

STUDY THE PROPERTIES OF GEOPOLYMER CONCRETE WITH PARTIAL REPLACEMENT OF E-WASTE

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Technology degree in Civil Engineering

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **NITHISHKUMAR.S (37200049)** and **ROHITH.R (37200063)** who carried out the project entitled "Study the properties of geopolymer concrete with partial replacement of e-waste" under our supervision from October 2020 to March 2021.

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DECLARATION

We **NITHISHKUMAR.S** (Reg.No.37200049) and **ROHITH.R** (Reg.No.37200063) hereby declare that the Project Report entitled “Study the properties of geopolymer concrete with partial replacement of e-waste” done by us under the guidance of Mr.Vanjinathan J, at Sathyabama institute of science and technology, Jeppiar nagar, Rajiv Gandhi Salai, Chennai-600119 is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Civil Engineering.

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Abstract

The use of industrial by-products in the construction industry can reduce the impact of pollution on the environment. Geopolymer concrete is a concrete in which Portland cement is completely replaced by fly ash and GGBS (ground granular blast furnace slugs). The present study incorporates the use of E-waste as partial replacement of fine aggregate in Geopolymer concrete. Sand is replaced with E-Waste at 10, 20 and 30 percent. The alkaline liquids used in this study are sodium hydroxide (NaOH) and sodium silicate (Na₂Si₃). The amount of sodium hydroxide (12M) is considered. Fly ash and GGBS were used in combination with 90 and 10 percent, respectively. This study was conducted to find out the compressive and tensile strength of geopolymer concrete with e-waste and to compare it with geopolymer concrete. It turns out that a 20 percent replacement with E-Waste achieved higher strength than M30 grade normal geopolymer concrete.

Keywords: Geopolymer Concrete, Fly Ash, GGBS, Alkaline Solution, E-waste, Mechanical Properties

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CHAPTER-1

INTRODUCTION

1.1 General

Concrete is the most widely used construction material in the world. Ordinary Portland Cement (OPC) has traditionally been used as a binding material for concrete. The creation of OPCs requires the burning of large quantities of fossil fuels and the decomposition of limestone resulting in significant emissions of carbon-dioxide (CO₂) into the atmosphere. This CO₂ emission is the main cause of global warming. To reduce this, the geopolymer technique was introduced. New electrical and electronic products have become an integral part of our daily lives providing us with greater comfort, security, easier and faster acquisition. Due to technological advances, electronic devices have a high rate of obsolescence which is one of the fastest growing waste streams in the world. Life in this waste stream is the end of electrical and electronic equipment products. The European Union (EU) defines this new waste stream as waste electrical and electronic equipment (WEEE). Since there is no definition of WEEE in environmental regulations in India, it is simply called e-waste. E-waste covers a growing range of obsolete electronic devices such as computers, servers, main frames, monitors, TV and display devices, cellular phones, calculators, audio and video devices, printers, scanners, copiers, refrigerators, air conditioners, washing. Machines, microwave ovens, electronic chips, processors, mother boards, printed circuit boards (PCBs), industrial electronics such as sensors, alarms, etc. Electronic and electrical equipment are made up of many components, many of which contain toxins, such as Lead, chromium, mercury, beryllium, cadmium, acid and plastic etc.

Processing of electronic waste in developing countries leads to serious health and pollution problems. Electronic devices have serious pollution like lead, cadmium, beryllium, arsenic, mercury, nickel. Pollutants or toxins in e-waste such as silver, zinc, copper, chrome, cobalt, etc. are usually concentrated in circuit boards, batteries, plastics, and LCDs (liquid crystals). Displays al). This paper deals with the non-hazardous and inert components of e-waste generated from obsolete computers, TV cabins, refrigerators, mobile phones and washing machines etc. The postconsumer components of the above devices have traditionally been dealt with in domestic refuse, which ends. In landfills, was collected in designated collection locations for reuse or recycling. Iron and steel are the most common substances found in electrical and electronic equipment and account for about half of the total weight of WEEE. Plastic is the second largest component of weight, representing about 21 percent of the WEEE. Plastic waste can be used as partial or total replacement of fine aggregate, added to coarse aggregates or as filler material. As many research works was done using E-Waste as a partial replacement for the coarse aggregate. The major objective of this study is to reduce the use and discarded electronic and electrical equipment as far as possible and to make waste socially and industrially beneficial. It is used as a raw material with low cost and environmentally friendly technology.

1.2 GEOPOLYMER CONCRETE

Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement is made using waste materials such as concrete fly ash and ground

granulated blast furnace slag (GGBS). Fly ash is a waste product generated from a thermal power plant and as a ground material blast furnace slag waste material in a steel plant. Both fly ash and GGBS are processed by suitable technology and are used for concrete works as geologic concrete. The use of this concrete helps reduce waste reserves and also reduces carbon emissions by reducing the demand for Portland cement. The main components of the geopolymer source of silicon and aluminium that are provided by thermally activated natural materials (eg , chloride) or industrial biproducts (for example, fly ash or slab) and an alkaline active solution - polymers make these materials molecular chains and Network to build. Rigid binder. It is also called alkali-activated cement or inorganic polymer cement.

1.1 PROPERTIES OF GEOPOLYMER CONCRETE

- The drying shrinkage of is much less compared to cement concrete.
- This makes it well suited for thick and heavily restrained concrete structural members.
- It has low heat of hydration in comparison with cement concrete.
- The fire resistance is considerably better than OPC based concrete.
- This concrete has chloride permeability rating of 'low' to 'very low' as per ASTM 1202C. It offers better protection to reinforcement steel from corrosion as compared to traditional cement concrete.
- This concrete is found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids.

1.2 APPLICATIONS OF GEOPOLYMER CONCRETE

- The applications are same as cement concrete. However, this material has not yet been popularly used for various applications.
- This concrete has been used for construction of pavements, retaining walls, water tanks, precast bridge decks.
- Geopolymer Concrete Building
- Recently world's first building Structural Building, The University of Queensland's Global Change Institute (GCI) has been constructed with the use of geopolymer concrete. It is a four-story high building for public use.

1.3 PROPERTIES OF FLYASH

Fly ash is the residue or non-combustible substance formed after the combustion of lignite or coal in the furnace at a temperature of 1300 degree Celsius. It is removed as slag from the fly of the furnace. The total amount of fly ash and fly ash produced in Neyveli lignite corporation is 3.75 lakh tons per annum (approx.). The fly ash produced is used as Pozzolanic material in cement, fly ash bricks etc. nevertheless the fly ash is being merely deposited in piles which is becoming hazardous to the environment. Sand is one of the major constituents of concrete is diminishing in its quantity around the world, which creates a need for finding an alternative. Fly ash has particle size similar to sand.

1.4 APPLICATION AND USES OF FLY ASH

Coal fly ash is beneficially utilized in a variety of manufacturing and construction applications. Fly ash is predominantly being used for the following applications: -

- Road base and sub-base
- Structural fill / Backfill
- Drainage media
- Aggregate for concrete, asphalt and masonry
- Abrasives/traction
- Manufactured soil products

1.5 PROPERTIES OF GGBS

Granulated blast furnace slag (GGBS) is obtained from the blast furnace in water or steam from molten iron slag (by-products of iron and steel), to dry and fine-tune the ground into fine powder.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

In this chapter, it has been describing about the literature studies of Geo Polymer concrete beams.

2.2 LITERATURE STUDY

Flexural Behavior of Fly Ash Geopolymer Reinforced Concrete Beams (Kumar & Revathi (2016). Asian Journal of Research in Social Sciences and Humanities)

The present work is concerned with the flexible behaviour of fly ash geopolymer to reinforced concrete beams. A total of twelve beams were cast, with six beams controlling the reinforced concrete beam and six beams constructed from fly ash geopolymer reinforced concrete (BAGPRC) beams. The BAGPRC beam was fixed at ambient temperature. The load bearing capacity, load deflection behaviour, initial stiffness, ductility factor and energy absorption capacity of the beam were arrived at and compared to control reinforced cement concrete (RCC) samples. The test results show that BAGPRC performed excellently on the control RCC beam. However, the ductility index and hardness behaviour of the BAGPRC beam with the control index RCC beam were comparable

Comparison of the Flexural Performance and Behaviour of Fly-Ash-Based Geopolymer Concrete Beams Reinforced with CFRP and GFRP Bars (Hemn Qader Ahmed , Dilshad Kakasor Jaf, and Sinan Abdulkhaleq Yaseen-2019)

A construction system with high stability, high durability, and suitable strength can be reinforced by Geopolymer Concrete (GPC) with glass fibre-reinforced polymer (GFRP) bars and carbon fibre-reinforced polymer (CFRP) bars. Some studies deal with a combination of GPC and FRP bars, most notably the CFRP bars. The present investigation presents the flexural capacity and behaviour of fly-ash-based GPC beams reinforced with two different types of FRP bars: six reinforced geophysical concrete (RGPC) beams consisting of three specimens reinforced with GFRP bars and CFRP bars. Are reinforced with. The beam was tested under four point bending with an apparent span of 2000 mm. Test parameters include longitudinal-reinforcement ratio and longitudinal-reinforcement type, including GFRP and CFRP. The methods of ultimate load, first crack load, load-deflection behaviour, load-strain curve, crack width, and failure are studied. The experimental results were compared to the equations recommended by ACI 440.1R-15 and CSA S806-12 for flexural strength and span deflection between beams. The results suggest that reinforcement ratio had a significant effect on ultimate load capacity and failure mode. The ultimate load capacity of CFRPRGPC beams was higher than that of GFRP-RGPC, more cracks were observed in CFRP-RGPC beams than in CFRP-RGPC beams, and crack width was wider than that in GFRP-RGPC beams. In the CFRP-RGPC beam. Beams with a low reinforcement ratio experienced a low number of cracks and a high value of crack width, while beams with a high

reinforcement ratio saw many cracks and a low value of crack width. BEMs with lower reinforcement ratios were more affected by the type of FRP bars, and the deflection in the GFRP-RGPC beam was higher than the CFRP-RGPC beam for the same conformal load level. ACI 440.1R-15 and CSA S806-12 underestimated the flexible strength and mid-term deflection of RGPC beams; However, the CSA S806-12 made more accurate predictions.

Studies on Flexural Behavior of Geopolymer Concrete Beams with GGBS (M. Ratna srinivas, Y. Himath Kumar, B. Sarath Chandra Kumar-2019)

As CO₂ emissions into the atmosphere increase and cause global warming with the production of cement, alternative pozzolanic materials are needed. The alternative pozzolanic material for cement in the production of concrete is GGBS. Geopolymer concrete (GPC) is an alternative material to conventional concrete. Geopolymer concrete is made by mixing GGBS, fine aggregate, coarse aggregate and alkaline activator solution. GGBS is a by-product of the iron industry. This paper shows the results on experimental investigations conducted on reinforced geopolymer concrete beams to find out the flexible behaviour. The alkaline catalytic solution is prepared by sodium hydroxide NaOH and sodium silicate Na₂SiO₃ in a 1: 2.5 ratio. The flexible behaviour of the beam is investigated with different molarities of the NaOH solution. GPC beams are compared to conventional reinforced concrete beams of M40 grade concrete. The type of treatment adopted in the experimental study is ambient. The beam size is 1000 mm × 150 mm × 150 mm. Flexural test capacity is

carried out on a loading frame of 200 tons. The final load, cracking load and maximum deflection and crack pattern are determined and load versus deflection graphs are plotted. This experimental study gives a clear conclusion on the flexible behaviour of conventional reinforced concrete beams and reinforced geo-concrete concrete beams made with GGBS.

Properties of Self Compacting Concrete (SCC) prepared with coarse and fine recycled concrete aggregates (Kou-2009)

Studied the fresh and hard properties of SCC using RCA as both fine and coarse aggregate states. 100% recycled coarse aggregates were used for the replacement of river sands and natural coarse aggregation with different levels of recycled fine aggregates and three aggregates. The cement content was kept constant for all SCC mixtures. W / B ratios of 0.35, 0.40 and 0.44 were used. The experimental results indicated that there was only a slight difference in the properties of SCCs with river sand and crushed fine recycled aggregates. The feasibility of optimally utilizing fine and coarse recycled aggregates with Class F fly ash for unacceptable fly ash and SCC.

Strength behaviour of geopolymer concrete replacing fine aggregates by M- sand and E-waste (Bhupal Reddy Ch-2016).

Geo binder is a permanent binding material that emits no carbon dioxide during treatment and after treatment. The geological contributes more than

65% of the total to the production of concrete. Construction sands called eco-friendly sand materials and cost-effective materials were used as a partial replacement material for fine aggregates by various percentages. Construction sand is typically produced by crushing, screening, and washing a rock to desired shapes and sizes. Electronic waste is one of the hazardous waste materials; It is a non-degrading waste material that causes harmful effects on the environment. Such material is cost effective for processing, other than using this process to degrade it; These electronic materials were partially removed from here in place of finer aggregates, a very expensive technique to degrade from the earth. Polypropylene fibres were used in the concrete to avoid micro cracks and to obtain the closed surface of the concrete which gives good strength. Construction sand and electronic waste were partially cured in 10%, 20%, 30%, 40% and 50%. Mix designs were prepared and cast separately and then tested and then the results were compared with respect to concrete made by conventional geopolymer concrete and replacement materials.

A newly developed self-compacting geopolymer concrete under ambient Condition Sherin Khadeeja Rahman, Riyadh Al-Ameri (November 2020)

The exponential growth of infrastructure has created an urgent need for sustainable building materials with low carbon emissions. Recent studies have explored the suitability of geopolymer concrete as an alternative permanent building material, but the need for high temperatures and chemical activations has hindered widespread application. This study reports on the development

of a novel self-compacting geopolymer concrete using a single alkali catalyst under ambient curing as a new construction material. Eight different concrete mixes with fly ash, slag and micro fly ash were tested for their practicality, mechanical and microstructure properties. Newly developed self-compacting geopolymer concrete with zero cement, zero superplastic cured under ambient conditions achieved 40 MPa after 28 days of curing which is equivalent to an M40 grade conventional concrete.

Evaluation of performances of volcanic-ash-laterite based blended geopolymer concretes: mechanical properties and durability Jordan Valdès Sontia Metekong, Cyriaque Rodrigue Kaze, Juvenal Giogetti Deutou, Paul Venyite, Achile Nana, Elie Kamseu, Uphie Chinje Melo, Thomas Tamo Tatietse (October 2020)

The current project is concerned with the production of alkali active constituents based on volcanic and calcined laterite under different curing temperatures (28–80 ° C). A fraction of 0– 40% calcined laterite was added to improve the reactive phase content and the resulting mixtures were labelled GL0, GL20 and GL40. XRD, FTIR, optical microscopy, mechanical properties and durability were used in raw materials and rigid products. The results showed that both calcined laterite joints (40%) and curing temperatures (28– 80 ° C) have a beneficial effect on mechanical performance. At 28 days, the flexural and compressive strength ranged between 5.05–5.35 MPa and 39.68–48.80 MPa for the GL40 samples. Water absorption and porosity decreased from 7.23 to 4.51% and from 9.70 to 6.01%; 16.70 to 10.32% and 22.20 to 13.80% for the geophysical GL40 and GL20 samples, respectively. Bulk density values were 2398.44 / 2400.16; 2362.46 / 2364.16 and 2338.50 / 2340.20 kg / m for

the GL40 and GL20 samples, respectively. After 19 weeks of sulfuric acid attack ($\text{pH} = 1$), a significant mass loss (1.28–6.22%) was measured in the geopolymer concierge. This behaviour is associated with the construction of a strong and compact matrix. The above-mentioned alkali active constituents appear to be suitable candidates for engineering applications in heterogeneous conditions.

Development of High Performance Sustainable Optimized Fiber Reinforced Geopolymer Concrete and Prediction of Compressive Strength A. Chithambar Ganesh, M. Muthukannan(October 2020)

Geopolymer concrete is a durable construction material that can be used as an alternative to cement concrete. There are several factors that affect the property of geopolymer concrete such as the type of binder material used, the molar and curing conditions of the catalytic solution. The drawback of the practical application of geophysical concrete lies in its brittle nature. The main objective of this work is to reinforce the synthesis of high impact strength fibres that adapt to various factors that affect its strength and reduce its brittleness. The novelty of the work lies in the approach to enhancement of high modulus glass fibre over optimized geopolymer concrete. In the present investigation, extensive experimental work was carried out to optimize the amount of alkaline solution for the use of ground grinded blast furnace slag and glass fibre in geopolymer concrete under different curing conditions. Further microstructural investigations were carried out through scanning electron microscopic analysis and energy dispersive spectroscopy analysis to understand the microstructure of the geopolymer matrix. Exhaustion and carefully discussed parts are included to broaden the effects of curing conditions, the use of ground granulated blast furnace slag, and the incorporation of fibres into the geopolymer matrix. Analytical investigations though artificial neural networks have been performed to estimate the compressive strength of fibre reinforced geopolymer concrete based on three

different input conditions. The study reported optimal molarity of sodium hydroxide as 13M and optimal use of GGBS slag under ambient treatment and 20 percent under heat treatment. Furthermore, the work showed an increase in energy absorption capacity of almost tenfold and significantly reduced the brittleness of geopolymer concrete with the use of glass fibre. This research work can pave the way for the development of high-performance durable geopolymer concrete in ambient curing conditions, which enables the application of geopolymer concrete in the industry to high impact strength materials such as machine foundations, pile caps, spill methods Makes demands. This concrete can pave the way to replace traditional concrete in all its existing applications.

2.3 OBJECTIVE

The main objectives of this project are,

1. Study the effect of geo polymer concrete with fly ash and conventional concrete on the properties of fresh concrete.
2. Study the effect of geo polymer concrete with fly ash and conventional concrete on strength properties of hardened concrete.
3. Study the effect of geo polymer concrete with fly ash and conventional concrete on durability properties of hardened concrete.

2.5 SCOPE

The scopes of this project are,

- I. Characterization of material
- II. Design of concrete mix
- III. Preparation of concrete mixtures of geo polymer concrete with fly ash and conventional concrete
- IV. Casting of specimens
- V. Testing for strength properties of hardened control concrete.

CHAPTER-3

MATERIAL PROPERTIES

3.1 INTRODUCTION

The material testing includes the tests on cement, coarse aggregate and fine aggregate. This chapter includes all these tests and its results and observations.

3.2 DETAILS OF SPECIMEN & NAMING

A total of eight beams were cast, in which four beams were control reinforced concrete beams and four beams were bottom ash

geopolymer reinforced concrete beam. Both beams are arranged in two types of reinforcement are shown in Fig. 4.1. A four-lettered designation is given to the specimens; first two letters represent the nature of concrete whether it is conventional or geopolymer, 3rd and 4th indicate the type of reinforcement. Full details of the specimen's configuration are shown in Table 3.1.

Sl. No	Specimen Designation
1	RCM1
2	GPCM1
3	RCM2
4	GPCM2

Table 3.1 Details of the beam specimens tested

3.3 CEMENT

Ordinary Portland cement of 53 grade [IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement] has been used in the study. It was procured from a single source and stored as per IS: 4032 – 1977. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 12269 – 1987.

Table 3.2 shows the physical characteristics of cement used, tested in accordance with IS: 4031-1988 [Methods of physical tests for hydraulic cement].

**Table: 3.2 Physical properties of Ordinary Portland
cement**

S. No	Property	Test Method	Test Results	IS Standard
1.	Normal Consistency	Vicat Apparatus (IS: 4031 Part - 4)	30%	25-35%.
2.	Specific gravity	Sp. Gr bottle (IS: 4031 Part - 4)	3.09	3.1-3.6
3.	Initial setting time	Vicat Apparatus (IS: 4031 Part - 4)	96 minutes	Not less than 30 minutes.
	Final setting time		207 Minutes	Not less than 10 hours
4.	Fineness	Sieve test on sieve no.9 (IS: 4031 Part – 1)	1.3%	10%
5.	Soundness	Le-Chatlier method (IS: 4031 Part – 3)	2 mm	Not more than 10 mm

3.4 FINE AGGREGATES

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement]. The fine aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test for aggregate for concrete] and is shown in Table 3.3. The sand was surface dried before use.

Table: 3.3 Physical properties of Fine Aggregate

S. No	Property	Method	Fine Aggregate
1.	Specific gravity	Pycnometer IS:2386 Part 3-1986	2.41
2.	Bulk Density Loose Compacted	IS:2386 Part 3-1986	1548kg/m ³ 1680kg/m ³
3.	Bulking	IS:2386 Part 3-1986	6% w c
4.	Flakiness Index	(IS:2386 Part 2-1963)	--
5.	Elongation Index	(IS:2386 Part 2-1963)	--
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.62

3.5 COARSE AGGREGATE

The coarse aggregate was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete and geopolymer concrete. The size of coarse aggregate used in concrete was between 10mm to 16mm. The rounded and smaller aggregate particles provide better flowability and deformability of concrete and also prevent segregation. Graded aggregate is also important particularly to cast concrete in highly congested reinforcement or formwork having small dimensions. The presence of the adhered cement mortar makes Recycled aggregate to yield different physical and mechanical properties than the Normal aggregate. These were tested as per IS 383-1970 [Methods of physical tests for hydraulic cement]. The physical properties like specific gravity, bulk density, flakiness index, and elongation index and fineness modulus are shown in Table 3.4.

Table: 3.4 Physical properties of Normal Coarse Aggregate

S. No	Property	Method	Normal Coarse Aggregate
1.	Specific gravity	Pycnometer IS:2386 Part 3 -1986	2.63
2.	Bulk Density Loose Compacted	IS:2386 Part 3 -1986	1451kg/m ³ 1602kg/m ³
3.	Bulking	IS:2386 Part 3 -1986	--

4.	Flakiness Index	(IS:2386 Part 2 -1963)	8.08%
5.	Elongation Index	(IS:2386 Part 2 -1963)	0%
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	6.04

3.6 WATER

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS: 3025 – 1964 part22, part 23 and IS: 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

3.7 FLY ASH

Fly ash is one of the most extensively used supplementary cementitious materials in the construction field resembling Portland cement. It is an inorganic, noncombustible, finely divided residue collected. Most of the fly ash particles are solid spheres and some particles, called cenosphere's, are hollow and some are the pedosphere's, which are spheres containing smaller spheres inside. The particle sizes in Fly ash vary from less than 1 μm to more than 100 μm with the typical particle size measuring less than 20 μm . Their surface area is typically 300 to 500 m^2/kg , although some Fly ashes can have surface areas as low as 200 m^2/kg and as high as 700 m^2/kg . Fly ash is

primarily silicate glass containing silica, alumina, iron and calcium. The relative density or specific gravity of Fly ash generally ranges between 1.9 and 2.8 and the color is generally grey.

It confirms with grade I of IS: 3812 – 1981 [Specifications for fly ash for use as pozzolana and admixture]. It was tested in accordance with IS: 1727 –1967 [Methods of test for pozzolana materials]. A typical oxide composition of Indian fly ash is shown in Table 3.5. The chemical composition and physical characteristics of Fly ash used in the present investigation were given in Tables 3.6.

Table: 3.5 Typical Oxide Composition of Indian fly ash.

S No	Characteristics	Percentage
1.	Silica, SiO ₂	49-67
2.	Alumina Al ₂ O ₃	16-28
3.	Iron oxide Fe ₂ O ₃	4-10
4.	Lime Ca O	0.7-3.6
5.	Magnesia Mg O	0.3-2.6
6.	Sulphur Trioxide SO ₃	0.1-2.1
7.	Loss on Ignition	0.4-1.9
8.	Surface area m ² /kg	230-600

Table: 3.6 Chemical requirements of fly ash

S No.	Characteristics	Requirements (% by weight)	Fly Ash used (% by weight)
1.	Silicon dioxide (SiO ₂) plus aluminum oxide (Al ₂ O ₃) plus iron oxide (Fe ₂ O ₃)	70 (minimum)	94.46
2.	Silicon dioxide (SiO ₂)	35 (minimum)	62.94
3.	Magnesium Oxide (MgO)	5 (max.)	0.60
4.	Total Sulphur as Sulphur trioxide (SO ₃)	2.75 (max.)	0.23
5.	Availablealkalies as sodium oxide (Na ₂ O)	1.5 (max.)	0.05
6.	Loss on ignition	12 (max.)	0.30
7.	Chlorides		0.009

3.8 ALKALINE SOLUTION

In the present investigation, sodium-based alkaline actuators are used. Single activator either sodium hydroxide or sodium silicate alone is not as effective as has been clearly seen from previous investigations. So, for the activation of fly ash based geopolymer concrete a combination of sodium hydroxide and sodium silicate solution is used. It has been observed that the compressive strength of geopolymer concrete increases with increasing concentrations of sodium hydroxide solution and or sodium silicate solution with increased viscosity of the fresh mixture. In the context of molar (M) sodium hydroxide makes the solids brittle with more compressive strength due to the increase in

concentration of the solution. Secondly, sodium hydroxide solids cost more and the preparation is very caustic. Similarly, to achieve the desired degree, additional water is required which ultimately decreases the concentration of sodium hydroxide solution. So, the concentration of sodium hydroxide was maintained at 13 M, while Na₂O of 16.37%, SiO₂ of 34.35% and 49.72% H₂O in the concentration of sodium silicate solution are used as alkaline solutions. Similarly, the sodium silicate-to-sodium hydroxide ratio by mass was maintained at least 1 which sets the cubes within 24 hours after casting and gives fairly good results of compressive strength. These solutions were. These solutions were purchased from the local supplier.



Fig 3.1 NaOH

3.9 SUPER PLASTICIZER

Used to reduce high-grade water mixtures called super plasticizers, which are used to improve flow or work efficiency, at least for the water-cement ratio. These mixtures when dispersed in cement agglomerates significantly reduce the viscosity of the paste by forming a thin film around the cement particles. In the present work, the water reducing mixture conforms to Glenium IS 9103: 1999 [Specification of Mixtures for Concrete], ASTM C - 494 [Standard Specification for Chemical Mixtures for

Concrete] Types F, G and BS 5075 part .3 [British Standards Institute] was used. The details of the super plasticizers used are given in Table 3.7.

Table: 3.7 Details of Super Plasticizer

S. No.	Property	Result
1.	Form or state	Liquid (sulphonated naphthalene-based formaldehyde)
2.	Color	Brown
3.	Specific gravity	1.220 to 1.225 at 30°C
4.	Chloride content	Nil to IS:456
5.	Air entrainment	Approx. 1% additional air is entrained
6.	Compatibility	Can be used with all types of cements except high alumina cement. Conplast SP430 is compatible with other types of Fosroc admixtures when added separately to the mix.
7.	Workability	Can be used to produce flowing concrete that requires no compaction.
8.	Cohesion	Cohesion is improved due to dispersion of cement particles thus minimizing segregation and improving surface finish.
9.	Compressive strength	Early strength is increased up to 20%. Generally, there is improvement in strength up to 20% depending upon W/C ratio and other mix parameters.
10.	Durability	Reduction in w/c ratio enables increase in density and impermeability thus enhancing durability of concrete
11.	Dosage	The rate of addition is generally in the

		range of 0.5 - 2.0 liters /100 kg cement.
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3.10 MIX DESIGN

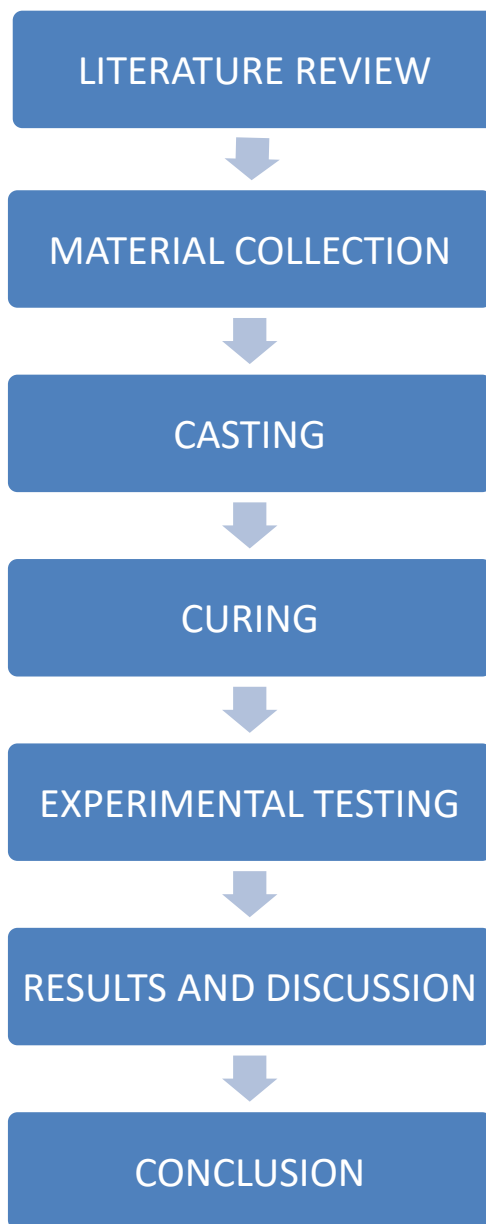
Mix design can be defined as the process of selecting suitable components of concrete and determining their relative proportions with the objective of producing concrete as economically as possible with minimum strength and durability. Mix design is done as per Indian Standards: 10262-2009 for both conventional and geophysical concrete.

3.11 PREPARATION OF SPECIMENS

Preparation of geopolymer concrete is similar to cement concrete. Coarse aggregates, sand and fly ash were added to the dry state. Then dissolve the prepared mixture of sodium hydroxide and sodium silicate with additional water, based on the water – geopolymer binder ratio, and mix well for 3 to 4 minutes to give a homogeneous mixture. It was found that the fresh fly ash based geomorphic solid was viscous, viscous and dark in colour. After making homogeneous mixtures, the workability of fresh geopolymer concrete according to IS 5512–1983 and IS 1727–1967 was measured by flow table mechanism. 150 mm edge concrete cubes are poured into three layers. Each layer is well compacted by rods of diameter 16 mm. All the cubes were placed on a table vibrator and vibrated for 2 minutes for proper condensation of the concrete. After the compaction of the concrete, the top surface was levelled using a trowel. After 24 hours of casting, all the cubes were removed and then placed for treatment in laboratory ambient condition.

3.12 METHODOLOGY

It describes about the work flow of the project as follow



CHAPTER 4

MIX DESIGN

4.1 INTRODUCTION

Mix design is done as per the Indian standards IS: 10262-2009 for both conventional and geopolymer concrete.

4.2 MIX DESIGN FOR M₃₀ GRADE CONCRETE

SPECIFICATIONS FOR MIX DESIGN

Grade of cement	: OPC53
Type of exposure	: Medium
Size of coarse aggregate	: 20 mm
Specific gravity of cement	: 3.15
Specific gravity of Fine aggregate	: 2.54
Specific gravity of coarse aggregate	: 2.85

(i) Target strength for mix proportion

The target mean compressive strength at 28 days is given by

$$f'_{ck} = f_{ck} + 1.65S$$

From IS 10262:2000 S = 5 N/mm² (S – Standard Deviation)

$$\begin{aligned} f'_{ck} &= 30 + (1.65 \times 4) \\ &= 36.6 \text{ N/mm}^2 \end{aligned}$$

(ii) Selection of water cement ratio

From IS456:2000 table 5

Exposure condition: Moderate

W/C ratio = 0.4

Maximum water cement ratio = 0.5

Adopt 0.45

$0.45 < 0.5$ (hence ok)

(iii) Selection of water content

From IS10262:2009 tables 2

Aggregate size = 20 mm = 186 liters (25 - 50mm slump)
From IS456 - Page 17

Reinforced wall-medium (slump 50 - 100, 75 - 100)

Adopt 75mm (slump)

Estimated water content for 100mm slump

$$= 186 + ((3/100) \times 186)$$

$$= 191.58 \text{ litres}$$

(iv) Cement content

W/C ratio = 0.45

Cement content = $186/0.45$

$$= 413.4 \text{ Kg/m}^3$$

IS 456:2000 Table 5,

Minimum cement content = 360 Kg/m^3

From IS 456:2000 cl.8.2.4.2

Cement content is limited to 450 Kg/m^3

$$\begin{aligned} \text{Cement content} &= 360 \text{ Kg/m}^3 < 413.4 \text{ Kg/m}^3 < 450 \\ &\text{Kg/m}^3 \end{aligned}$$

(v) Proportion of volume of coarse aggregate and fine aggregate content

From IS10262:2009 tables 3

- Volume of coarse aggregate corresponding to 20 mm size and fine aggregate (zone II) for water cement ratio of 0.5 = 0.60.
- In the present work water cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.05 the proportion of volume of coarse aggregate is increased by 0.01(at the rate of ± 0.01 for every ± 0.05 change in water cement ratio).
- Therefore, correct proportion of volume of coarse aggregate for the water cement ratio of 0.4 = 0.5.
- Volume of coarse aggregate for water cement ratio of 0.4 = 0.5
- Proportion of volume of FA = $1 - 0.5 = 0.5$

(vi) Mix calculation

a) Volume of concrete = 1 m^3

b) Volume of cement

$$\begin{aligned} &= \frac{\text{Mass of cement}}{(\text{sp. gravity of cement}) \times (\text{density of cement})} \\ &= 413.4 / (3.15 \times 1000) \\ &= 0.1314 \text{ m}^3 \end{aligned}$$

c) Volume of water

$$\begin{aligned} &= \frac{\text{Mass of water}}{(\text{sp. gravity of water}) \times (\text{density of water})} \\ &= 191.58 / (1 \times 1000) \end{aligned}$$

$$= 0.192 \text{ m}^3$$

d) Volume of all in aggregate $= a - (b + c)$

$$= 1 - (0.1314 + 0.192)$$

$$= 0.6766 \text{ m}^3$$

e) Mass of coarse aggregate $= e \times \text{Volume of coarse aggregate} \times \text{Specific gravity of coarse aggregate} \times 1000$

$$= 0.6766 \times 0.5 \times 2.85 \times 1000$$

$$= 964.2 \text{ kg.}$$

$= e \times \text{volume of fine aggregate} \times \text{Specific gravity of fine aggregate} \times 1000$

$$= 0.6766 \times 0.5 \times 2.54 \times 1000$$

$$= 859.3 \text{ kg.}$$

MIX DETAILS

The mix proportion chosen for this study is 1:1.89:3.0 with water/cement ratio of 0.4 shown in table M₃₀ concrete are used.

Water	Cement	Fine aggregate	Coarse aggregate
192	413 kg/m ³	859.3 kg/m ³	964.2 kg/m ³
0.4	1	2.0	2.5

Table 4.1 Mix proportion of concrete

4.3. MIX DESIGN OF FLY ASH BASED GEOPOLYMER CONCRETE

(i) Target strength for mix proportion

The target mean compressive strength at 28 days is given by

$$f'_{ck} = f_{ck} + 1.65S$$

From IS 10262:2000 $S = 5 \text{ N/mm}^2$ (S – Standard Deviation)

$$f'_{ck} = 30 + (1.65 \times 4)$$

$$= 36.6 \text{ N/mm}^2$$

ii) Selection of Quantity of Fly Ash

The quantity of fly ash required is 405 kg/m³ for the target mean strength of 36.6MPa at solution-to-fly ash ratio of 0.35 and for 430 m²/kg fineness of fly ash. (From previous literature)

(iii) Calculation of the quantity of alkaline activators

Calculate the quantity of alkaline activators considering:

Solution=fly ash ratio by mass = 0.35

i: e: Mass of (Na₂SiO₃+ NaOH)/fly ash = 0.35

Mass of (Na₂SiO₃+ NaOH)/405= 0.35

Mass of (Na₂SiO₃+ NaOH) =141.7kg/m³

IV) Calculation of total solid content in alkaline solution

Solid content in sodium silicate solution = (50.32/100) x 70.88

$$= 35.67 \text{ kg/m}^3$$

Solid content in sodium hydroxide solution = (38.20/100) x 70.88

$$= 27.29 \text{ kg/m}^3$$

Total Solid content in both alkaline solutions = 62.96 kg/m³

v). Selection of water content

For medium degree of workability and fineness of fly ash of 430m²/kg, water content per cubic meter of geopolymer concrete is selected from Table 2 Water content = 110 kg/m³

vi. Adjustment in water content

For sand conforming to grading-I, correction in water content is taken from Table 3

Adjustment in water content = -1.5%

$$\begin{aligned}\text{Total quantity of water required} &= 110 - (1.5/100) \times 110 \\ &= 108.35 \text{ kg/m}^3\end{aligned}$$

$$\begin{aligned}\text{Water content in alkaline solutions} &= 141.75 - 62.96 \\ &= 78.79 \text{ kg/m}^3\end{aligned}$$

vii. Calculation of additional quantity of water

$$\begin{aligned}&= [\text{Total quantity of water}] - [\text{Water present in alkaline solutions}] \\ &= 108.35 - 78.79 = 29.46 \text{ kg/m}^3\end{aligned}$$

viii. Selection of wet density of geopolymer concrete

Wet density of geopolymer concrete is 2,528 kg/m³ for the fineness of fly ash of 430 m²/kg

ix. Selection of fine-to-total aggregate content

Fine-to-total aggregate content is 35% for fineness modulus of sand of 3.35

x. Calculation of fine and coarse aggregate content

Total aggregate content = [Wet density of GPC] - [Quantity of fly ash]

+Quantity of both solutions + extra water, if any]

$$= 2528 - [405 + 141.75 + 29.46]$$

$$= 1951.79 \text{ kg/m}^3$$

Sand content = [Fine to total aggregate content in %] x [Total quantity of

All-in-aggregate]

$$= (35/100) \times 1951.79$$

$$= 683.13 \text{ kg/m}^3$$

Coarse aggregate content = [Total quantity of all-in-aggregate]-
[Sand content]

$$= 1951.79 - 683.13$$

$$= 1268.66 \text{ kg/m}^3$$

Quantity of materials required per cubic meter for M30 grade of geopolymer.

Concrete is shown in below Table.

Ingredients of geopolymer concrete	Fly ash	NaOH	Na ₂ SiO ₃	Sand	Coarse aggregate	Total water (W/GPB)
Quantity (kg/m ³)	405	70.88	70.88	683.13	1268.66	108.35
Proportion	1	0.35		1.82	3.37	0.211

CHAPTER 5

EXPERIMENTAL INVESTIGATION

5.1 INTRODUCTION

This chapter presents the details of experimental investigations carried out on the test specimens to study the strength characteristics of beam in different concrete. Tests are performed on test models to determine strength-related properties such as cube compressive strength, cylinder split tensile strength, prism flexural strength and RC beam flexural strength. Three samples are tested, and an average of each compound is reported for each test. All tests are conducted according to Indian standards. The optimum percentage has come based on the strength test results of the cube and cylinders. After 7, 14 & 28 days of curing, the samples are tested for compression, tensile strength and flexural strength.

5.2 test on Fresh Concrete

Fresh concrete or plastic concrete is freshly mixed material that can be moulded into any shape. The strength of concrete depends mainly on the

strength of the material paste. In other words, the cement content increases the strength of the paste and decreases the amount of air and water. The Abrams W / C ratio law states that the strength of concrete is dependent only on the W / C ratio required from the standpoint of workability.

100% compaction of concrete will result in voids, whose deleterious effect on strength and durability is the same or more potent than the presence of capillary cavities. In order to enable concrete to be fully compacted with the given efforts, a greater w / c ratio may be required than is normally calculated by theoretical considerations.

5.1.1 Slump Test

Recession testing is the most well-known and widely used test method to characterize the practicality of fresh solids. Inexpensive testing, which measures stability, is increasingly used at job sites to determine whether concrete should be accepted or rejected. The test method is widely standardized worldwide.

The slump test is not considered applicable for concrete with a maximum coarse aggregate of sizes greater than 1.5 inches. For concrete with more than 1 inch in aggregate size, such large particles can be removed by wet sieving. Additional qualitative information on the dynamics of fresh concrete can be obtained after reading the deceleration measurement. Slabs with the same slump may exhibit different behaviour when manipulated by a rodding rod. A hardened concrete, with some fines, will collapse when broken, which will only be suitable for applications such as pavement or large-scale concrete. Alternatively, concrete can be very homogeneous when tempered

thus suitable for difficult placement conditions. This is a site test to determine the workability of the finished composite concrete before being placed in the final position inside the formwork and always carried out by the supervisor on site and always conducted by supervisor on the site.



Fig:5.1 Slump Specimen

5.2 PREPARATION OF TEST SPECIMEN

The preparation of test specimen including sampling of materials, preparation of materials, proportioning, weighting, testing for workability, choice of size of test specimens, compacting, and capping of specimen shall be in accordance with IS: 516-1959*, if test is intended to draw correlation curve between the results from compressive strength tests on specimens cures by normal curing method and accelerated curing. If the test is intended for control purposes, sampling shall be done in accordance with IS: 1199-1959* and choice of the size of the test specimens, compacting and capping of specimen shall be done the size of the test specimens, compacting and capping of specimen

shall be done in accordance with IS: 516-1959*, immediately after molding, each specimen shall be covered with a steel mold thinly coated with oil to prevent adhesion of concrete.

Threat and extent of hydration of cement under a particular curing regime depend mainly upon the chemical composition of cement, water cement ratio and mix proportions, which are considerable to be important parameters in the correlation of results from compressive strength test on specimens cured by normal curing method.

5.3 TESTS ON HARDENED CONCRETE

For testing concrete in hardened state, it is required to cast various moulds like cubes, cylinders and beams. It is cured for the required period after 24hrs of casting

5.3.1 Introduction About Hardened Concrete

Compressive strength of hardened concrete is most important parameter and representative of overall quality of concrete. It is mainly depended upon water cement ratio of the mix and curing and age after it is casted. Compressive strength of concrete is determined by testing cubical specimens using compressive strength testing machine at various ages such as 3days, 7days and 28 days.

Tensile strength of concrete is found to be proportional to its compressive strength. It is determined either using flexure test or using slit cylinder test on cylindrical specimens. Although the tensile strength of concrete is of no practical relevance, it is determined to show how a brittle material like concrete has very low tensile strength as compared to its compressive strength.

Modulus of elasticity is yet another very important property of hardened concrete. It is obtained through testing cylindrical specimens. The stress applied and resulting deformation in the specimens are plotted and then stress strain curve, the modulus of elasticity is determined. Modulus of elasticity test on concrete is required for calculating deflection and predicting shrinkage cracking.

5.3.2 Compressive Strength Test:

Out of many tests applied to the concrete, this is the most important test which gives an idea about all the characteristics of concrete. By this single test one can judge that concrete is has done properly or not. For cube tests 2types of specimens are either 15cm*15cm*15cm or 10cm*10cm*10cm depending on the size of aggregate are used. For most of the works cubical molds of size 15cm*15cm*15cm are commonly used.

The concrete is poured in the mold and tamed properly so as not to have any voids. After 24 hours these molds are removed and test specimens are put into water for curing. The upper of mold is rough hence can be deceptive while showing results. Hence, the surface is made smooth with cement paste on specimen.

These specimens are tests by compression testing machine after 7days or 28 days of curing. Load should be applied gradually at a rate of 14kg/cm² per minute till the specimen fails. Load at failure divided by area of specimen gives the compressive strength of concrete.

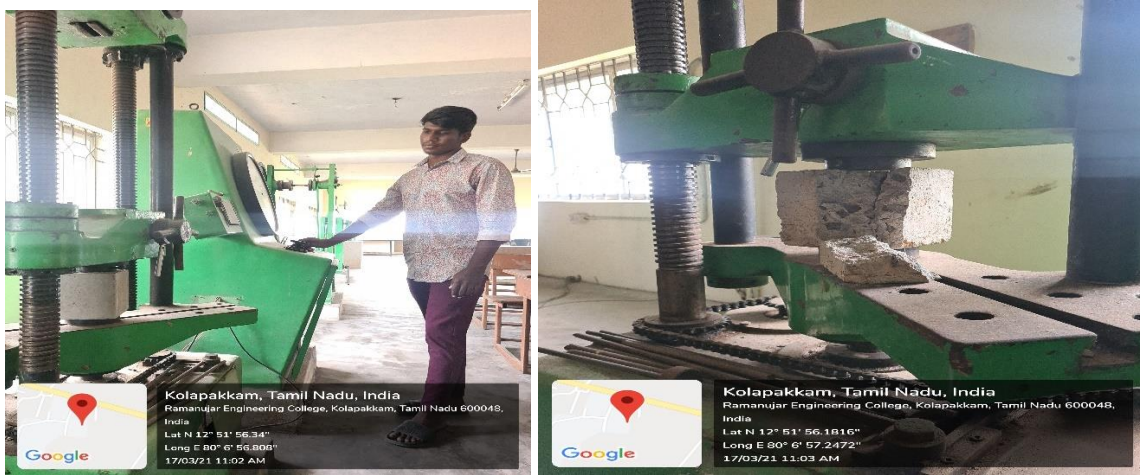


Fig 5.2 Compressive Strength Test

5.3.3 Tensile Strength Test of Concrete

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

$$\text{Horizontal tensile stress} = \frac{2P}{\pi D L}$$

Where,

P= Compressive load on the cylinder.

L= Length of cylinder.

D= Diameter of cylinder.



Fig: 5.3 Tensile Strength Test of Concrete

5.4.4 Flexural Strength Test of Concrete

Standard beam test (Modulus of rupture) was carried out on the beams of size 100 mm x 100 mm x 500 mm as per IS: 516 [Method of test for strength of concrete], by considering that material is homogeneous. The beams were tested on a span of 400 mm for 100 mm specimen by applying two equal loads placed at third points. To get these loads, a central point load has applied on a beam supported on steel rollers placed at third point as shown in Fig.3.9. The rate of loading is 1.8 kN/minute for 100 mm specimens and the load was increased until the beam failed. Depending on the type of failure, appearance of fracture and fracture load, the flexural tensile strength of the sample was estimated.

As explained earlier, in the present investigation, the flexural strength test has been conducted on concretes with different type of coarse aggregate M30 grade of concrete at 7 and 28 days.

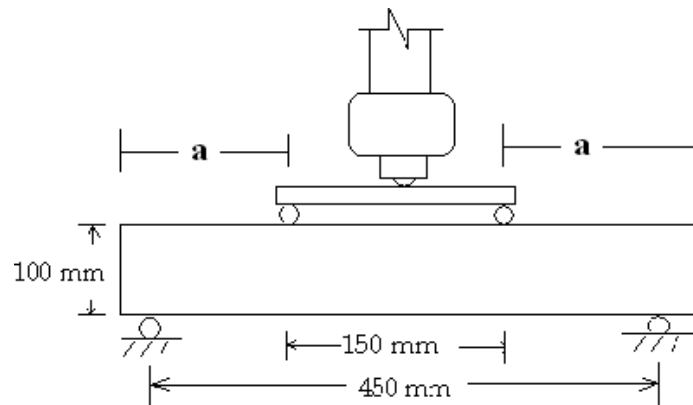


Fig.5.4 Schematic diagram for flexure test setup

If 'a' be the distance between the line of fracture and the nearer support, then for finding the modulus of rupture, these cases should be considered.

i. When $a > 133$ mm for 100 mm specimen

$f_{cr} = PL/bd^2$, where P = total load applied on the beam

ii. When $110 \text{ mm} < a < 133 \text{ mm}$, $f_{cr} = 3Pa/bd^2$

iii. When $a < 110$ mm, the result should be discarded.



Fig 5.5 Flexural strength testing machine

5.4.5 RC Beam Test

A total of six beams were cast, in which two beams were control reinforced concrete beams and two beams were bottom ash geopolymer reinforced concrete with bottom ash beam. Both beams are two different reinforcement arrangements. The beams were considered as simply supported and two-point static loading was applied. The effective span of the beam measurement is 1200 mm. This beam load was tested by hydraulic jack and deviation was measured by load cell. Fig. 2.5 shows the experimental set up of simply supported beams subjected to monotonic loading. The load was increased till the failure of the specimen occurs. Then, the deflections at mid-span by LVDT were noted.

The beams were assumed to be simply supported, and two-point fixed loading was used. The effective spacing of the beam measurement is 1200 mm. This beam load was tested with a hydraulic jack and the deflection was measured by the load cell. Figure 2.5 shows the test structure of simply supported beams subject to monotonic loading. The load was increased until the model failed. Then, the deflections at mid-span by LVDT were noted.

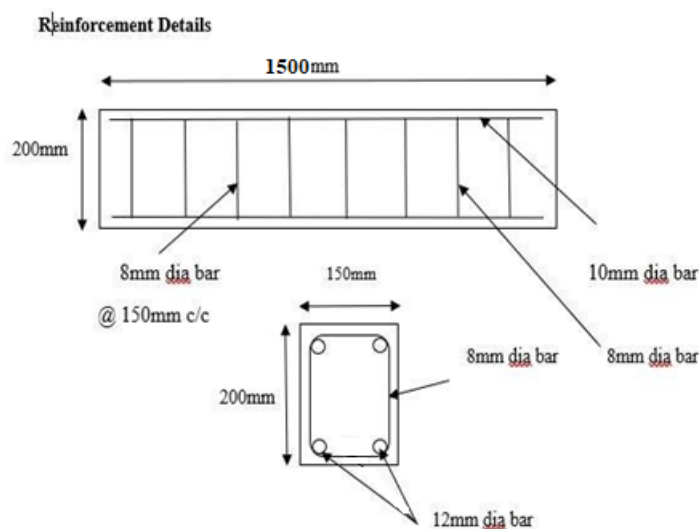
Specimen details:

Model: 1

Main reinforcement = 2 number of 12mm

Dia bars Stirrups = 8 mm dia bars @ 150mm c/c

Specimen dimension: 150mmx200mmx1500mm



Model: 2

Main reinforcement = 3 number of 12mm

Dia bars Stirrups = 8 mm dia bars @ 150mm c/c

Specimen dimension: 150mmx200mmx1500mm

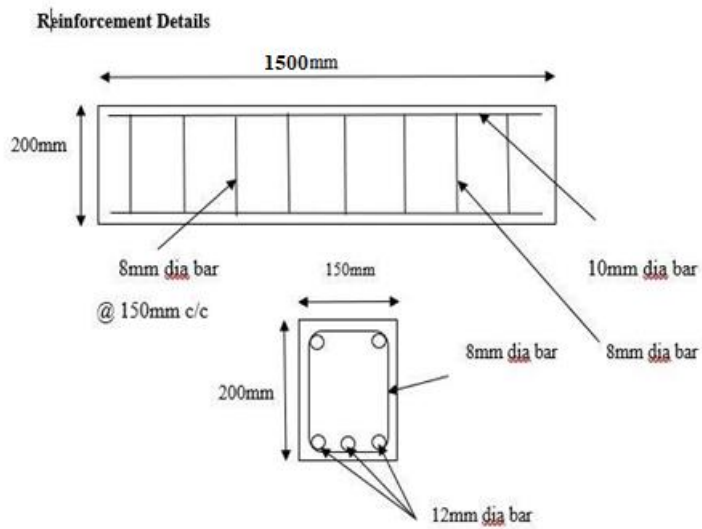


Fig. 5.6 Reinforcement Details



Fig. 5.7 RC Beam Test Setup

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 INTRODUCTION

Numerical simulation and experimental investigation analysis is carried out considering different concrete property on the beam to determine its structural performance. The results of the parameter study are discussed here.

6.2 EXPERIMENTAL RESULTS

6.2.1 Compressive strength

The results of the mechanical properties (according to IS: 516) obtained on the basis of the samples tested according to Indian standard testing procedures are discussed. M30 grade conventional and geo polymer concrete with fly ash are trial variables with their three different age cures. Details of the compressive strengths of the M30 standard are shown in Table 7.2.

Mix Type	7 Days N/mm²	21 Days N/mm²	28 Days N/mm²
RC-Mix	20.1	27.335	31.82
GPC-Mix	22.75	31.50	35.14

Table: 6.1 Compressive strength of M30 grade

From the table it is observed that rate of gain in Compressive strength is more at 28 days compared to 21 days.

6.2.2 Split tensile strength

The splitting tensile strength is presented. For a mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 7.3.

Mix Type	7 Days N/mm ²	21 Days N/mm ²	28 Days N/mm ²
RC-Mix	2.75	3.91	4.46
GPC-Mix	3.2	4.48	5.21

Table: 6.2 splitting tensile strength of M30 grade

From the table it is observed that rate of gain in splitting tensile strength is more at 28 days compared to 21 days.

6.2.3 Flexural strength

The Flexural strength is presented. For a mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 7.4.

Mix Type	7 Days N/mm ²	21 Days N/mm ²	28 Days N/mm ²
RC-Mix	2.6	3.62	4.11
GPC-Mix	3.01	4.21	4.83

Table: 6.3 Flexural strength of M30 grade

From the figure it is observed that rate of gain in Flexural strength is more at 28 days compared to 21 days.

6.2.4 RC Beam

The beam is subjected two-point loading after 28 days of curing. Three LVDTs were placed two-point loading support and below the middle. For every 4kN, three deflection values were noted. The first crack load for Model-I conventional beams was 36.5 kN and the geo polymer concrete with fly ash beam was 57.65 kN, which was higher than the first crack load for conventional beams. And first crack load for Model-II conventional beams was 66.5 kN and the geo polymer concrete with fly ash beam was 72 kN, which was higher than the first crack load for conventional beams.

This clearly shows that conventional beam strength for concrete does not contribute greatly to development. As the load increased, hair cracks appeared at the base of the beam and moved toward the top of the beam. A comparison of the first crack load and the final load for the beams is shown in Figure 7.7.

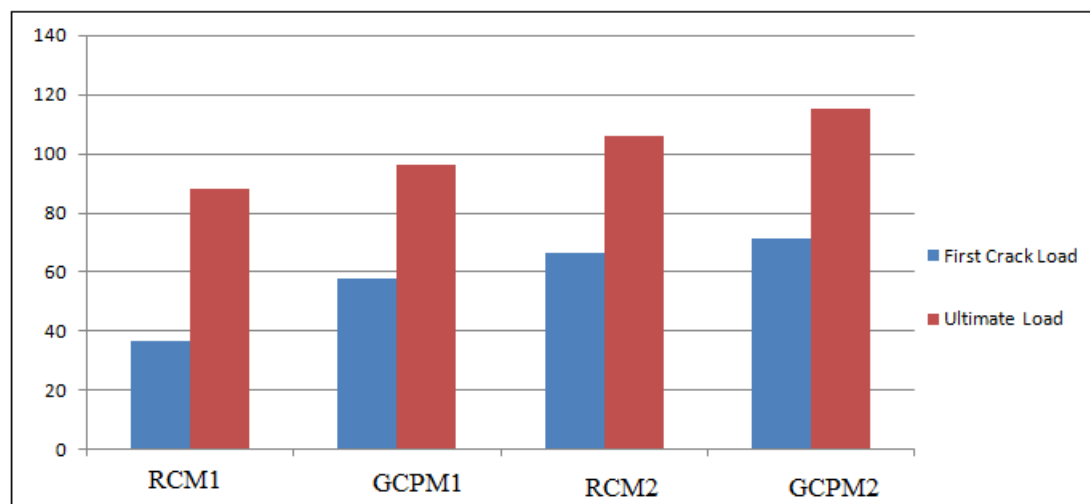


Figure6.1 Comparisons of First Crack Load and Ultimate Load

6.2.5 LOAD-DEFLECTION BEHAVIOUR:

The load – deflection curve for all the beams were plotted. The comparisons of load-deflection curve for the conventional, geopolymers with fly ash beam was shown in figure 7.8. The deflection values of conventional beam were larger compared to other beams. The result clearly indicates that increasing the reinforcement in RCM2 and GPCM2 increases the load carrying capacity and deflection when compared to RCM1, GPCM1. In fact, the load deflection behavior of GPC was improved than RCC.

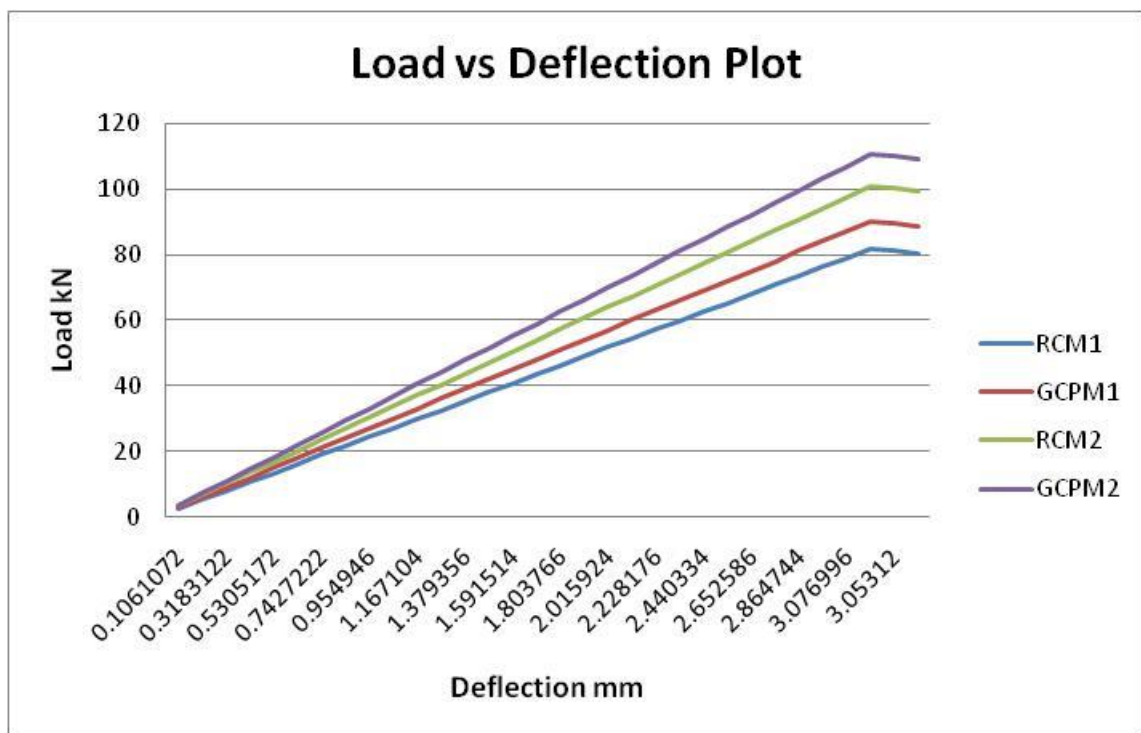


Fig. 6.2 Load Vs Deflection Curve for all Beams
(Experimental Result)

CHAPTER 7

CONCLUSION

The Geopolymer mix planned for this study with replacement of E-Waste found possible and economical. In this study the cement is fully replaced by industrial by-products fly ash and GGBS. The following observations were made from the present study.

- Geopolymer concrete with E-Waste gives high compressive and tensile strength than conventional Geopolymer concrete.
- Compressive and split tensile strength of Geopolymer concrete with E-Waste gives 14.75 and 6.5 percent increases compared to conventional Geopolymer concrete.
- Increase in E-waste as fine aggregate reduces the strength of concrete beyond 20 percent of replacement.
- SEM analysis test has been proved that Geopolymer concrete with E-waste has better surface configuration when compared with conventional Geopolymer concrete.
- Usage of E-waste in concrete will reduce the environmental pollution and helps to protect the environment in some extent.

CHAPTER 8

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