (1:1.09:1.52) was adopted. For the alkaline activators, the parameters chosen for the mixture constituents include a ratio of sodium silicate solution-to-sodium hydroxide solution, by mass, as 2.5, sodium hydroxide solution molarity as 8 M, and a ratio of activator solution-to-binder, by mass, as 0.61. Refer **Table 1** Proportion of the mixes per m3

Mixing

NaOH pellets were dissolved in distilled water(M8) and thoroughly mixed with Na2SiO3 one day prior to the casting. Fly ash and aggregates were mixed homogeneously and then the prepared alkaline solutions were added to it. The mixing of total mass was continued until the mixture become homogeneous and uniform in colour.

Table 1 Proportion of the mixes per m3

Ingredients	**M30 (kg/m^3)**	**GPC (kg/m^3)**
PPC	340.6	
Flyash		500
Fine aggregate	750.2	600
Coarse aggregate	1277.39	838.3
Sodium silicate solution		239.64
Sodium hydroxide solution		95.86
Water	153.26	

Curing Conditions

The specimens were casted and allowed to set for 24 hours. The specimens were then removed from the moulds and kept wrapped in polythene sheets till testing at ambient temperature.

3.3 Tests and Results

Mechanical Test

The mechanical properties of the geopolymer concrete were tested as per the standard in 28th day. The compressive test was conducted on cubes. The split tensile test was conducted on cylinder specimen after 28 days. The flexure test conducted on prism specimens.

Table 2 Briefly explains the test analysis values at 28 days

Modulus of elasticity

The modulus of elasticity is essentially the measurement of the stiffness of a material. Modulus of elasticity of concrete is a key factor for estimating the deformation of buildings and members, as well as a fundamental factor for determining modular ratio, m, which is used for the design of section of members subjected to flexure. Knowledge of the modulus of elasticity of high strength concrete is very important in avoiding excessive deformation, providing satisfactory serviceability, and for cost-effective designs. Chart-5 shows the average value of modulus of elasticity determined by means of an extensometer as per IS 516 -1959.Refer Table 3

Mix	Compressive Strength, N/mm^2		Split Tensile Strength N/mm^2	Flexural Strength N/mm^2
	Cube	Cylinder		
PPC	37	18	2.9	4.7
GPC	80	40	3.5	6.7

Table 3 Modulus of Elasticity of mix

Mix ID	Binder Composition	Modulus of Elasticity, N/mm^2
M30	PPC	1.8x10^4
GPC	Flyash	2.2x10^4

2.4 *Experimental program of Beam Column joint.*

The prototype of the exterior beam-column joint was scaled down to its one-third size. The dimensions of beam column joint is, column-230mmx120mmx600mm, Beam-120 mm x170mmx 450mm. The specimens in were cast with reinforcement detailed as per IS 456 (BIS, 2000). All the four specimens were tested under constant axial load with cyclic load at the end of the beam.

Casting of Specimens

The two specimens were cast by using the PPC and geopolymer concrete. Medium river sand passing through 4.75 mm IS sieve and having a fineness modulus of 2.76 was used as the fine aggregate. Crushed granite stone of maximum size not exceeding 20 mm and having a fineness modulus of 3.54 was used as the coarse aggregate. The mix proportion for Conventional concrete was 1:2.20:3.75 by weight and the water-cement ratio was kept as 0.45. The mix proportion for geopolymer concrete was 1:1.2:2.46. All the specimens were cast in the horizontal position inside a steel or wooden mould on the same day and demolded 24 hours.

Experimental Setup

The joint assemblages were subjected to the axial load and reverse cyclic loading. The specimens were tested in an upright position and the reverse cyclic loading was applied statically at the end of the beam. One end of the column was given an external hinge support that was fastened to the strong reaction floor, and the other end was laterally restrained. A schematic drawing of the setup is shown in Figure 5. The experimental setup at the laboratory is shown in Figure 6. Past theoretical and experimental studies on the influence of the simultaneous changing of the axial load in the column and lateral displacement in the external beam-column joints indicate that significant deterioration is caused in the joint shear strength by the axial load change and P-Δ effect. In the present study, the application of the axial load was controlled in order to maintain a constant value during the entire testing procedure. The axial load was 10 kN for both CC and GPC. The reverse cyclic load was applied at 20 mm from the free end of the beam portion of the assemblage. The test was load-controlled and the specimen was subjected to an increasing cyclic load up to its failure.

The load and deflection readings were noted for both CC and GPC beam column joint. Further calculations are under process. The ultimate load value for beam column joint:

SPECIMEN	ULTIMATE LOAD
CC	22.5
GPC	39

3. Conclusions

Based on the experimental investigation done the following conclusion can be drawn:

- The split tensile strength of geopolymer concrete is higher than the conventional concrete by 24%.
- The compressive strength of geopolymer is 2.16 times greater than conventional concrete.
- The flexural strength values for geopolymer concrete mixture is higher than conventional concrete by 41%.
- The modulus of elasticity of geopolymer concrete is more than the conventional concrete by 22.22%.
- For any grade of GPC, as ratio of alkaline solution increase, the workability of mix goes on increasing, I adopted 2.5.
- The fly ash can be used to produce geopolymeric binder phase which can bind the aggregate systems consisting of sand and coarse aggregate to form geopolymer concrete (GPC). Therefore, these concrete can be considered as eco-friendly material.

References

[1] Abdul Aleem.M.I and Arumairaj.P.D.(2012). Optimum mix for the geopolymer concrete, Faculty of Sri Ramakrishna Institute of Technology, Coimbatore, India.

[2] Krishnan.L, Karthikeyan.S, Nathiya.S, Suganya.K.2014. Geopolymer concrete an eco-friendly construction material, Faculty of Department of Civil Engineering, Knowledge Institute of Technology, Salem, India.

[3] Madheswaran.C.K,AmbilyP.S,Dattatreya J.K,RameshG.2014.Experimental Studies on Behaviour of Reinforced Geopolymer Concrete Beams Subjected To Monotonic Static Loading, International journal of innovative research in science, Engineering .

[4] Madheswaran. C.K and Pinky Merlin Philip.2014. Experimental and analytical investigations on flexural behaviour of retrofitted reinforced concrete beams with geopolymer concrete composites, International Journal of Material and Mechanical Engineering (IJMME) Volume 3 Issue 3.

[5] Marlene, Jenifer.A, Sunder Kumar.S, DevadassC.S.C.2015. Fracture behaviour of fibre reinforced geopolymer concrete, International Journal of Advanced Technology in Engineering and Science, Volume No 03

[6] Mohamed Aquib Javeed, Veerendra Kumar.M, Narendra.H.2015. Studies on mix design of sustainable geo-polymer concrete, Faculty of M S Ramaiah Institute of Technology,

[7] More pratap kishanrao, 2013, Design of geopolymer concrete, International Journal of Innovative Research in Science, Engineering and Technology Vol. 2.

[8] Rangan, B.V., Wallah, S.E. 2006. Low-calcium fly ash based geopolymer concrete: long term properties. Research report GC-2, Faculty of Engineering, Curtin University of Technology, and Perth, Australia.

[9] Sathia.R, Ganesh Babu, Manu Santhanam. (2008). Durability study of low calcium fly ash geopolymer concrete, Faculty of Indian Institute of Technology Madras, Chennai, India.