JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

GEOPOLYMER CONCRETE – AN INNOVATIVE & ECOFRIENDLY CONSTRUCTION MATERIAL AND AN ALTERNATIVE TO PORTLAND CEMENT CONCRETE

Shubham Dubey[1], Prof. Vishnu Pore[2], Prof. Dr. Navnath V. Khadake[3]

M.E. Student[1], Assistant Professor[2], Head of Department[3]
Department of Civil Engineering, JSPM's Imperial College of Engineering & Research, Wagholi, Pune, India.

Abstract

This research presents a research review on the comparison of Geopolymer concrete with Ordinary cement concrete. Now a day the world is in need of many types of improvements in every field of science. Especially, in order to mere the demand of the advancements. In the field of civil engineering, advancements in the concrete technology is an area in which many researchers are working on. Everybody in the universe emits appropriate amount of carbon dioxide into the atmosphere called as the carbon foot print. But the carbon foot print of the cement is comparatively more than the remaining aspects. As the concrete is one of the widely used construction material, manufacture of concrete results in CO2 emissions and hence pollution in the universe results in the global warming problem. So there has evolved the geo polymer concrete called as green concrete. The Geopolymer materials is an environmental friendly construction material. This study is based on the use of Ground Granulated Blast Furnace Slag (GGBS) in synthesizing cement free geo polymer concrete. The Geopolymer concrete is manufactured by polymerization of GGBS slag, Silica fumes with alkali activator fluid (Sodium silicate and sodium hydroxide). Further based on this review, later an experimental study was performed on the application of the reinforced geo polymer beams. Tests will be performed in order to show whether they follow any pattern in their properties as that of a normal cement concrete, these geo polymer beams will be tested for the Flexural strength, shear strength and the characteristic compressive strength followed by the crack width patterns to inter relate with the normal RCC beams. Because, we have conventional code of practice for ordinary reinforced cement concrete where as we do not have for the geo polymer concrete in order to fetch some relation for both the type of concretes whether it becomes overestimate or under estimate.

The study is conducted to compare the similarity (if any) between GPC and OPCC on the mechanical properties mainly like flexure, shear, crack width, crack pattern, residual load, Residual strength etc… are considered for the comparison. The objective of the study is to assess if the code applicable for normal RCC are also applicable for Geopolymer concrete.

Keywords – Geopolymer concrete, GGBS (Ground Granulated blast furnace slag), Carbon footprints, flexural strength, compressive strength, crack width.

1. Introduction

This paper presents a brief history and review of Geopolymer technology with the aim of introducing the technology and the vast categories of materials that may be synthesized by alkali activation of Alumino silicates. Cement is indispensable for construction activity, so it is tightly linked to the global economy. Cement production has a growth of 2.5% annually, and is expected to rise from 2.55 billion tons in 2006 to 3.7-4.4 billion tons by 2050. Now a day's concrete is playing a vital role in this emerging world and has brought a great change in the evolution of the world. But at present, the making of concrete is effecting the atmospheric conditions. The temperatures got increased to a great extent as a result of the emission of carbon dioxide as the greenhouse gas emissions in to the atmosphere. This is creating a great problem in the environment, causing imbalances in the eco system, which has brought a mutation in the bio diversity as well. Everybody in the universe emits appropriate amount of carbon dioxide into the atmosphere called as the **carbon foot print**. But the carbon foot print of the cement is comparatively more than the remaining aspects. So, many researchers are doing research on various emerging concretes which are suitable for that appropriate conditions one among them is the geo polymer concrete. Concrete is used globally in the construction of Buildings, bridges, pavements, runways, sidewalks, and dams. It is usually got associated with Portland cement as the main component for making concrete. Portland cement concrete industry has grown universally in recent years. With the over growing urbanization and industrialization the infrastructural development is responsible for huge amount of utilization of concrete as a construction material. It is estimated that the production of cement will increase from 1.5 billion tons in 1995 to 2.5 billion tons in 2015. In this respect, the Geopolymer technology proposed by **Davidovits** shows considerable promise for application in concrete industry as an alternative binder to the Portland cement and has generated lot of interest among engineers.

What is Geopolymer concrete?

Geopolymer concrete is an innovative and ecofriendly construction material and an alternative to Portland cement concrete. Use of Geopolymer reduces the demand of Portland cement which is responsible for high CO_2 emission. Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant. Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

Composition of Geopolymer Concrete

Following materials are required to produce this concrete:

- Fly ash - A byproduct of thermal power plant
- GGBS - A byproduct of steel plant
- Fine aggregates and coarse aggregates as required for normal concrete.

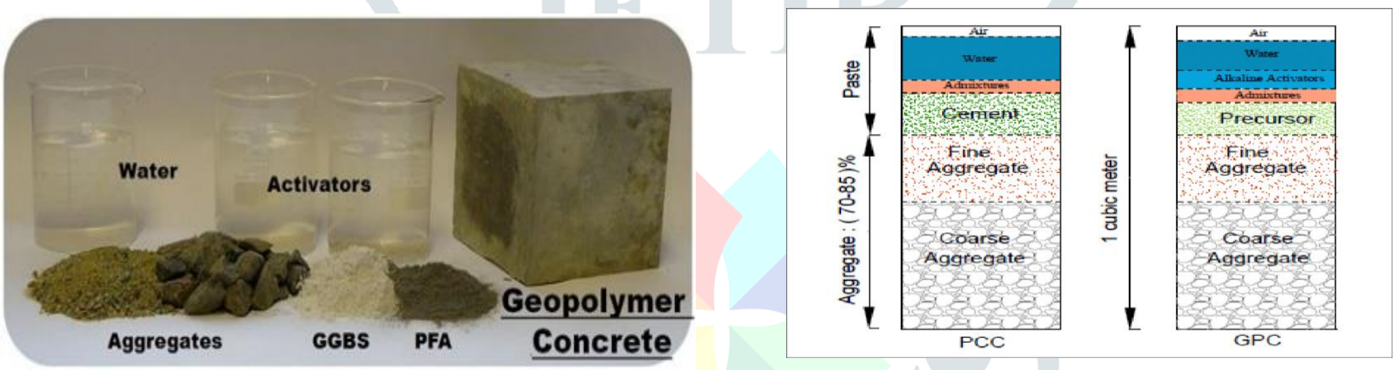


Fig.1 Composition of Geopolymer concrete

- Alkaline activator solution for GPCC as explained above. Catalytic liquid system is used as alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water.
- The role of alkaline activator solution is to activate the geopolymeric source materials containing Si and Al such as fly ash and GGBS.

2. Literature Review

Davidovits (1994) [1] has done a research the presence of alkalis in the normal Portland cement or concrete could generate dangerous Alkali-Aggregate-Reaction. However the geo polymeric system is safe from that phenomenon even with higher alkali content. Previous studies have reported that geo polymers possess high early strength, low shrinkage, freeze-thaw resistance, sulfate resistance, corrosion resistance, acid resistance, fire resistance, and no dangerous alkali-aggregate reaction. Based on laboratory tests, Davidovits (1988b) reported that Geopolymer cement can harden rapidly at room temperature and gain the compressive strength in the range of 20 MPa after only 4 hours at 20 degree Celsius and about 70-100 MPa after 28 days. **Comrie et.al. (1988)** [2] has conducted tests on Geopolymer mortars and reported that most of the 28-day strength was gained during the First 2 days of curing.

Hai–yan zhang , venkatesh kodur ,liang cao, shu-liang Qi (2013) [3] has done a research on the fiber reinforced geo polymers for fire resistance applications they have got to know that the addition of chopped fibers in the Geopolymers provides effective crack patterns, They got to know that the fly ash based Geopolymer cured at ambient temperature provide lower strength than that the metakaolin 2% carbon fibers provides optimum bending properties and compressive strength at ambient temperatures and finally it is useful for fire resistive applications.

Bakharev, Gourley , Johnson& Song et. Al (2005) [4] has done a research on the acid resistance of concrete and reported the results of the tests on acid resistance of Geopolymers and Geopolymer concrete. By observing the weight loss after acid exposure, these researchers concluded that Geopolymers or Geopolymer concrete is superior to Portland cement concrete in terms of acid resistance as the weight loss is much lower.

Thangamani Bindhu & Rama Chandra Murthy (2016) [5] has done a research on Flexural behavior of reinforced geo polymer concrete beams with fly ash and partially replaced with GGBS. He has opted a molarity of 10M and the ratio of alkaline solution as 2.5 with various different proportions of 100% fly ash ,75% fly ash & 25% GGBS and 50% fly ash & 50% GGBS. They have observed that increase in the proportion GGBS has results in increased compressive strength and also observed that geo polymer concrete beams having more tensile reinforcement withstood greater ultimate loads. Beams with the proportion of 25% GGBS will have higher strength than only with normal concrete.

Madeheswaran, Ambily, Dattatreya, Ramesh(2014) [6] have done a research work on the behavior of reinforced geo polymer concrete beams subjected to monotonic static loading they have taken the beam and made to test on the loading frame and the Deflection is calculated with the help of the LVDT (linear variable data transformer). they have got to know that the load Deflection characteristic at mid span of the reinforced GPC and OPCC control beams are found to be similar the crack pattern at different ratios are found to be similar for both GPC and OPCC and also all the beams failed in steel in the flexure and crushing of concrete is done in compression face. They got that Geopolymer is more ecofriendly and economical and has a potential to replace the cement concrete beams.

Anurag Mishra et. al. (2012) [7] has done a research on the Effect of concentration of alkaline liquid and curing time on strength and water absorption of Geopolymer concrete. With NaOH, Na_2SiO_3 as alkali activators. Three different concentrations of NaOH at the same 3 different curing times. For compressive strength 7 & 28 days and for tensile strength test 28 days using specimen. In the test separate solutions of NaOH & Na_2SiO_3 of required concentrations were prepared 24 hours before to casting. The concentrations of NaOH 8M, 12M & 16M. The cubes size is 5cm X 5cm X 5cm, 12 cubes are used. With the increase in concentration of NaOH from 8M, 12M, & 16M. Increases in compressive strength were also observed with increases in curing time 24 to 48 hours. When curing time further increased from 48 to 72 hours, there is no change in compressive strength at the same time for tensile strength was decreased.

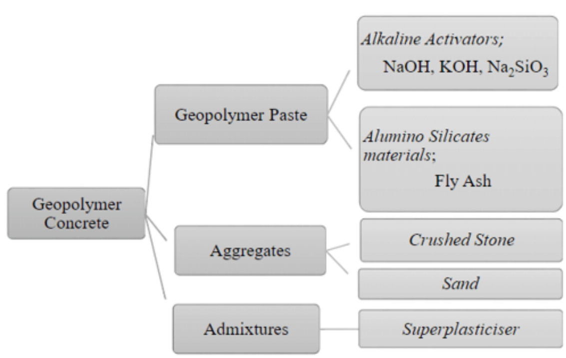
S. Jaydeep and B. J. Chakravarthy [8] prepared an optimum mix for Geopolymer concrete using admixtures. Concrete cubes of size 150×150×150mm were prepared to find out compressive strength at 7 and 28 days. Results showed that the addition of sodium silicate solution to the sodium hydroxide solution as an alkaline activator enhanced the reaction between the source material and solution. Oven cured specimen gives the higher compressive strength as compared to direct sunlight curing. It was also observed that Geopolymer concrete is more advantageous, economical and ecofriendly method when compared with conventional concrete**.**

3. PREPERATION OF GEOPOLYMER CONCRETE

3.1 Ingredients of Geopolymer Concrete

(I) Alkali Activators

Alkaline activators are the substances in which they revitalize the reaction rate for the process of the reaction to occur the most commonly used alkaline liquid used in Geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) or potassium hydroxide (KOH) and potassium silicate (K_2SiO_3). Alkali activators plays an important role in the polymerization process. Reactions occurs at a high rate when the alkaline liquids contain soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Furthermore, after a study of the Geopolymerisation of sixteen natural Al-Si minerals, they found that generally the NaOH solution caused a higher extent of dissolution of minerals then the potassium hydroxide solution. But economically sodium hydroxide and sodium silicate is less cost compare to potassium hydroxide and potassium silicate.

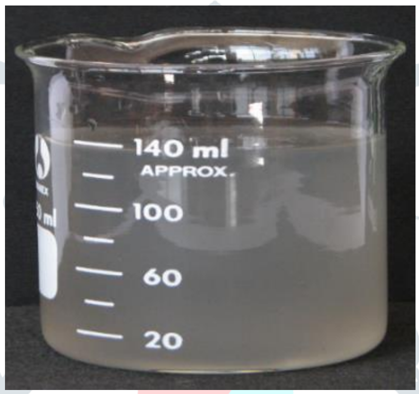


(a) Sodium Hydroxide (NaOH)

Sodium hydroxide also known as lye and caustic soda, it is an inorganic compound. It is a white solid and highly caustic metallic base and alkali of sodium which is available in pellets, flakes, granules, and as prepared solutions at different concentrations. Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air. Sodium hydroxide is used in many industries, mostly as a strong chemical base in the manufacturing of pulp and paper, textiles, drinking water, soaps, and detergents, and as drain cleaner. Pure sodium hydroxide is a whitish solid, sold in pellets, flakes, and granular forms, as well as in solution. Sodium hydroxide is highly soluble in water and lower soluble in ethanol and methanol.

(b) Sodium Silicate (Na_2SiO_3)

Sodium silicate is also called as water glass or liquid glass, these materials are available in aqueous solution and in solid form. The pure composition is colorless or white, but commercial samples are often greenish or blue owing to the presence of iron containing impurities.



(II) Aggregates

Aggregates are the substances which plays major role in concrete. Aggregates include as much as 70-85% of a typical concrete mix, so they must be properly selected to be durable, blended for optimum efficiency, and properly controlled to produce consistent concrete strength, workability, finishbility, and durability Aggregates play a key role in the taking of the strength of the concrete so, they are generally mixed in higher proportions than remaining things in the concrete they are discriminated as follows

(a) Coarse Aggregate

The mechanical properties of coarse aggregate will consume a more effect in conventional concrete strength. The main limitations of coarse aggregate are shape, texture, grading, cleanliness and nominal maximum size. These properties are considering to contain strength, stiffness, bonding potential and absorption. Rough texture and angular coarse aggregate provide greater mechanical bond and are generally more suitable for use in high strength concrete than smooth texture aggregates. Depending on the required strength and other necessary properties, clean, well-shaped, locally available rounded aggregates might perform satisfactory.

(b) Fine aggregates (Quartz Sand)

Fine aggregates are the materials in which the voids which is created by the coarser are to be filled in order to gain higher strength this task will be performed by the fine aggregates generally anything having high density will have a high strength than Less denser material having same material properties so one among them in the finer aggregate is a quartz sand. Quartz sand is plentiful of silica minerals, usually in the form of quartz, which because of its chemical inertness and considerable hardness. It takes place from igneous and metamorphic and sedimentary rocks. It is highly resistance to both chemical and mechanical weathering. Quartz is worldwide, plentiful and durable.

Good examples of quartz sand can be found in Florida. Sand from siesta key beach is sometimes called the whitest in the world although it has competitors. They are found mostly on the coast al areas

(III) Ground Granulated Blast Furnace Slag (GGBS)

GGBS is nothing but ground granulated blast furnace slag which Manufactured as a by-product from the manufacture of pig iron. It is manufactured by quenching of molten iron in blast furnace sent immediately into water or a stream, to produce a glass granular product which is then dried in open yards and ground them into a fine powder. The product obtained at last is GGBS. It acts as an excellent binder in the manufacturing of high performance cement and special concretes. It is a cheaply available material which is a waste, can be used in the concrete making as the traces of iron is present in it imparts more strength than that of normal fine aggregates

(IV) Silica Fume (SF)

Silica fume is a by-product which is obtained by the reduction process of carbothermic in high purity quartz with carbonaceous material like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume is also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150nm. Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material. Silica fume added in concrete to increase compressive strength, bond strength and abrasion resistance. It is typically used in quantities ranging from 7-12% of the mass of the cementitious material..

3.2 Design Mix Calculations

A. General mix calculations

Density = (Mass)/volume
Size of the cube: 0.150m X 0.150m X 0.150m
Volume of one cube = 3.375 X 10-3 m3
Assumed density = 2500kg/ m3
Weight of one cube = 8.43kg
Mix proportion: X: Y: Z
Here, X = Binder for one cube in kg

Y = Fine aggregate for one cube in kg
Z = Coarse aggregate for one cube in kg
Alkali to Binder ratio (A/B): 0.8
Alkali solution = 0.8 X binder
Gypsum=5% of binder
Total Mix proportion: X+Y+ Z
For one cube and one cylinder weights:
The Weight of binder = (Weight of cube / Total Mix proportion) X (X)
The Weight of quartz sand = (Weight of cube / Total Mix proportion) X (Y)
The Weight of Coarse Aggregates = (Weight of cube / Total Mix proportion) X (Z)
The ratio of Na_2SiO_3 to NaOH = 2.5
The Mass of NaOH solution = (2/7) of the alkali solution
The Mass of Na_2SiO_3 solution = (5/7) of the alkali solution

B. Design Mix Calculation for Cube

Mix proportions for a nominal mix of 1:1:2 Geopolymer concrete mix for one cube of size (0.15m X 0.15m X 0.15m) with alkali binder ratio of 0.8.

D. Geo polymer material content

Material		Cube (kg)
GGBS(80%)		1.686
Silica Fumes (20%)		0.421
FINE AGGREGATE (quartz sand)		2.025
COARSE AGGREGATE		4.05
Solution	NaOH	0.924 solids 0.29 of water
Alkaline Liquid	Silicate gel	0.421 of liquid 0.782 of water

3.3 Manufacture of Fresh Concrete and Casting

The fly ash and the aggregates were first mixed together in the 10-litre capacity laboratory concrete pan mixer for about 4 minutes. Then the liquid component of the mixture was then added to the dry materials and the mixing continued for further about 5 minutes to manufacture the fresh concrete.

The fresh concrete was cast into the moulds. For compaction of the specimens, each layer was given 60 to 80 manual strokes using a rodding bar, and then vibrated for 12 to 15 seconds on a vibrating table

3.4 PREPARATION OF TESTING SPECIMEN

Mixing

Mixing of ingredients is done in concrete pan. The cement, fine aggregate and coarse aggregate are mixed with gradual increasing of water to the mix. Wet mixing is done until a mixture of uniform colour and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found by Slump cone test.

Casting of specimens

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides before concrete is poured in to the moulds. The moulds are placed on a level platform. The well mixed green concrete is filled in to the moulds by vibration with the help of beam road and compactors as well. Excess concrete was removed with trowel and top surface is finished level and smooth as per IS 516-1969.

CURING OF TEST SPECIMENS

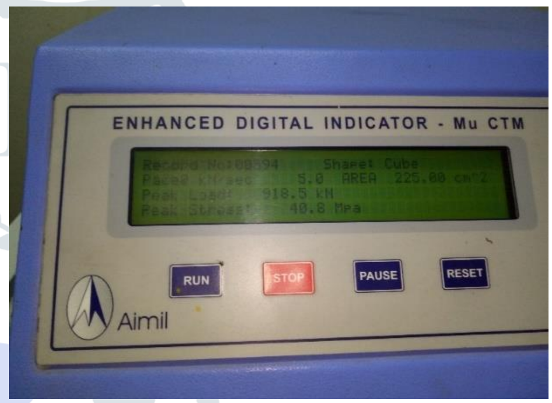
The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting.

Generally, with the help of the literature review it was known that there are Two types involved in the curing process of the specimens i.e heat curing (steam curing) & dry curing. For heat curing (steam curing), the test specimens were cured in the oven and for dry curing, they were cured in the ambient air curing Based on studies, the specimens were heat-cured at 40 °C for 28 days.

After the curing period, the test specimens were left in the moulds for at least six hours in order to avoid a drastic change in the environmental conditions. After demoulding, the specimens were left to air-dry in the laboratory until the day of test. Some series of specimens were not heat-cured, but left in ambient conditions at room temperature in the laboratory.

4. EXPERIMENT SETUP & RESULT

Compressive Strength Test



Compressive strength of Plain cement concrete Cube

Sr.No.	Cube ID	Size of Specimen (Cm^2)	Failure Load (kN)	Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
I	1	22.5	960	42.67	**42.07**
II	3	22.5	928	41.24	
III	5	22.5	952	42.31	
IV	7	22.5	938	41.69	**41.82**
V	9	22.5	956	42.49	
VI	11	22.5	929	41.29	
VII	13	22.5	912	40.53	**41.00**

Compressive strength of Geopolymer concrete Cube

Sr.No.	Cube ID	Size of Specimen (Cm^2)	Failure Load (kN)	Compressive Strength N/mm²	Average Compressive Strength N/mm²
I	2	22.5	909.2	40.41	**39.42**
II	4	22.5	880.5	39.13	
III	6	22.5	871.2	38.72	
IV	8	22.5	869.6	38.65	**40.37**
V	10	22.5	866	38.49	
VI	12	22.5	989.4	43.97	
VII	14	22.5	940	41.78	**41.00**

5. CONCLUSION

With the progress of science and technology in the future, Geopolymers are expected to be widely used as cementing materials through strengthening the control and analysis of raw materials, rational use of catalysts, formulation of standardized efflorescence phenomena. As many researchers expect, the application of Geopolymers will be beneficial for the global environment and economy.
Here, During the Entire 1st stage research of project following are the points of progress achieved.

- Geopolymer concrete exhibits significantly lower CO2 emissions than OPC concretes – up to 90%.
- Alkali-activated material is an innovative and environmentally friendly-engineered material.
- Compressive Strength is almost achieved same as ordinary cement concrete.
- Very Low Creep and Shrinkage – Geopolymer concrete does not hydrate it is not as permeable and will not experience significant shrinkage. The creep of geopolymer concrete is very low.
- GeoPolymer concrete exhibited greater long-term durability properties such as acid, corrosion, sulphate, and fire resistance.
- The application of Geopolymers will be beneficial for the global environment and economy.
- Investigations aimed at user friendly systems, particularly non-corrosive alkali activators.

6. FUTURE PLAN OF ACTION

In the final stage of the project following objective shall be implemented: -

- Design of RCC Beam by using Limit state method considering the factors and properties of Geopolymer concrete with respect to plain concrete.
- Casting Beams as per the finalized mix design for both the concrete i.e. Geopolymer and plain Concrete.
- Curing.
- Experimental setup for Flexural load test in loading Frame.
- Flexural Strength testing.
- Result comparison in each aspect.
- Research and best way forward for the implementation of research to the current Global scenario.

7. REFERENCES

1. *J. Davidovits, "Geopolymers: Inorganic Polymeric New Materials". Journal of Thermal Analysis, 1991, 37, p1633-1656.*
2. *Comrie, D. C., Paterson, J. H., & Ritchey, D. J. (1988). Geopolymer Technologies in Toxic Waste Management. Paper presented at the Geopolymer", First European Conference on Soft Mineralogy, Compiegne, France.*
3. Hai-yan Zhang, Venkatesh Kodur, Liang Cao, Shu-liang Qi. - FIBER REINFORCED GEOPOLYMERS FOR FIRE RESISTANCE APPLICATIONS.
4. Bakharev, T. (2005) Resistance of Geopolymer Materials to Acid Attack: Cement and Concrete Research.
5. Thangamani Bindhu K., and Ramachandra Murthy D.S., Flexural Behaviour of Reinforced Geopolymer Concrete Beams using Fly ash partially replaced with GGBS, International Research Journal of Engineering and Technology (IRJET), Vol.3, Issue 8, August 2016.
6. Anurag Mishra et. al. (2012) Effect of concentration of alkaline liquid and curing time on strength and water absorption of geopolymer concrete.
7. S. Jaydeep , B.J. Chakravarthy. "Study On Fly Ash Based Geo-Polymer Concrete Using Admixtures". International Journal of Engineering Trends and Technology (IJETT).
8. *IS 10262-2009, "Concrete Mix Proportioning – Guidelines", Bureau of Indian Standards, New Delhi.*
9. IS 516- 1959, "*Method of Test for Strength of Concrete*", Bureau of Indian Standards, New Delhi.