STUDY OF PROPERTIES OF FLY ASH BASED GEOPOLYMER CONCRETE

A major project report submitted in the partial fulfillment of the requirement for the award

of the Degree of
Master of Technology

In
Structural Engineering

Submitted By

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DECLARATION

I hereby declare that the work presented in this minor project report entitled **"STUDY OF PROPERTIES OF FLY ASH BASED GEOPOLYMER CONCRETE"** is original and has been carried out by me in the partial fulfillment of the requirement for the award of the Master of Technology in Structural Engineering in the Department of Civil Engineering, Delhi Technological University, Delhi – 110042, under the supervision of **Prof. Nirendra Dev**, Professor, Faculty of structural engineering, Department of Civil Engineering. This report is contribution of my original research work. Wherever research contributions of others are involved, effort has been made to cite that in text. To the best of my knowledge, this research work has not been submitted in part or full for the award of any degree or diploma of Delhi Technological University or any other University/Institution.

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CERTIFICATE

This is to certify that the work presented in this minor project report entitled **"STUDY OF PROPERTIES OF FLY ASH BASED GEOPOLYMER CONCRETE**" has been submitted to the Delhi Technological University, Delhi-110042, in fulfilment for the requirement for the award of the degree of **M.Tech. in Structural Engineering** by the candidate **Mr. Shashank Chaudhary (2K17/STE/19)** under the supervision of **Prof. Nirendra Dev,** Professor, Faculty of, Structural Engineering, Department of Civil Engineering. It is further certified that the work embodied in this report has neither partially nor fully submitted to any other university or institution for the award of any degree or diploma.

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ABSTRACT

The serious issue the world is confronting today is the natural contamination. In the construction industry basically the creation of Portland cement will causes the emanation of toxins brings about natural contamination, like emission of CO_2 gas. By using the industrial by products in construction industry we can reduce effect of pollution on environment. . Geopolymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with fly ash and the fine aggregate is replaced with quarry dust and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3). 13M, molarity sodium hydroxide is used in this work. The cube specimens are taken of size 150mm x 150mm x 150mm.The Geopolymer concrete specimens are tested for their compressive strength at the age of 28 days. Cylindrical concrete specimen are prepared of test of modulus of elasticity and possion's ratio of Geopolymer concrete. Ambient and oven curing are used for it, and compare the result of both. Varying fly ash/ slag ratio are used and results are compared.

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CHAPTER 1

INTRODUCTION

1.1GENERAL

For the development of any structure, Concrete is the principle material. Solid use the world over is second just to water. The primary fixing to deliver cement is Portland bond. On the opposite side an unnatural weather change and natural contamination are the greatest danger to humankind on earth today. The creation of concrete methods the generation of contamination in view of the discharge of CO2 during its creation. There are two distinct wellsprings of CO2 emanation during bond generation. Ignition of petroleum products to work the rotational furnace is the biggest source and other one is the concoction procedure of calcining limestone into lime in the bond oven additionally creates CO2.In India around 2,069,738 a large number of metric huge amounts of CO2 is discharged in the time of 2010. The bond business contributes about 5% of absolute worldwide carbon dioxide outflows. And furthermore, the bond is made by utilizing the crude materials, for example, lime stone, earth and different minerals. Quarrying of these crude materials is additionally causes natural corruption. To deliver 1 ton of concrete, about 1.6 huge amounts of crude materials are required and the time taken to frame the lime stone is any longer than the rate at which people use it. Be that as it may, the interest of cement is expanding step by step for its simplicity of getting ready and manufacturing in a wide range of advantageous shapes. So to beat this issue, the solid to be utilized ought to be natural agreeable.

In India the contribution of Coal-based thermal power is about 65% of the total installed capacity for electricity generation. In order to meet the growing energy demand of the country, coal-based thermal power generation is expected to play a dominant role in the future as well, since coal reserves in India are expected to last for more than 100 years. The ash content of coal used by thermal power plants in India varies between 25 and 45%. However, coal with an ash content material of round 40% is predominantly utilized in India for thermal energy technology. As a consequence, very large amount of fly ash (FA) is generated in thermal power plants, causing several disposal-related problems In spite of initiatives taken by the government, several N.G.O’s and research and development organizations, the total utilization of FA is only about 50%. India produces 130 million ton of FA annually which is expected to reach 175 million ton by 2012 and may exceed 225 million tons by 2017. Disposal of FA is a growing trouble as only 15% of FA is presently used for high cost addition packages like concrete and constructing blocks, the rest getting used for land filling. Flyash utilized around the World is less than 25% of the total annual FA produced . FA has been successfully used as a mineral admixture component of Portland cement for nearly 60 years. There is effective utilization of flyash is used in making cement concretes as it extends technical advantages as well as controls the environmental pollution (Vijai 2006).

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. It is a glassy, granular, non metallic material consisting essentially of silicates and aluminates of calcium. It has almost the same particle size as cement. Ground granulated blast furnace slag (GGBS), often blended with Portland cement as low cost filler, increases concrete workability, density, durability and resistance to alkali-silica reaction.

Elective utility of FA and GGBS in development industry that has risen lately is as Geopolymer cement (GPC), which by proper process innovation use all classes and grades of FA and GGBS, in this way there is an awesome potential for diminishing stockpiles of these waste materials. Geopolymer concrete (GPC) are inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing or supplementing the conventional concretes. GPC have high strength, with good resistance to chloride penetration, acid attack, etc. Those are typically formed by means of alkali activation of industrial alumino-silicate waste substances which includes FA and GGBS, and feature a totally small Greenhouse footprint whilst as compared to traditional concretes

The expression "geopolymer" was first acquainted by Davidovits in 1978 with portray a group of mineral fasteners with concoction organization like zeolites however with a formless microstructure. Not at all like conventional Portland bonds, geopolymers don't shape calcium-silicate - hydrates for framework development and quality, however use the polycondensation of silica and alumina forerunners to accomplish basic quality. Two principle constituents of geopolymers are source materials and antacid fluids. The source materials on alumino-silicate ought to be wealthy in silicon (Si) and aluminum (Al). They could be result materials, for example, fly fiery remains, silica seethe, slag, rice-husk cinder, red mud, and so on.

Geopolymers are additionally one of a kind in contrast with other alumino-silicate materials (for example alumino-silicate gels, glasses, and zeolites) (Davidovits 1978).

The geopolymer innovation may lessen the all out vitality interest for delivering solid, bring down the CO2 emanation to the environment brought about by concrete and totals businesses by about 80%, in this way diminishing the an Earth-wide temperature boost. They have the advantages of fast power gain, expulsion of water restoring, appropriate mechanical and sturdiness properties and can fill in as eco-accommodating and feasible chance to customary Portland bond cements (Thokchom et al., may 2006).

1.2 NEED OF GEOPOLYMER CONCRETE

To deliver natural amicable solid, we need to supplant the concrete with some different covers which ought not make any terrible impact on condition. The utilization of modern results as folios can diminish the issue. In this regard, the new innovation geo-polymer cement is a promising strategy. As far as lessening the an unnatural weather change, the geo-polymer innovation could decrease the CO2 emanation to the environment brought about by concrete and totals businesses by about 80% (Davidovits, 1994c). And furthermore the best possible utilization of mechanical squanders can decrease the issue of arranging the waste items into the air.

1.3 AIM OF THE RESEARCH

As referenced before, the majority of the distributed research on geopolymers examined the conduct of glues utilizing different kinds of source materials. The present investigation managed the production and the transient properties of low-calcium fly-ash based geopolymer concrete. Two different examinations, led in parallel, managed long haul properties and basic uses of strengthened low-calcium fly-ash based geopolymer concrete. The consequences of those investigations will be depicted in future Reports.

The points of this investigation were:

1. To build up a blend proportioning procedure to make low-calcium fly ash based geopolymer concrete.

2. To distinguish and concentrate the impact of striking parameters that influences the properties of low-calcium fly ash based geopolymer concrete.

3. To examination the momentary designing properties of geopolymer concrete.

1.4 SCOPE OF WORK

The examination used low-calcium (ASTM Class F) fly ash as the base material for making geopolymer concrete. The fly ash was gotten from just one source. Beyond what many would consider possible, the innovation and the hardware at present used to produce OPC cement were utilized to make the geopolymer concrete.

The solid properties concentrated incorporated the compressive and roundabout rigidities, the versatile constants, the pressure strain relationship in pressure, and the usefulness of new concrete.

1.5 LIMITATIONS

While various geopolymer frameworks have been proposed (many are licensed), the greater part of them are hard to work with and require extraordinary consideration in their creation. What's more, the polymerization response is touchy to the temperature and for the most part requires that the geopolymer cement ought to be relieved at raised temperature under a carefully controlled temperature routine (Hardjito et al. 2004; Tempest et al. 2009; Lloyd and Rangan 2009). In numerous regards, these actualities may confine the viable uses of the geopolymer concrete in the transportation foundation to the precast applications.

CHAPTER 2

LITERATURE REVIEW

2.1 CONCRETE AND ENVIRONMENT

The exchanging of carbon dioxide (CO2) discharges is a basic factor for the ventures, including the concrete enterprises, as the nursery impact made by the emanations is considered to create an expansion in the worldwide temperature that may result in atmosphere changes. The 'tradeable discharges' alludes to the monetary components that are required to help the nations worldwide to meet the outflow decrease targets set up by the 1997 Kyoto Protocol. Hypothesis has emerged that one ton of emanations can have an exchanging an incentive about US$10 (Malhotra 1999; Malhotra 2004).

The environmental change is credited to the an Earth-wide temperature boost, yet additionally to the dumbfounding worldwide darkening because of the contamination in the air. Worldwide diminishing is related with the decrease of the measure of daylight achieving the earth because of contamination particles noticeable all around hindering the daylight. With the push to diminish the air contamination that has been taken into execution, the impact of worldwide darkening might be decreased; anyway it will expand the impact of a dangerous atmospheric devation (Fortune 2005). Starting here of view, the a dangerous atmospheric devation marvel ought to be viewed as more truly, and any activity to diminish the impact ought to be given more consideration and exertion.

The generation of concrete is expanding about 3% yearly (McCaffrey 2002). The creation of one ton of bond frees around one ton of CO2 to the environment, as the aftereffect of de-carbonation of limestone in the oven during assembling of concrete and the burning of non-renewable energy sources (Roy 1999).

The commitment of Portland concrete generation worldwide to the ozone depleting substance outflow is assessed to be about 1.35 billion tons every year or about 7% of the absolute ozone harming substance emanations to the world's environment (Malhotra 2002). Bond is likewise among the most vitality serious development materials, after aluminum and steel. Besides, it has been accounted for that the sturdiness of conventional Portland bond (OPC) concrete is under examination, the same number of solid structures, particularly those inherent destructive situations, begin to break down following 20 to 30 years, despite the fact that they have been intended for over 50 years of administration life (Mehta and Burrows 2001).

The solid business has perceived these issues. For instance, the U.S. Solid Industry has created plans to address these issues in 'Vision 2030: A Vision for the U.S. Solid Industry'. The report expresses that 'solid technologists are looked with the test of driving future improvement in a manner that secures ecological quality while anticipating concrete as a development material of decision. Open concern will be capably tended to with respect to environmental change coming about because of the expanded centralization of a dangerous atmospheric devation gases. In this archive, methodologies to hold concrete as a development material of decision for foundation advancement, and in the meantime to make it a naturally well disposed material for the future have been sketched out (Mehta 2001; Plenge 2001).

So as to deliver ecologically cordial cement, Mehta (2002) proposed the utilization of less common assets, less vitality, and limit carbon dioxide discharges. He ordered these transient endeavors as 'modern environment'. The long haul objective of lessening the effect of undesirable side-effects of industry can be accomplished by bringing down the rate of material utilization. In like manner, McCaffrey (2002) recommended that the measure of carbon dioxide (CO_2) emanations by the bond businesses can be diminished by diminishing the measure of calcined material in bond, by diminishing the measure of bond in cement, and by diminishing the quantity of structures utilizing concrete.

2.2 GEOPOLYMER

In 1978, Davidovits prescribed that covers could made by a polymeric response of basic fluids with the silicon and the aluminum in source materials of geographical inception or side-effect materials, for example, fly ash and rice husk remains. These folios were named as geopolymers, on the grounds that the synthetic response that happens for this situation is a polymerization procedure. geopolymers are individuals from the group of inorganic polymers.

The synthetic sythesis of the geopolymer material is like naturalzeolitic materials, however the microstructure is indistinct rather than crystalline. The polymerization procedure includes a significantly quick synthetic response under soluble condition on Si minerals, that outcomes in a three dimensional polymeric chain and ring structure comprising of Si-O-Al-O bonds are shaped. The schematic arrangement of geopolymer material can be portrayed by the accompanying conditions (Ragan and Hardjito 2006).

Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline (Palomo et al. 1999; Xu and van Deventer 2000). The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three- dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds, as follows (Davidovits 1999):

$$Mn\ [-(SiO2)\ z\ –AlO2]\ n\ .\ wH2O \quad 1)$$

Where: M = the alkaline element or cation such as potassium, sodium or calcium; the symbol – indicates the presence of a bond, n is the degree of polycondensation or polymerisation; z is1,2,3, or higher, up to 32.

The schematic formation of geopolymer material can be shown as described by Equations (2-2) and (2-3) (van Jaarsveld et al. 1997; Davidovits 1999).

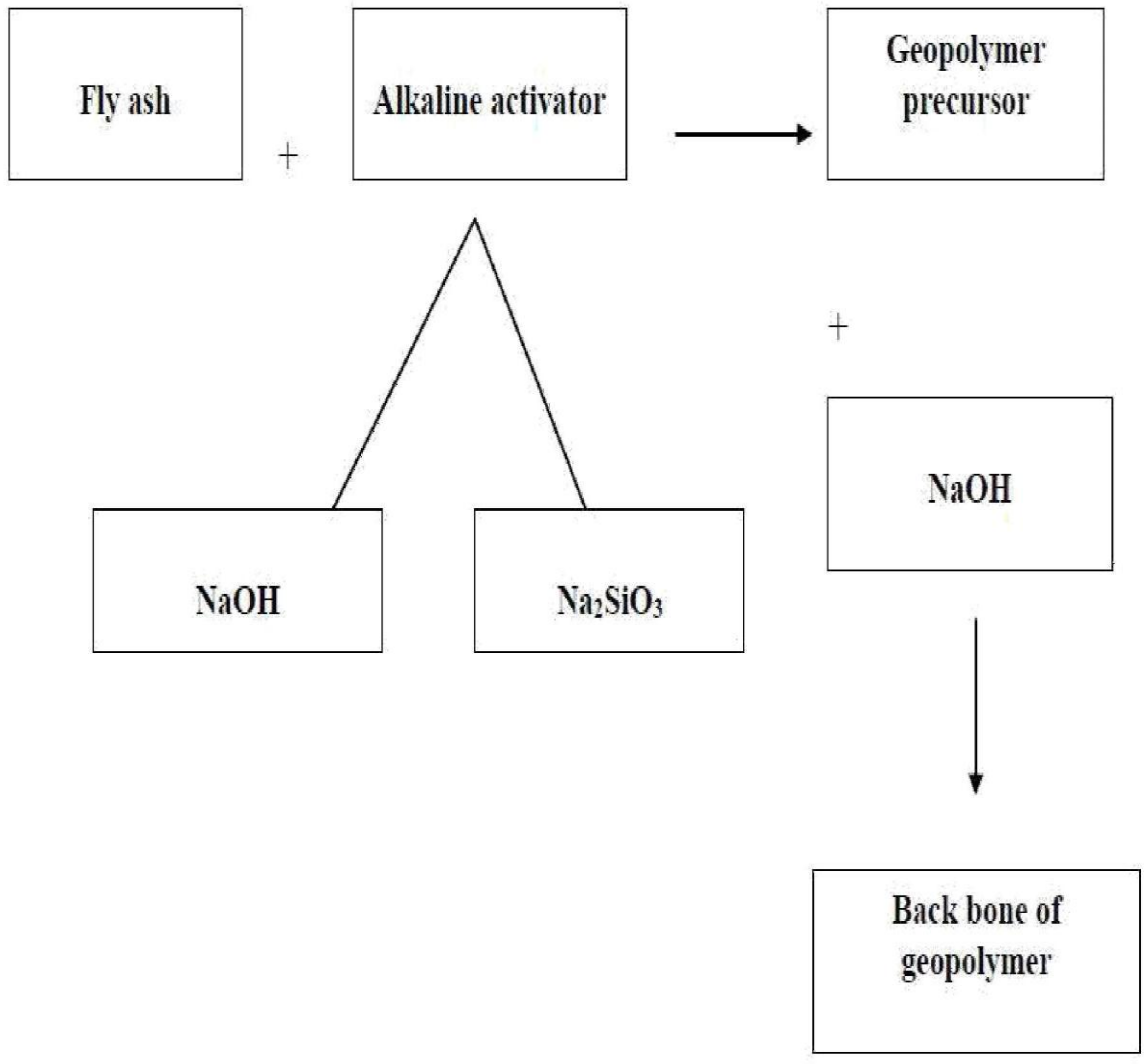
n(Si_2O_5,Al_2O_2)+2nSiO_2+4nH_2O+NaOH or KOH € Na^+,K^+ + n$(OH)_3$-Si-O-Al^--O-Si-$(OH)_3$
(Si-Al materials)

$(OH)_2$ (2-2)

n$(OH)_3$-Si-O-Al^--O-Si-$(OH)_3$+NaOH or KOH€(Na+,K+)-(-Si-O-Al^--O-Si-O-)+4nH_2O

$(OH)_2$ O O O (2-

(Geopolymer



The substance response may contain the accompanying advances (Davidovits 1999; Xu and van Deventer 2000):

•Dissolution of Si and Al iotas from the source material through the activity of hydroxide particles.

•Transportation or direction or buildup of forerunner particles into monomers.

•Setting or polycondensation/polymerisation of monomers into polymeric structures. Notwithstanding, these three stages can cover with one another and happen all the while, in this way making it hard to disengage and inspect every one of them independently (Palomo et al. 1999).

A geopolymer can take one of the three fundamental structures (Davidovits 1999):

•Poly (sialate), which has [-Si-O-Al-O-] as the rehashing unit.

•Poly (sialate-siloxo), which has [-Si-O-Al-O-Si-O-] as the rehashing unit.

•Poly (sialate-disiloxo), which has [-Si-O-Al-O-Si-O-Si-O-] as the rehashing unit.

Sialate is a truncation of silicon-oxo-aluminate.

The last term in Equation 2-3 uncovers that water is discharged during the compound response that happens in the development of geopolymers. This water, removed from the geopolymer lattice during the relieving and further drying periods, abandons spasmodic nano-pores in the framework, which give advantages to the presentation of geopolymers. The water in a geopolymer blend, along these lines, assumes no job in the compound response that happens; it only gives the functionality to the blend during dealing with. This is as opposed to the substance response of water in a Portland bond blend during the hydration procedure.

Davidovits (1999) proposed the potential uses of the geopolymers relying upon the molar proportion of Si to Al, as given in Table 2.1.

TABLE 2.1

Si/Al ratio	**Application of geoploymer**
1	Fire protection, bricks, ceramics
2	Low co2 concrete, cement, toxic waste & radioactive encapsulation
3	Glass fibre composites, , foundry equipment, heat resistance composites
>3	Industry’s sealants
20<Si/Al<35	Heat resistance and fire resistance fibre composites

APPLICATIONS OF GEOPOLYMERS

Geopolymeric materials have a wide scope of utilizations in the vehicle and aviation enterprises, non ferrous foundries, structural building and plastic businesses. The kind of use of geopolymeric material is dictated by the synthetic structure as far as the nuclear proportion Si: Al in the polysialate. A low proportion of Si: Al of 1, 2 or 3 starts a 3 D system that is unbending, while Si : Al proportion higher than 15 gives a polymeric character to the geopolymeric material. For some applications in the structural building field, a low Si: Al proportion is reasonable [Ragan and Hardjito 2006]. In light of different Si : Al nuclear proportion, the uses of geopolymer cement are appeared Table 2.1

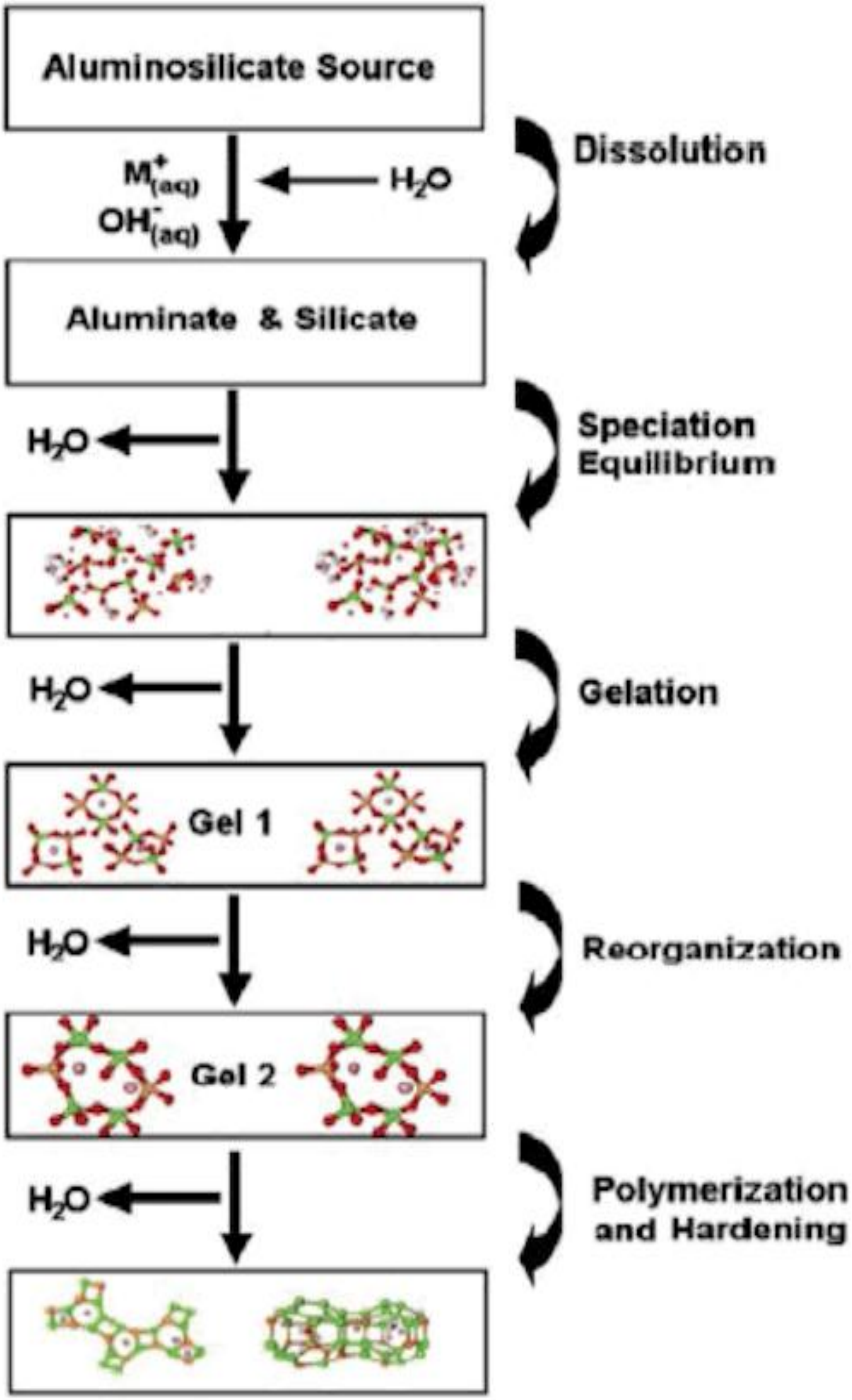


FIG 2.1 STEPS OF GEOPOLYMERIZATION

2.3 CONSTITUNTS OF GEOPOLYMER

2.3.1 SOURCE MATERIALS

Any material that contains for the most part Silicon (Si) and Aluminum (Al) in indistinct structure is a conceivable source material for the production of geopolymer. A few minerals and mechanical result materials have been explored previously. Metakaolin or calcined kaolin (Davidovits 1999; Barbosa et al. 2000; Teixeira-Pinto et al. 2002), low-calcium ASTM Class F fly ash (Palomo et al. 1999; Swanepoel and Strydom 2002), characteristic Al-Si minerals (Xu and van Deventer 2000), blend of calcined mineral and non-calcined materials (Xu and van Deventer 2002), mix of fly fiery remains and metakaolin (Swanepoel and Strydom 2002; van Jaarsveld et al. 2002), and mix of granulated impact heater slag and metakaolin (Cheng and Chiu 2003) have been examined as source materials.

Metakaolin is favored by the specialty geopolymer item designers because of its high rate of disintegration in the reactant arrangement, simpler control on the Si/Al proportion and the white shading (Gourley 2003). Be that as it may, for making concrete in a large scale manufacturing state, metakaolin is costly.

Low-calcium (ASTM Class F) fly ash is favored as a source material than high-calcium (ASTM Class C) fly slag. The nearness of calcium in high sum may meddle with the polymerisation procedure and modify the microstructure (Gourley 2003).

Davidovits (1999) calcined kaolin mud for 6 hours at 750oC. He named this metakaolin as KANDOXI (KAolinite, Nacrite, Dickite OXIde), and utilized it to make geopolymers. To make geopolymer solid, he proposed that the molar proportion of Si-to-Al of the material ought to be about 2.0 (Table 2.1).

On the idea of the source material, it was expressed that the calcined source materials, for example, fly ash, slag, calcined kaolin, showed a higher last compressive quality when contrasted with those made utilizing non-calcined materials, for example kaolin mud, mine tailings, and normally happening minerals (Barbosa et al. 2000). Notwithstanding, Xu and van Deventer (2002) found that utilizing a blend of calcined (for example fly fiery remains) and non-calcined material (for example kaolinite or kaolin dirt and albite) brought about huge improvement in compressive quality and decrease in response time.

Regular Al-Si minerals have appeared potential to be the source materials for geopolymerisation, albeit quantitative forecast on the reasonableness of the particular mineral as the source material is as yet not accessible, because of the unpredictability of the response systems included (Xu and van Deventer 2000). Among the side-effect materials, just fly ash and slag have been demonstrated to be the potential source materials for making geopolymers. Fly fiery debris is viewed as favorable because of its high reactivity that originates
from its better molecule estimate than slag. In addition, low-calcium fly ash is more attractive than slag for geopolymer feedstock material.

The appropriateness of different sorts of fly powder to be geopolymer source material has been contemplated by Fernández-Jim nez and Palomo (2003). These scientists asserted that to deliver ideal restricting properties, the low-calcium fly fiery remains ought to have the level of unburned material (LOI) under 5%, $Fe2O3$ substance ought not surpass 10%, and low CaO content, the substance of receptive silica ought to be between 40-half, and 80-90% of particles ought to be littler than 45 μm. Despite what might be expected, van Jaarsveld et al (2003) found that fly ash with higher measure of CaO created higher compressive quality, because of the arrangement of calcium-aluminate-hydrate and other calcium mixes, particularly in the early ages. Different qualities that affected the reasonableness of fly cinder to be a source material for geopolymers are the molecule measure, formless substance, just as morphology and the inception of fly ash.

2.3.2 ALKALINE LIQUID

The most widely recognized antacid fluid utilized in geopolymerisation is a mix of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate (Davidovits 1999; Palomo et al. 1999; Barbosa et al. 2000; Xu and van Deventer 2000; Swanepoel and Strydom 2002; Xu and van Deventer 2002). The utilization of a solitary antacid activator has been accounted for (Palomo et al. 1999; Teixeira-Pinto et al. 2002),

Palomo et al (1999) inferred that the kind of soluble fluid assumes a significant job in the polymerisation procedure. Responses happen at a high rate when the antacid fluid contains dissolvable silicate, either sodium or potassium silicate, contrasted with the utilization of just antacid hydroxides. Xu and van Deventer (2000) affirmed that the expansion of sodium silicate answer for the sodium hydroxide arrangement as the soluble fluid upgraded the response between the source material and the arrangement. Moreover, after an investigation of the geopolymerisation of sixteen common Al-Si minerals, they found that for the most part the NaOH arrangement caused a higher degree of disintegration of minerals than the KOH mixture.

2.3.3 FLY ASH

As indicated by the American Concrete Institute Committee (ACI) 116R, fly ash is characterized as "the finely partitioned buildup that produce from the ignition of ground or powdered coal and that is transported by pipe gases from the burning zone to the molecule expulsion framework". Fly ash particles are ordinarily circular, better than Portland concrete and lime, extending in breadth from under 1μm to close to 150μm.The synthetic sythesis is primarily made out of the oxides of silicon (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and calcium (CaO), though magnesium, potassium, sodium, titanium, and sulpher arelikewise present in a lesser sum. The real effect on the fly ash compound creation originates from the sort of coal.

The burning of sub-bituminous coal contains more calcium and less iron than fly fiery remains from bituminous coal. The physical and compound attributes rely upon the ignition strategies, coal source and molecule shape. Fly fiery remains that outcomes from consuming sub-bituminous coals is alluded as ASTM Class C fly slag or high-calcium fly ash, as it regularly contains in excess of 20 percent of CaO. Then again, fly ash remains from the bituminous and anthracite coals is alluded as ASTM Class F fly slag or low-calcium fly cinder. It comprises of for the most part an alumino-silicate glass, and has under 10 percent of CaO (Hardjito.d and Ragan.b.v 2007).

Low-calcium (ASTM Class F) fly ash is favored as a source material than high calcium (ASTM Class C) fly slag. The nearness of calcium in high sum may meddle with the polymerization procedure and adjust the microstructure. Low calcium fly fiery debris has been effectively used to make geopolymer solid when the silicon and aluminum oxides comprised about 80% by mass, with Si to Al proportion of around 2. The substance of iron oxide typically extended from 10 to 20% by mass, though the calcium oxide substance was under 3% by mass and the misfortune on start by mass, was as low as under 2% and 80% of the fly ash particles were littler than 50μm (Vijaya Ragan , Hardjito 2005-2006).

FIG.2 .2 FLY ASH

Beside the chemical organization, different qualities of fly powder that for the most part considered are misfortune on start (LOI), fineness and consistency. LOI is an estimation of unburnt carbon staying in the powder. Fineness of fly fiery remains generally relies upon the working states of coal smashers and the pounding procedure of the coal itself. Better degree for the most part results in an increasingly responsive fiery remains and contains less carbon.

In 2001, the yearly generation of fly ash in the USA was around 68 million tons. Just 32 percent of this was utilized in different applications, for example, in concrete, basic fills, squander adjustment/hardening and so on. (ACAA 2003). Fiery debris generation in Australia in 2000 was approximated 12 million tons, with some 5.5 million tons have been used (Heidrich 2002). Around the world, the evaluated yearly generation of coal fiery remains in 1998 was in excess of 390 million tons. The primary supporters for this sum were China and India. Just around 14 improved solid solidness, decreased utilization of vitality, lessened ozone harming substance percent of this fly cinder was used, while the rest was arranged in landfills (Malhotra 1999). Constantly 2010, the measure of fly fiery debris created worldwide is evaluated to be around 780 million tons every year (Malhotra 2002). The use of fly powder, particularly in solid generation, has huge ecological advantages, viz, creation, decreased measure of fly cinder that must be arranged in landfills, and sparing of the other characteristic assets and materials (ACAA 2003).

2.4 SUMMERY ON GEOPOLYMER CONCRETE

Rangan led examines on warmth restored low calcium fly fiery remains based geopolymer concrete. The impact of notable factors, for example, water to geopolymer solids proportion, blending time, relieving time and restoring temperature on the properties of geopolymer concrete in the new and solidified states were distinguished. The present moment and long haul properties of geopolymer solid, creep and drying shrinkage, sulfate and sulfuric corrosive opposition of geopolymer cement were talked about. The financial advantages of the geopolymer cement were likewise quickly examined. This paper presumed that warmth relieved low - calcium fly fiery debris based geopolymer cement have astounding protection from sulfate assault, great corrosive opposition, experiences low downer and drying shrinkage.

Hardjito and Rangan had examined the utilization of fly fiery debris as fastener to make concrete with no bond. The trial work has been finished utilizing low calcium fly cinder as fastener and sodium hydroxide and sodium silicate arrangement as activators. The impact of striking parameters like centralization of sodium hydroxide arrangement, proportion of sodium silicate answer for sodium hydroxide arrangement, relieving temperature, restoring time, dealing with time, expansion of super plasticizer, water content in the blend and blending time on the properties of new and solidified cement were examined. In light of the compressive quality of geopolymer concrete, the prescribed qualities for test factors are the accompany in the convergence of sodium hydroxide arrangement was in the range between 8 M and 16 M. The sodium silicate answer for sodium hydroxide arrangement proportion by mass was in the scope of 0.4

to 2.5. (iii)The antacid answer for fly fiery debris proportion by mass was around 0.35 to 0.45.

Vijai et al., portrayed the impact of restoring types, for example, surrounding relieving and hot relieving on the compressive quality of fly fiery remains based geopolymer concrete. For hot relieving, the temperature was kept up as60oC for 24 hrs in sight-seeing oven. The compressive quality of hot relieved cement was higher than the surrounding restored concrete. In encompassing relieving, the compressive quality increments around multiple times with time of cement from7days to 28 days. The compressive quality of hot restored fly fiery remains based geopolymer cement has not expanded significantly following 7 days. The thickness of geopolymer cement was around 2400 Kg/m3, which is proportional to that of traditional cement.

Hardjito et al., displayed the impact of blend piece on the compressive quality of fly fiery remains based geopolymer concrete. Water to sodium oxide molar proportion and water to geopolymer solids proportion had impact on the compressive quality of geopolymer concrete. At the point when these proportion increments, compressive quality of geopolymer diminishes. As the water to sodium oxide molar proportion expanded, the blend contained more water and turned out to be increasingly useful. The all out mass of water is the whole of mass of water in sodium silicate arrangement, mass of water in sodium hydroxide arrangement and additional water if any additional in cement. The mass of geopolymer solids is the whole of the mass of fly fiery debris, mass of sodium hydroxide drops and mass of sodium silicate solids. Sodium oxide to silicon oxide molar proportion inside the scope of 0.095 to 0.120 had no huge impact on the compressive quality.

Mourougane et al., introduced the building properties, for example, compressive quality, split elasticity and flexural quality of fly cinder based geopolymer concrete and contrasted and ordinary cement. The impact of affecting parameters, for example, proportion of antacid fluid to fastener, restoring time on the compressive quality of geopolymer concrete. At the point when the basic fluid to cover proportion and molarity of sodium hydroxide expands, the compressive quality likewise increments, while it diminishes with increment in additional water. In this experimentation 10% by mass of folio (fly fiery remains) was supplanted by granulated impact heater slag. One day compressive quality of warmth restored fly slag based geopolymer solid extents from 60MPa to 80MPa, with various basic fluid to cover proportion as 0.3 and 0.35. The expansion of 10% of granulated impact heater slag builds the 3D shape quality from 25 to 33%.The flexural quality of geopolymer concrete and typical cement was observed to be comparative.

Zhang et al., revealed the hydration procedure of interfacial change in potassium polysialate geopolymer concrete. For experimentation metakaolin was utilized as a source material and potassium hydroxide was utilized as an activator. Natural checking electron microscopy (ESEM) was utilized to consider the hydration procedure of the interfacial progress zone (ITZ) between coarse total and potassium polysialate (K-PSDS) geopolymer under a 80% relative mugginess condition. A vitality scattering X-beam examination (EDXA) was additionally used to recognize the concoction organization of the hydration items. The ESEM micrographs and relating EDXA results demonstrated that the advancement of the microstructure of ITZ is very not the same as that of lattice. Toward the start there were numerous huge voids loaded up with water in the new ITZ as appeared in Figure 2.2, however these voids were not found in the mass lattice. As hydration continued, gel items steadily accelerated on the edges of these voids and expanded outward. In the long run these voids were totally loaded up with hydration item as appeared in Figure 2.3. At this stage, the distinction in the micrograph between the ITZ and the lattice was barely discernable. Anyway EDXA results demonstrated that the substance of K/Aland Si/Al in the ITZ were higher than those in the mass framework. This shows K and Si collect in the ITZ, which results in a distinction in synthetic piece between the ITZ and the network. What's more, well17developed gems were not found in the ITZ at any stage and wipe like shapeless gel was constantly watched.

Hardjito et al., portrayed the advancement of geopolymer concrete. The fastener, the geopolymer glue is framed by actuating by item materials, for example, low-calcium (Class F) fly fiery remains, that are wealthy in silicon and aluminum. A blend of sodium silicate arrangement and sodium hydroxide arrangement was utilized as the activator. The geopolymer glue ties the free coarse and fine totals and any unreacted materials to shape the geopolymer concrete. In view of the test work, the paper presumed that higher the convergence of sodium hydroxide arrangement, higher the proportion of sodium silicate answer for sodium hydroxide arrangement, longer restoring term, and higher relieving temperature expands the compressive quality of geopolymer concrete. The low calcium fly slag based geopolymer cement have phenomenal protection from sulfate assault, experiences low jerk and drying shrinkage.

Hardjito and Tsen, exhibited the designing properties of geopolymer mortar produced from class F (low calcium) fly cinder with potassium-based basic reactor. The outcomes uncovered that as the convergence of KOH expanded, the compressive quality of geopolymer mortar additionally expanded. The proportion of potassium silicate-to-potassium hydroxide by mass in the range between 0.8–1.5 created most elevated compressive quality geopolymer mortar. Geopolymer mortar examples were tried for warm dependability for three hours under 400oC, 600oC and800oC. At the point when presented to temperature of 400oC for three hours, the compressive quality multiplied than the one of control blend. This demonstrates the geopolymerisation procedure proceeds with when geopolymer mortar is presented to high temperature, up to 400oC. Geopolymer mortar groups fantastic imperviousness to fire up to 800°C introduction for three hours. Above 800oC, compressive quality of fly cinder based geopolymer solid abatements with increment in temperature.

Thokchom et al., a test study was directed to evaluate the corrosive obstruction of fly powder based geopolymer mortar examples having rate Na2O going from 5% to 8% of fly fiery remains. The examples were inundated in arrangements of 10% Sulfuric corrosive and 10% Nitric corrosive up to a time of 24 weeks. The corrosive obstruction was assessed as far as surface erosion, remaining alkalinity, changes in weight and compressive quality at ordinary interims. Geopolymer mortar tests did not demonstrate any adjustment in shading and remained basically unblemished however the uncovered surface turned marginally milder. Through Optical magnifying instrument, eroded surface could be seen which expanded with length of presentation. Loss of alkalinity relied upon soluble base substance in the geopolymer mortar. Mortar with lesser Na2O lost its alkalinity quicker than those with higher Na2O content in both Sulfuric corrosive and Nitric corrosive arrangements. The weight reduction in the range from 0.81% to 1.64% in Sulfuric corrosive and from 0.21% to 1.42% in Nitric corrosive was seen in 12weeks introduction. Toward the finish of 24 weeks of presentation, the compressive quality expanded from 44% to 71% and 40% to 70% in

Sulfuric corrosive and Nitric corrosive individually. This paper reasoned that fly fiery debris based geopolymers were very impervious to both Sulfuric and Nitric acid.

Wallah et al., this paper exhibited the presentation of fly cinder based geopolymer cement to sulfate assault. The examples were absorbed sodium sulfate arrangement and sulfuric corrosive answer for different times of presentation. The presentation of geopolymer cement was examined by assessing the impact on the compressive quality, change long and change in mass. There was no noteworthy change in the outer appearance of the outside of examples absorbed sodium sulfate as long as 12 weeks. In any case, But, the surfaces of examples absorbed sulfuric corrosive arrangement began to disintegrate following multi week of presentation. From the test outcome, it was seen that presentation to sodium sulfate arrangement as long as 12 weeks had next with no impact on the compressive quality. In any case, a huge change in compressive quality is seen on account of examples presented to sulfuric corrosive arrangement. For the 12 weeks dousing time frame, the decrease of compressive quality was around 30 % . It gives the idea that the entrance of sulfuric corrosive may have influenced the microstructure and diminished the bond between geopolymer glue and the totals, along these lines bringing about a decline in compressive quality. The adjustment long of examples absorbed sodium sulfate answer for different times of presentation is exceptionally little, under 0.01%. The mass did not change for examples absorbed sodium sulfate arrangement. On account of examples absorbed sulfuric corrosive, the mass diminished short of what one percent following 12 weeks.

Wallah and Rangan, contemplated the long haul properties of low calcium fly fiery remains based geopolymer concrete. The low-calcium fly powder from Collie Power Station, Western Australia was utilized as a source material. The antacid fluid utilized was a blend of sodium silicate arrangement and sodium hydroxide arrangement. The two unique blends, Mixture-1 and Mixture-2, were utilized for the exploratory work and relieved at 60°C for 24h. In Mixture-1, the grouping of the sodium hydroxide arrangement was 8 Molars (M), and there was no additional water. In Mixture-2, the centralization of the sodium hydroxide arrangement was 14 Molars (M), and the blend contained additional water. The normal compressive quality of Mixture-1 was around 60 MPa and that of Mixture-2 was around 40 MPa. The geopolymer examples were tried for downer, drying shrinkage, sulfate opposition and corrosive obstruction. In view of the compressive quality test results, there was no considerable addition in the compressive quality of heatcured fly fiery debris based geopolymer concrete with age. Fly powder based geopolymer concrete, restored in encompassing conditions increases compressive quality with age. Warmth relieved fly fiery debris based geopolymer cement experiences low drag. The particular downer following one year went from 15 to 29 x10-6 MPa for the comparing compressive quality of 67 MPa to 40 MPa. The heatcured fly fiery remains based geopolymer cement experiences almost no drying shrinkage in the request of around 100 small scale strains following one year. This worth is altogether littler than the scope of estimations of 500 to 800 smaller scale strains for Portland bond concrete. The warmth restored fly powder based geopolymer concrete additionally had a superior protection from sulfate and corrosive assault.

Skvara et al., had explored the properties of the cements based on geopolymers. The structure of the geopolymers arranged based on fly cinder was prevalently of the AlQ4 (4Si) type and SiQ4 (4Al), SiQ4 (2-3Al). The geopolymer based on fly slag was a permeable material. The porosity of the geopolymers was fundamentally the same as in the district of nanopores paying little heed to the states of their planning. The geopolymers quality was influenced generously by full scale pores (103 nm and the sky is the limit from there) shaped in consequence of the air entrained into the geopolymers, these might be because of halfway response of fly powder particles. The nearness of Ca-containing added substances (slag, gypsum) decreases significantly the porosity in view of the concurrence of the geopolymer stage with the C-S-H stage. No shrinkage because of hydration, happens in the geopolymer concrete. The proportion of the compressive solidarity to the rigidity under twisting changes in the scope of 10.0: 5.5.The progress stage was not found between the cover and the totals in geopolymer concrete.

Bakharev, introduced an examination concerning the toughness of geopolymer materials made utilizing class F fly slag and the antacid activators when presented to a sulfate situation. The tests, used to decide opposition of geopolymer materials were 5% arrangement of sodium sulfate and magnesium sulfate, 5% of sodium sulfate+5% magnesium sulfate for a time of 5 months. Fly fiery remains was initiated by sodium hydroxide, a blend of sodium and potassium hydroxide and sodium silicate arrangements, giving 8-9%Na in the blend and water cover proportion of 0.3. The blends were relieved for 24 h at room temperature, after that the blends were sloped at 90°C and restored at this temperature for 24 h and restored at room temperature for 2 days preceding test. In sodium sulfate arrangement, critical vacillations of solidarity happened with quality decrease of 18% in the sodium silicate enacted test and 65% decrease in the example arranged with sodium hydroxide and potassium hydroxide as activators, while 4% expansion of solidarity was estimated in sodium hydroxide initiated test. In magnesium sulfate arrangement, 12% and 35% quality increment was estimated in sodium hydroxide and blend of sodium hydroxide and potassium hydroxide as activators individually and 24% quality decrease was estimated in sodium silicate initiated tests. The most critical vacillation of solidarity and smaller scale basic changes occurred in 5% arrangement of sodium sulfate and magnesium sulfate. The movement of soluble bases from the geopolymer tests into the arrangement was seen in sodium sulfate arrangement. The dissemination of salt particles into the arrangement caused noteworthy pressure and development of profound vertical splits in the examples arranged utilizing a blend of sodium and potassium hydroxides. In magnesium sulfate arrangement, notwithstanding relocation of alkalies from geopolymer into the arrangement, there was additionally dissemination of Mg and Ca in the surface layer of geoplolymers, which improved their quality. In material arranged utilizing sodium silicate, development of ettringite was likewise watched, which added to lost quality. The best execution in various sulfate arrangements was seen in the geopolymer material arranged utilizing sodium hydroxide and relieved at raised temperature. Great execution was ascribed to an increasingly steady cross-connected aluminosilicate polymer structure.

Bakharev, had explored the solidness of geopolymer materials utilizing class F fly and sodium silicate, sodium hydroxide and a blend of sodium hydroxide and potassium hydroxide as activators, when presented to 5% arrangements of acidic and sulfuric acids. The critical debasement was seen in geopolymer materials arranged with sodium silicate and a blend of sodium hydroxide and potassium hydroxide as activators. The crumbling was because of depolymerisation of aluminosilicate polymers and freedom of silicic, substitution of Na and K cations by hydrogen and dealumination of the geopolymer structure. In acidic condition, superior geopolymer materials break down with the development of crevices in shapeless polymer network, while low execution geopolymers decay through crystallization of zeolites and arrangement of delicate grainy structures. The more crystalline geopolymer material arranged with sodium hydroxide was increasingly steady in the forceful condition of sulfuric and acidic corrosive arrangements than formless geopolymers arranged with sodium silicate activator. The substance shakiness would likewise rely upon the nearness of the dynamic destinations on the aluminosilicate gel surface, which seemed to increment in nearness of K particles.

CHAPTER 3

EXPERIMENTATION AND METHODOLOGY

3.1 MATERIALS AND THEIR PROPERTIES

Materials used in fly-ash based geopolymer concrete specimen were fly-ash, coarse aggregatate, fine aggregates, Sodium hydroxide, Sodium silicate and extra water.

3.1.1 FLY ASH

As indicated by ASTM C-618, two noteworthy classes of fly ash are perceived. These two classes are identified with the sort of coal consumed and are assigned Class F and Class C in a large portion of the present writing. Class F fly ash is regularly created by consuming anthracite or bituminous coal while Class C fly ash is for the most part acquired by consuming sub-bituminous or lignite coal. The important properties are discussed below.

Class F fly ashes with calcium oxide (CaO) content less than 6%, designated as low calcium ashes, are not self hardening but generally exhibit pozzolanic properties. These ashes contain more than 2% unburned carbon determined by loss on ignition (LOI). Quartz, mullite and hematite are the major crystalline phases identified fly ashes, derived from bituminous coal. Essentially, all the fly ashes and, therefore, most research concerning use of fly ash in cement and concrete are dealt with Class F fly ashes. Previous research findings and majority of current industry practices indicate that satisfactory and acceptable concrete can be produced with the Class F fly ash replacing 15 to 30% of cement by weight. When Class F fly ash is used for producing air entrained concrete to improve freeze-thaw durability, the demand for air entraining mixtures is generally increased. Use of Class F fly ash in general reduces water demand as well as heat of hydration. The concrete made with Class F fly ash also exhibits improved resistance to sulphate attack and chloride ion ingress. Density of fly ash used 405kg/m^3

3.1.2 COARSE AGGREGATES

Locally accessible granite rock stone total of 10mm size was utilized as coarse total. The coarse total going through 10mm and holding 4.75mm was utilized for exploratory work. The properties of coarse totals were resolved according to IS: 2386-1963. Density of coarse aggregates used 1268.66kg/m^3

Fig 3.1 Coarse Aggregates

3.1.3 FINE AGGREGATES

The locally accessible waterway sand, passing through 4.75 mm was utilized in this trial work. The properties of fine totals were resolved according to : 2386-1963. Density of fine aggregates 683.13kg/m^3

3.1.4 ALKALINE SOLUTION

The mixture of sodium hydroxide and sodium silicate is used as Alkaline solution.

3.1.4.1 SODIUM HYDROXIDE

The most well-known alkaline activator utilized in geopolymerisation is a mix of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2Sio3) or potassium silicate (K_2 SiO_3). The sort and grouping of soluble base arrangement influence the disintegration of Pozzolanic material. It is a white strong and very scathing metallic base and antacid salt which is accessible in pellets, pieces, granules, and as readied arrangements at various focuses. Sodium hydroxide shapes an around half (by weight) immersed arrangement with water. Sodium hydroxide is dissolvable in water, ethanol and methanol. This soluble base is deliquescent and promptly assimilates dampness and carbon dioxide in air. Unadulterated sodium hydroxide is a whitish strong, sold in pellets, chips, and granular structure, just as in arrangement. It is profoundly dissolvable in water, with a lower dissolvability in ethanol and methanol, however is insoluble in ether and other non-polar solvents. Like the hydration of sulfuric corrosive, disintegration of strong sodium hydroxide in water is a very exothermic response where a lot of warmth is freed, representing a risk to wellbeing through the likelihood of sprinkling. The subsequent arrangement is typically dismal and scentless. Likewise with other soluble arrangements, it feels dangerous when it interacts with skin. Sodium hydroxide is modernly delivered as a half arrangement by varieties of the electrolytic chloralkali process. Chlorine gas is additionally created in this procedure. Strong sodium hydroxide is acquired from this arrangement by the vanishing of water. Strong sodium hydroxide is most ordinarily sold as pieces, pills, and cast squares. At the point when NaOH responds with water gives disassociation of the sodium and hydroxide particles and the hydration of those particles discharges a LOT of warmth, trough to bubble water in certain conditions. Incredible consideration is required. Subsequently it is an exothermic response. The convergences of sodium hydroxide arrangement as 13 Molar. Density of sodium hydroxide used is 70.88kg/m^3

Fig 3.2 NaOH flakes

3.1.4.2 SODIUM SILICATE

Sodium silicate is the regular name for mixes with the equation $Na_2(SiO_2)_nO$ Concrete treated with a sodium silicate arrangement serves to fundamentally decrease porosity in most stone work items, for example, concrete. A substance response happens with the abundance $Ca(OH)_2$ (portlandite) present in the solid that for all time ties the silicates with the surface, making them unmistakably increasingly tough and water repellent. This treatment by and large is connected simply after the underlying fix has occurred (7 days or so relying upon conditions). The sodium silicate arrangement A53 with SiO_2 to Na_2O proportion by mass roughly 2, (Na_2O = 14.7%,

SiO_2=29.4% and water 55.9% by mass) was utilized. The sodium with 97-98% virtue, in piece or pellet structure was utilized. The solids must be disintegrated in water to make an answer with the required focus. The proportion of sodium silicate answer for sodium hydroxide arrangement by mass was fixed as 2,2.5 and 3.The reason being the sodium silicate arrangement was less expensive than the sodium hydroxide arrangement.

Density of sodium silicate used is 70.88kg/m^3

3.1.5 EXTRA WATER

In ordinary Portland bond (OPC) solid, water in the blend synthetically responds with the concrete to deliver a glue that ties the totals. Conversely, the water in a fly ash based geopolymer solid blend does not cause a substance response. Actually, the synthetic response that happens in geopolymers produces water that is in the end ousted from the cover. Be that as it may, water content in the geopolymer solid blend influenced the properties of cement in the new state just as in the solidified state.

In this parameter, the all out mass of water is the aggregate of the mass of water contained in the sodium silicate arrangement, the mass of water in the sodium hydroxide arrangement, and the mass of additional water added to the blend. The mass of geopolymer solids is the total of the mass of fly fiery remains, the mass of sodium hydroxide solids, and the mass of solids in the sodium silicate arrangement. In this undertaking work, the "water to flyash" proportion was fixed as 0.45 additional water, to discover the impact of different parameters on the quality of Geopolymer concrete.

Density of extra water 29.46kg/m^3

3.1.6 SLAG

Slags from the iron and steel enterprises are now and again mistakenly characterized, and frequently viewed, as modern waste materials. In undeniable reality, these results are important and amazingly flexible development materials. The historical backdrop of slag use in street building goes back to the season of the Roman Empire, somewhere in the range of 2000 years prior, when broken slag from the rough iron-production manufactures of that period were utilized in base development. Applications were very sporadic until the only remaining century, when enormous amounts started to be utilized for various purposes. In generally ongoing years, the requirement for most extreme use and reusing of side-effects and recouped squander materials for financial and natural reasons has prompted quick improvement of slag usage. In certain regions, almost the majority of the iron and steel slags are presently being utilized, and use is quickly developing in numerous others.

Blast-furnace slag is characterized by the American Society for Testing and Materials as "the non-metallic item comprising basically of silicates and alumino-silicates of calcium and different bases that is "created in a liquid condition at the same time with iron in an impact blast-furnace" The blast-furnace is the essential methods for diminishing iron oxides to liquid, metallic iron. It is consistently accused of iron oxide sources (metals, pellets, sinter, and so forth.), transition stone (limestone and dolomite), and fuel (coke). Liquid iron gathers in the base of the heater and the fluid slag coasts on it. Both are intermittently tapped from the furnace. Density of slag used 405kg /m^3.

Fig. 3.3 Slag used

3.2 MIXTURE PROPORTIONS

As on account of Portland cement concrete, the coarse and fine totals possess around 75 to 80% of the mass of geopolymer concrete. The presentation criteria of a geopolymer cement rely upon the application. The compressive quality of solidified cement and the functionality of new cement are chosen as the exhibition criteria. So as to meet the exhibition criteria, the soluble fluid to folio proportion by mass, water to geopolymer solids proportion by mass, the encompassing restoring and the surrounding relieving time are chosen as parameters.

TABLE 3.1

Ratio of materials used and their density in mixer of Geopolymer concrete

Materials used	MASS (kg/m^{3})	Ratio of materials used
Fly ash/ slag	405	1
Sodium hydroxide (NaOH)	70.88	0.175
Sodium silicate (Na_2SiO_3)	70.88	0.175
Coarse aggregates	1268.66	3.13
Fine aggregates	683.13	1.686

3.2.1 GEOPOLYMER CONCRETE MAKING

The fly ash and aggregates were blended, at that point the activator arrangement was added to it and blending is proceeded till a consistency is watched. It was discovered that the new fly ash based geo-polymer solid blend was strong and dull in shading.

3.2.2 MAKING OF CUBIC AND CYLINDRICAL SPECIMENS

Fresh geopolymer concrete mix is placed in 150mm×150mm×150mm size cubic moulds and cylindrical moulds of 150mm dia. and 300mm height

3.3 CASTING AND PREPARATION OF GEOPOLYMER CONCRETE

3.3.1 MAKING OF LIQUIDS

The sodium hydroxide (NaOH) solids were broken up in water to make the mixture. The mass of NaOH solids in mixture relying upon the concentration of mixture defined in term of molar, M. For example, NaOH arrangement with a concentration of 13M comprised of 13x40 = 520 grams of NaOH solids (in chip or pellet structure) per liter of the mixture, where 40 is the molecular weight of NaOH.

The sodium silicate mixture and the sodium hydroxide mixture were combined one day preceding use to set up the alkaline fluid. The day of throwing of the examples, the alkaline fluid was combined with the additional water (assuming any) to set up the fluid part of the blend.

3.3.2 MAKING OF FRESH CONCRETE AND CASTING

Geopolymer cement can be produced by the traditional procedures utilized in the assembling of Portland cement concrete. In the research facility, the fly slag and the aggregates were first combined for 3 minutes. The aggregates were set up in soaked surface dry condition.

The alkaline mixture was then added to the dry materials and the blending proceeded for further around 4 minutes to produce the new concrete. The new concrete could be handled of as long as 120 minutes with no indication of setting and with no debasement in the compressive quality.

Total 12 cube are cast and 6 cylinder, of which 6 cube and 3 cylinder were cured and 6 cube and 3 cylinder are uncured.

We cast cube and cylinder with varying flyash/slag ratio as 75/25, 50/50 and 25/75 each having 4 cube and 2 cylinder out of which 2 cube and 1 cylinder are cured and 2 cube and 1 cylinder are uncured.

We specify the flyash/slag ratio on top of cubic and cylindrical specimens with marker.

Fig. 3.4 Test specimens

3.3.3 CURING OF GEOPOLYMER TEST SPECIMENS

Ambient curing of fly ash based geopolymer concrete is mostly preferred. Ambient curing considerably helps the chemical process which occurs in the geopolymer mix. Curing time and curing temperature affects the compressive strength of geopolymer concrete. The curing time changes from 12 to 24 hours. Greater curing time enhance the polymerization action resulting in greater compressive strength. The rate of enhance in strength was quick up to 24 hours of curing time and after 24 hours, the profit in strength was only become less extreme. Greater curing temperature of geopolymer concrete derived in greater compressive strength. Good curing is nothing but weather curing i.e, Room temperature.

After casting, geopolymer concrete test cube and cylinder were cured instantly. Two process of curing were performed in this process, i.e. Oven curing and good curing. For Oven curing, the test sample were cured in the oven and for Ambient curing, they were placed under good atmospheric condition for curing at room temperature. The samples were oven-cured at 60OC and 100 OC for 24 hours in an oven. After the curing time, the test samples were kept in the moulds for minimum six hours to avoid any big change in the atmospheric conditions. After unmoulding, the samples were kept to air-dry in the lab. till the day of testing. Likewise make the moulds of cylinders were ambient cured at room temperature for 24 hours after which they demould the sample were kept to air dry in the laboratory till the testing day.

Fig. 3.5 Oven used for curing

3.4 EXPERIMENTS PERFORMED

3.4.1 COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. Cubic and cylindrical specimens were tested in this. Both oven cured and ambient cured specimen were tested under "HEICO Compression testing machine" of capacity 2000KN. 28 days specimens were used for this test. Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. The test is performed as per IS 516-1959.

In the case of cubes, the sample is placed in the crushing machine on its side so that the two faces in contact with the platens of the machine are faces which were in contact with the polished steel sides of the mould, they should, therefore, be perfectly plane and smooth. Cylinders must, however, be tested in an upright position and the upper surface has only been float- finished. If the cylinder was crushed with the upper surface directly in contact with the platen of the test machine, the test result would almost certainly give a low result as the upper surface will be in contact with the machine at a number of high spots and compact
stress patterns will be developed. The steel platens of the crushing machine are brought together until they just touch the upper and lower surfaces of the specimen. The specimen should be central on the platens and the upper platen should be free to rotate so that any small differences in alignment between the upper and lower surfaces of the specimen may be accounted for.

The crushing machine should be fitted with a guard to contain the specimen on fracture. The load is then applied to the specimen at a constant rate. On automatic machines the rate of loading may be shown by a load pacer, but on manual machines, pacing should be done using a stopwatch. It is a good practice to overlay the dial with a clear plastic sheet with times corresponding to each dial gauge reading shown. Note that, as the sample begins to fail the actual speed of the platens must be increased to maintain the same rate of application of load. Compressive strength is calculated by using formula

$$F_{ck} = P_c/A$$

Where, Pc=load at failure in N

A=loaded area of cube in mm^2

Fig. 3.6 Compression testing machine

3.4.2 MODULUS OF ELASTICITY AND POISSON'S RATIO

Lateral Extensometer / Longitudinal compressometer are used for calculating Modulus of elasticity and poisson's ratio of Geopolymer concrete. Cylindrical specimen are used in this test.

Lateral Extensometer is used for calculation of lateral expansion of 150 mm dia x 300 mm high cement concrete cylinders during testing them in compression. The extensometer contain of two portable frames pivoted at one end. A dial gauge measures the lateral expansion, and a detachable spacer strip is for the initial fitting of the dial gauge. Mounting of extensometer on the sample is with the help of fastener.

Longitudinal compressometer is used for calculation of the strain and deformation characteristics of cement concrete cylindrical samples of 150 mm dia x 300 mm length. The Compressometer contain of two frames for clamping to the samples by means of five tightening fastener with hardened and tapered ends. Two spacers tight the two frames in position. An movable pivot rod rests on pivot fastener. A spring enables the pivot rod to stand in contact with pivot fastener. The ball chain is for regulating the tension of the spring. A dial gauge, fixed to a bracket, fitted to the top frame, is used for getting deformation measurement.

Together compressometer and extensometer for 6" dia. x 12"L (152 x 305mm) concrete cylinders is a satisfactory unbounded equipment. Apparatus contain of a third yoke situated midway between the two compressometer yokes and attached to the specimen at two diametrically opposite points. Middle yoke is pivoted to permit turning of the two segments of the yoke in the horizontal plane. Indicator gives deformation values. Second indicator is furnished for compressometer section. Unit determine changes in length and diameter. The apparatus is made of lightweight aluminum magnesium alloy. The fixture points and contact points are of machine steel. The command (spacer rods) is made of stainless steel. The axial and diametrical changes can be showed on the two dial gauge indicators by taking one-half of their indicated values. (The lever ratio of the device multiplies the changes by the factor 2*, therefore, actual deformation of the specimen is one-half the indicated value).

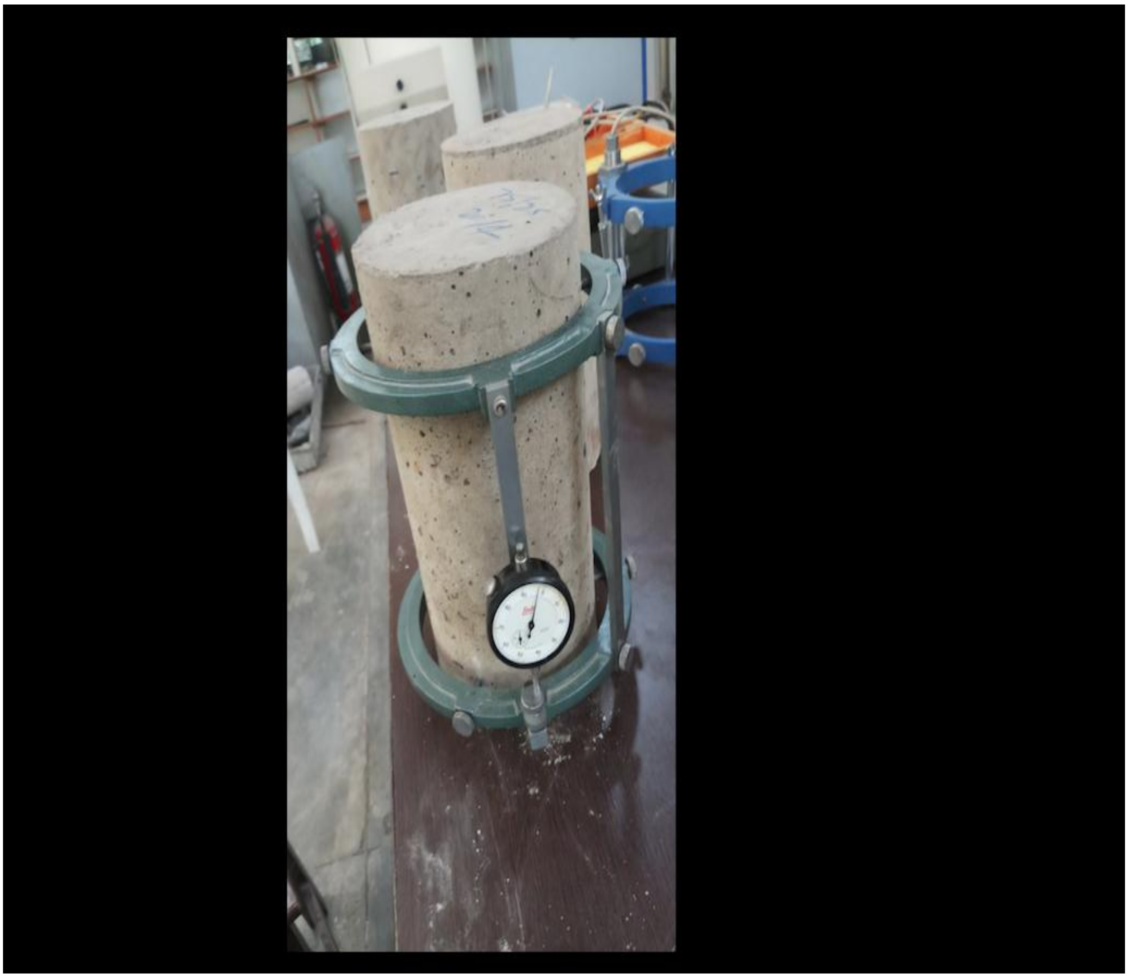


Fig. 3.7 Alignment of apparatus

Fig. 3.8 Specimen inside CTM for test

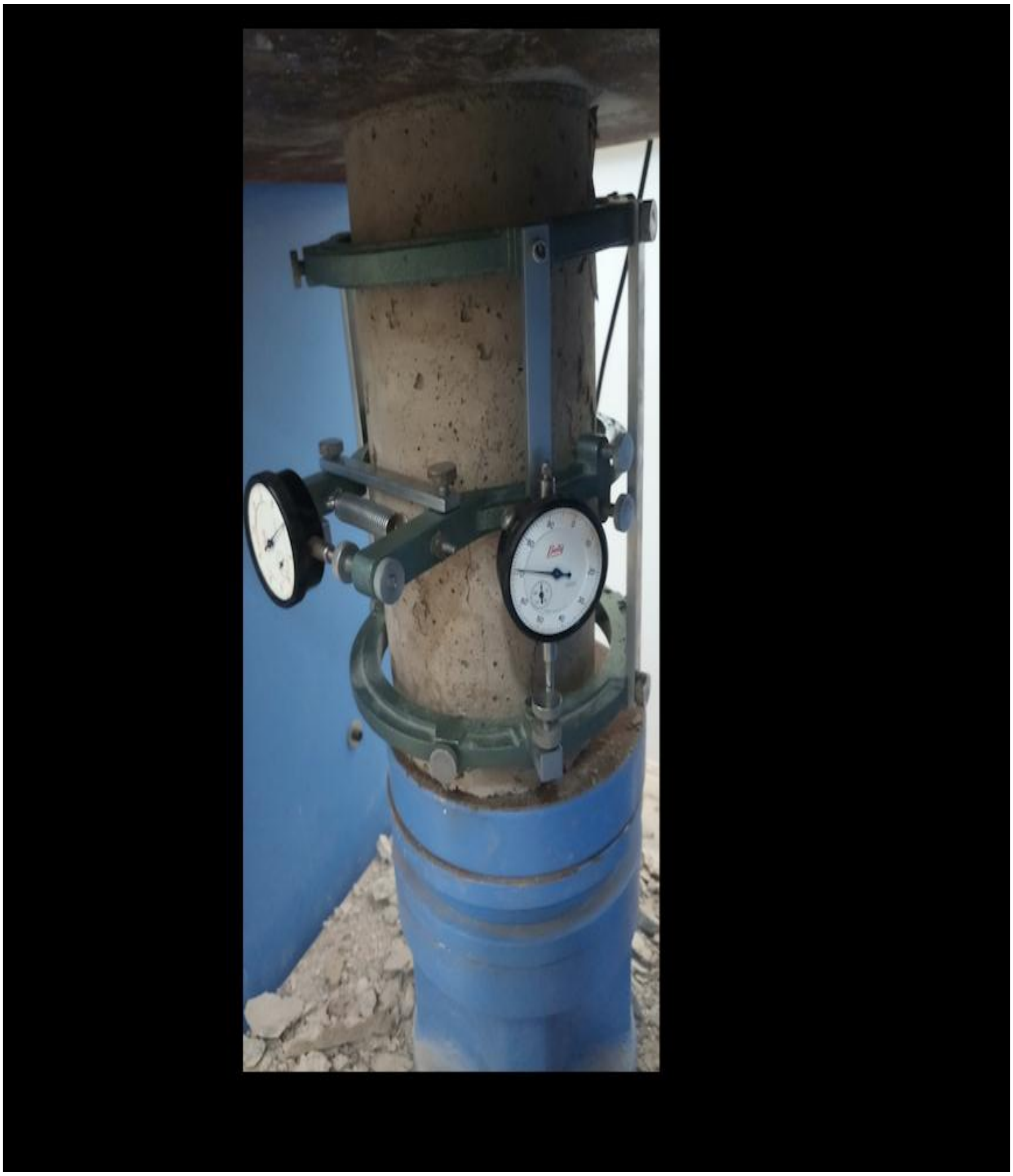


Fig 3.10 Reading after crack in specimen

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 COMPRESSIVE STRENGTH

Compressive strength is an important property for every concrete as it also rely on curing time and temperature. We test different cubes which are having different fly ash to slag ratio. The test were carried after 28 days of casting of geopolymer concrete. The ambient cured and oven cured both sample are tested.

Ambient cured cube strength according to their Fly ash/Slag ratio

FLY ASH/ SLAG	MEAN STRENGTH OF CUBE (MPa)
25/75	14.2
50/50	16.7
75/25	19.12

TABLE 4.1 STRENGTH V/S FLY ASH/SLAG FOR AMBIENT CURED SAMPLE

Oven cured cube strength according to their Fly ash / Slag ratio

FLY ASH / SLAG	MEAN STRENGTH OF CUBE (MPa)
25/75	25.2
50/50	26.5
75/25	29.2

TABLE 4.2 STRENGTH V/S FLY ASH/SLAG FOR OVEN CURED SAMPLE

Comparison between strength of Ambient cured sample and oven cured at a particular fly ash/slag ratio.

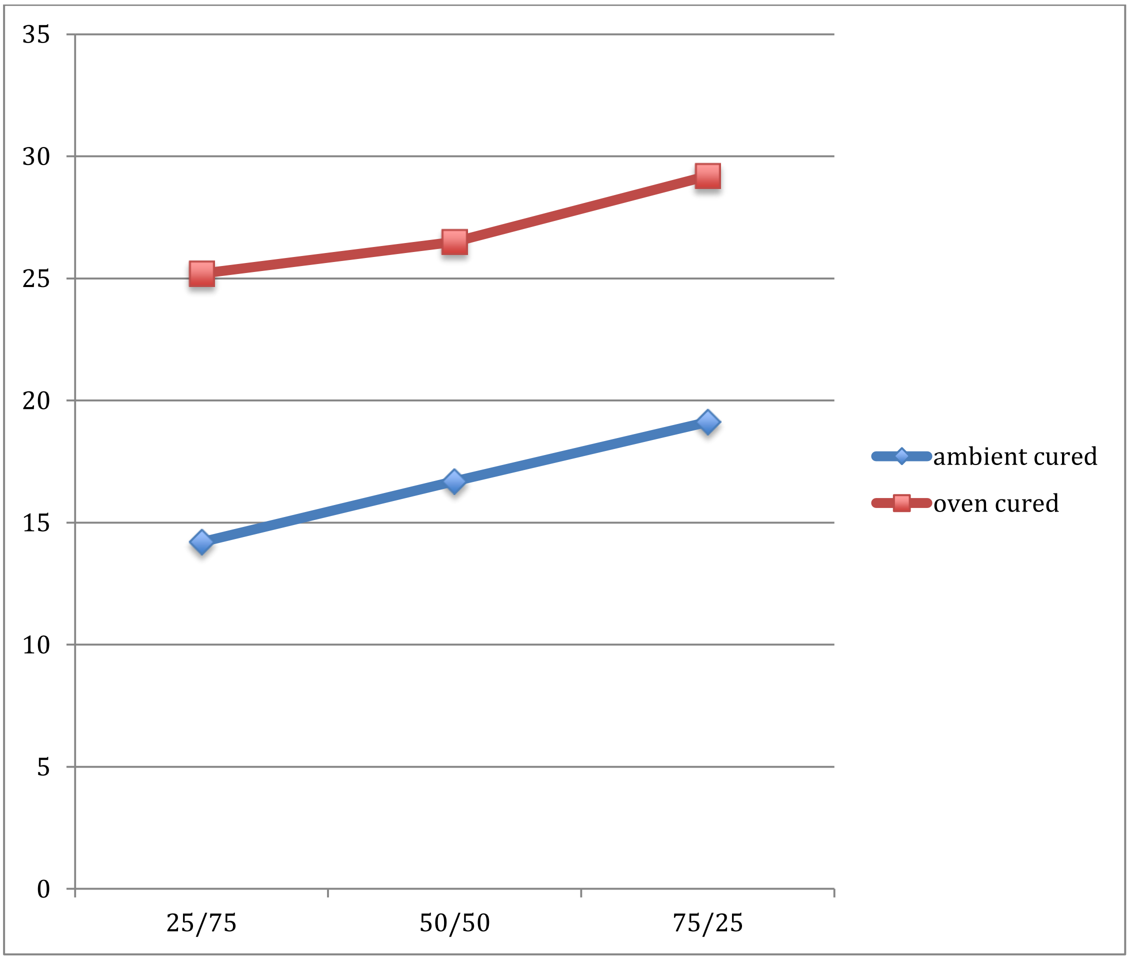


FIG. 4.1 GRAPH BETWEEN STRENGTH AND FLY ASH/ SLAG

4.2 GEOPOLYMER CONCRETE PROPERTY

Material properties of geopolymer concrete like modulus of elasticity and poisson's ratio is an important parameter in study of geopolymer concrete.

They both were determined by using Extensometer test . A dial gauge measures the lateral extension, and a removable spacer strip is for the initial setting of the dial gauge. Mounting of extensometer on the specimen is with the help of screws.
This test is carried on cylindrical specimen.

Modulus of Elasticity for ambient cured specimen according to Fly ash/ Slag ratio

FLY ASH/ SLAG	MODULUS OF ELASTICITY (GN/m^2)
25/75	19.5
50/50	19.3
75/25	20.7

TABLE 4.3 'E' V/S FLY ASH / SLAG FOR AMBIENT CURED

Modulus of Elasticity for Oven cured specimen according to Fly ash/ Slag ratio.

FLY ASH/ SLAG	MODULUS OF ELASTICITY (GN/m^2)
25/75	21.2
50/50	22.2
75/24	23.4

TABLE 4.4 'E' V/S FLY ASH / SLAG FOR OVEN CURED

Comparison between Modulus of Elasticity of Ambient cured sample and oven cured at a particular fly ash/slag ratio

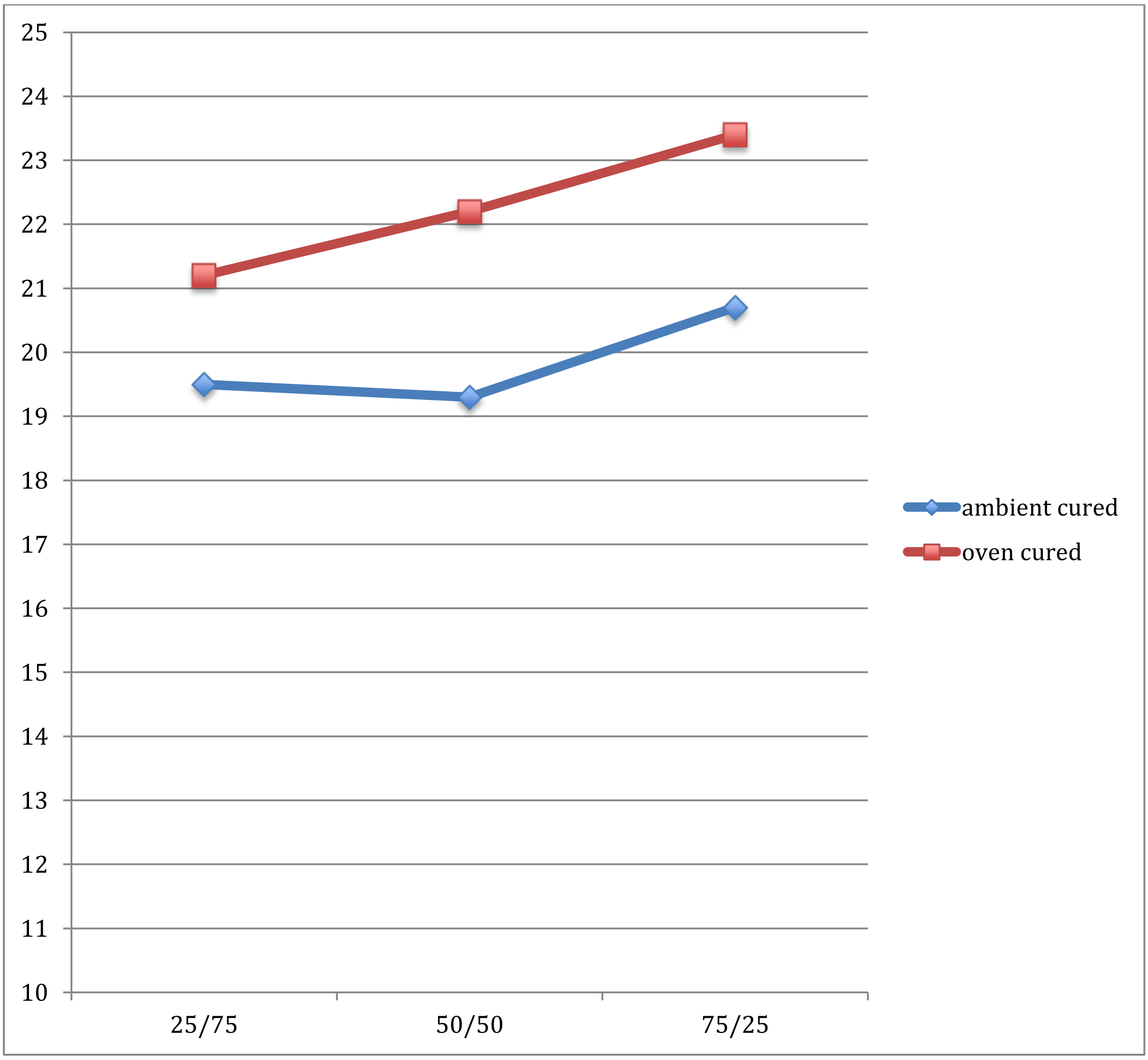


FIG. 4.2 GRAPH BETWEEN MODULUS OF ELASTICITY AND FLY ASH/ SLAG

Poisson’s ratio for ambient cured specimen according to Fly ash/ Slag ratio.

FLY ASH/SLAG	POISSON’S RATIO (μ)
25/75	0.141
50/50	0.129
75/25	0.158

TABLE 4.5 'μ' V/S FLY ASH / SLAG FOR AMBIENT CURED

Poisson's ratio for Oven cured specimen according to Fly ash/ Slag ratio.

FLY ASH/ SLAG	POISSON'S RATIO (μ)
25/75	0.142
50/50	0.13
75/25	0.16

TABLE 4.6 'μ' V/S FLY ASH / SLAG FOR OVEN CURED

Comparison between Poisson's ratio of Ambient cured sample and oven cured at a particular fly ash/slag ratio

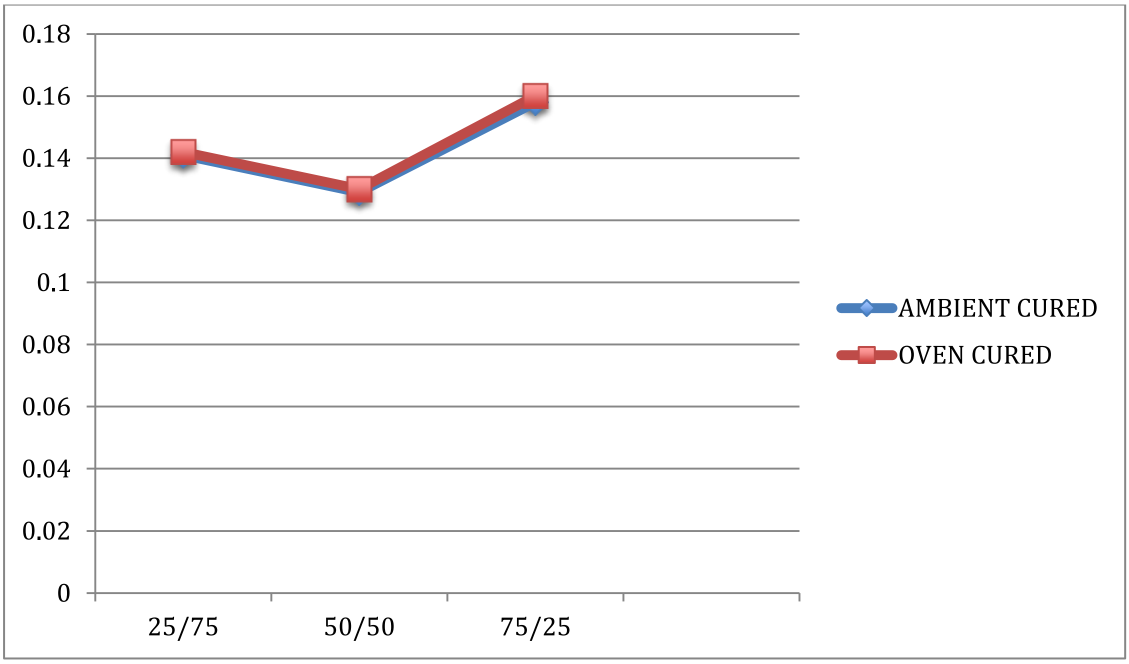


FIG. 4.3 GRAPH BETWEEN POISSON'S RATIO AND FLY ASH/ SLAG

CHAPTER 5

CONCLUSIONS

Regarding to the experiments conducted in the studies of Geopolymer concrete, followings conclusions are extracted

Compressive strength of Geopolymer concrete is increases with increase in fly ash content in fly ash/ slag. It is maximum at 75/25 and minimum at 25/75.

Compressive strength of oven cured samples is greater then ambient cured samples.

Modulus of elasticity of Geopolymer concrete is increases with increase in fly ash content in fly ash/ slag. It is maximum at 75/25 and minimum at 25/75.

Modulus of elasticity of oven cured samples is greater then ambient cured samples.

There is not much difference between poisson's ratio of oven cured samples and ambient cured samples.

Poisson's ratio is varying according to fly ash / slag ratio.

We can use Geopolymer concrete for infrastructure work as well.

In making of Geolopymer concrete fly ash are used. So, no extra land are required to dump fly ash.

Geoploymer concrete can be used for making beam column junction of reinforced concrete structure.

We prefer fly ash / slag ratio 75/25 and oven cured sample over any other samples.

CHAPTER 6

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