Chapter 1

INTRODUCTION

1.1 Background

Concrete is being used in construction industry from the last few decades as the constituents of the concrete are readily available. The strength of the concrete is based on the aggregate shape, size and gradation which form the 50-55% of concrete. Whereas the sand is used to reduce the shrinkage in the concrete and cement is used as the binding material. The sand has been categorized in 4 zones Mostly the sand of zone II is used in the construction works. Nowadays to make the concrete various techniques had been adopted to increase or to improve the mechanical properties of the concrete. Some of the techniques are addition of Glass fibre, coconut fibre,polypropelene fibre and many such kind of fibres are included in concrete to enhance its mechanical properties in some cases the robo sand (M sand) has been also used, but very less research has been carried out in the to make economical and ecofriendly concrete.one of the such concrete is made by mixing of Fly Ash of F class with solution of sodium Hydroxide and sodium silicate and the process that takes place is known as Geo Polymerization and the product is Geo polymer concrete which as ecofriendly or called as green concrete.

1.2 Introduction to Fly Ash

Fly ash is also known as fuel ash. Fly ash is a waste product obtained from thermal industries after burning the combustible substances like lignite ,coal, fossil fuels. This is one of the best examples for sustainable development because cement production is very costly process which involves machinery and it is polluting environment so to save environment and also the construction costs an alternative processes should be

adopted by researchers to find the way out for the utilization of the industrial waste mainly from the thermal power plants. Fly ash utilization has been taking a pace from the last few decades in the construction industry in terms of fly ash bricks even for production of cement although though it has low strength than cement.it can attain the strength comparable to that of the cement. In this study the replacement of cement was made by 30%, 70%, and 100% of Fly ash and fly used in the study was brought from Neveli Power plant, Tamil nadu.Fly ash is available in abundance all throughout the world. Mainly in India United Kingdom and in Saudi Arabia the fly ash is found in abundance.

1.2 Introduction to geo polymer concrete

Geo polymer concrete is defined as concrete in which the replacement of cement is made with fly ash by addition sodium hydroxide solution and sodium silicate and the samples need to be kept at the temperatures of 60ºC for 24 hours or more in oven.when compared to normal concrete geo polymer concrete has more difficulties in preparation so necessary precautions need to be considered while preparation of geo polymer concrete. Geo polymer is an ecofriendly because there is no use of cement which is made in rotary kilns by grinding process which depletes environment because it leads lot of dust and smoke from the chimneys of the industries that manufacture cement. Geo polymer is made up of fly ash which is obtained from thermal power plants and is very cost effective since it is available in abundance and it the Geo polymer concrete poses no major threat to environmental. Fly Ash has been classified into two categories class-C and class-F. Class-C fly ash reacts with alkalies and class-f fly ash doesn't react with alkalies whereas it is pertinent to mention here that in Geo polymer Class F fly ash should be used as it is on the lower side in the calcium content.Geo polymer is prepared just by mixing the sand and coarse aggregate and the chemical solution(i.e sodium Hydroxide and Sodium Silicate solution) in pan mixer for around 15-20 minutes the geo polymer forms semi solid paste which binds the aggregates together and takes the formation of just that of conventional concrete. Few Research studies have proved that the use of small quantity of nylon fibre can also enhance some of the mechanical properties of the Geo polymer, but the Geo Polymer attains comparable results to that of the conventional concrete and keeping in view that environmental aspect also.

1.4 Thesis Structure

Chapter 1. *Introduction-* Describes about the background on concrete, introduction to fly ash and geo polymer concrete.

Chapter 2. *Literature review-* Discusses about various investigations and findings from the researches as the studies that has been carried out so far.

Chapter 3. *Scope and objective of the study-* includes the scope and the objective of the present study.

Chapter 4. *Materials and Methodology* – Discusses about materials used and methodology followed in present study like material properties, mix design and sample preparation, mixing, casting, curing and testing procedure done in this study.

Chapter 5. *Results and Discussion-* Discusses about the tests conducted on the specimens, such as compressive strength, flexural strength, splitting tensile strength and modulus of elasticity.

Chapter 6. *Future scope of the research study* – The chapter Discusses about the research gap in the study that may pave way for future research scholars to full fill that gap.

Chapter 7. *Conclusions-* The total sum up of the results is discussed.

Chapter 8. *References*.

Chapter 2

LITERATURE REVIEW

2.1. General

The formation and investigation in the preparation of the geo polymer concrete carried out by various researchers in the different part of the world. In this chapter, the work done by the other researchers till date has been summarized and which makes the scope of this study.

2.2 Literature review

Pattanapong Topark-Ngarm (2014) studied about setting time, bond strength of geo polymer concrete of various mix proportions of sodium silicate and sodium hydroxide ratio of 1:1 and 1:2 tried with various molarity solutions 10M,15M,20M sodium hydroxide solution by casting cubes, cylinders, and checking their engineering properties and doing setting time test for various mixes and geo polymer concrete been reinforced with circular cages was checked for bond strength for 7day period and had been understood that 15M sodium hydroxide solution and ratio silicate : hydroxide is 1:1 has good compressive strength.

Farhad Aslani(2016) explained about thermal properties of geo polymer concrete.. he did temperature changes and rate of heating and calculated split tensile strength for 7day, 28 day strength. used cylinders after keeping the cylinder in oven at elevated temperatures and same process for compressive strength and flexural strength and modulus of elasticity and thermal strain occurred at different elevated temperatures of geo polymer concrete on comparison with ordinary Portland cement concrete. It has been understood in almost all the aspects geo polymer concrete has got good experimental values than ordinary Portland cement concrete.

Liu, C. S. Cai *et al* (2016) explained loess stabilization of fly ash based geo polymer concrete by calculating mix proportions of activator sodium hydroxide and potassium hydroxide then calculating unconfined compressive strength of samples out of these best six samples based on percent of water/fly ash+ loess, fly ash/loess were considered each three samples for activators sodium hydroxide and potassium hydroxide done their ucs graph and calculated modulus of elasticities for soil samples and thus did x ray diffraction spectroscope studies of fly ash and loess and all six soil samples and also microstructural model of geo polymer and loess. here it was proved that geo polymer gel with loess showed better mechanical properties and also best binding effect.

William Gustavo Valencia Saavedra *et al* (2016) studied about fly ash slag based geo polymer resistance to magnesium and sodium sulphate attacks by taking samples of opc with exposure of magnesium sulphate and sodium sulphate for different periods of time compared with fly ash/granulated blast furnace slag with exposure of magnesium sulphate and sodium sulphate for different periods of time used compressive strength graph and also calculated compressive strength loss and did XRD studies and SEM microscopic study here they proved fly ash slag based geo polymer is better in both sulphate attacks and magnesium sulphate attacks also when compared to ordinary Portland cement.

Alireza Mohammadinia, et al (2016) studied about strength development and micro fabric structure of recycled aggregates like crushed brick, recycled concrete aggregate, recycled asphalt pavement stabilized with geo polymers UCS 7-day test was done based on compaction either static or dynamic and curing temperatures at room temperature and 40°c and fly ash 0%,4%,8% variations etc scanning electronic microscope(SEM) did microstructure development study in fly ash and 4% fly ash with crushed brick, recycled concrete aggregate and recycled asphalt development and also EDS analysis of various samples and resilient modulus of recycled aggregates with 4%,16% fly ash at 40°c.this research has compared geo polymer stabilization with 8%,16% fly ash with crushed brick and proved recycled concrete aggregate will be useful for pavement as per the results obtained.

Les Vickers *et al* (2014) studied about thermally induced shrinkage in fly ash based geo polymers using fillers Alumina filler and wolastonite filler 5% 10% filled in the geo polymer concrete to control shrinkage loss tested under temperatures upto 1000℃ calculated densities at all temperatures of the control and the 4 samples calculated % mass loss and % volumetric shrinkage at different temperatures and compressive strength and flexural strength at different temperatures and also thermal expansion and SEM microscopic study showed the different samples normal and alumina wolanisite filler in microscopic study. This paper proved the addition of fibres improves the strength and other aspects under different temperature compared to normal concrete.

Partha Sarathi Deb *et al* (2015) studied about the shrinkage behavior of slag based geo polymer concrete.in the experiment the samples of fly ash replaced with 10%,20% blast furnace slag with sodium silicate/sodium hydroxide was either 1.5 or 2.5 varying with molar solutions 10M,20M solutions and checked their drying shrinkage at age of 180 days cured at a room temperature 20+-2℃ and had done compressive strength of various samples. compared drying shrinkage values with Australian standard codes AS3600 geo polymer mix values thus this research proved that compressive strength increases with increase of slag content and decrease in shrinkage.

Shi Cong Kou1 *et al* (2007) studied about Fly ash used as cement replacement which influence on the properties of recycled aggregates considering two concrete mixtures (w/B) ratios 0.45 and 0.55 with recycled aggregate replacing 0%,20%,40%,60%,80%,100% by weight replacements of natural aggregate. fly ash replaced by cement is 20-35%. compressive strength tests , tensile splitting test, static modulus of elasticity, drying shrinkage, chloride permeability tests done both the (w/B) ratios 0.45 and 0.55. This paper concluded that compressive strength, split tensile strength, modulus of elasticity decreases as recycled aggregate increases. but shrinkage decreases. creep also reduces fly ash replacement is done resistance to chloride ion pentration decreases as recycled aggregate content increases.

Aimin xu *et al*(1994) studied about microstructure development in high volume fly ash cement system with 60% fly ash by weight as a binder as the strength develops per age and 78% of control specimen at 180 days. calculated compressive strength and flexural strength for high volume fly ash compared without fly ash. did XRD studies and SEM studies of microstructural development of HVFA at one day curing and 7 day curing. the results proved high volume fly ash in coroporation(60% by weight of binder)in cement physically and chemically influenced the microstructure of the cementious material.

In this literature study the researchers studied about geo polymer concrete and its durability and they also explained about flyash and recycled aggregate replacement till date no paper or publication explained about 100% replacement of flyash and its mechanical properties.Till date many codes and publications has suggested replacement only upto 30% of cement but in this study the replacement of about 70% and 100% of cement was carried out.

Chapter 3

SCOPE AND OBJECTIVE

3.1 objective

- To Prepare the Design Mix for M-30 grade concrete and to study its mechanical properties.
- To make the 30% replacement of Cement in concrete with that of the Fly Ash of F class.
- To make the 70% replacement of cement in concrete witht that of the Fly Ash of F class.
- To prepare the concrete with 100% replacement of cement.
- To make the comparative studies of various Mix Designs on the basis of their mechanical properties

3.2 Scope

- To make the way out for the utilization of the fly Ash that is available at thermal Power plants in abundance.
- To make the sustainable environment for the future generations.
- To make the cost effective and ecofriendly concrete.
- To understand the process of polymerization and to make the optimum dosage of chemicals for the formation of geo polymer concrete.
- To put the usage of Geo polymer in the advanced Structural Engineering Structures

Chapter 4

MATERIALS AND METHODOLOGY

4.1 Materials used :- In this project work cement, fly ash, sand, coarse aggregate, and water, chemicals like sodium silicate, sodium hydroxide, and super plasticizer, ply wood boards were used.

4.1.1 Cement

The cement of Grade 53 was used and was obtained from Vellore Tamil nadu.

Table 4.1 Physical Properties of Cement

S.no	Test particulars	Result obtained
1	Fineness	4%
2	Intial setting time	28min
3	Final setting time	550min
4	Specific gravity	3.13

4.1.2 Fly ash

Fly ash in this project used was class f fly ash which is obtained from lignite factories as a waste product by burning combustible substances like fossil fuels, coal, lignite etc. It is a binding and soft in nature with low calcium content compared to another grade class c fly ash. It does not react with alkalis. Specific gravity of fly ash is 2.5. Fly ash here obtained from neyveli lignite corporation neyveli.

Table 4.2 Chemical Property of Class-F Flyash

S.no	Chemical Composition Of Fly Ash	Flyash (class f)%
1	Sio2 +Al2o3+Fe2o3 min	68.8
2	So3 max	7
3	Moisture content, maximum	4
4	Loss on ignition. maximum	6

4.1.3 Coarse aggregate

Coarse aggregate play an important role in preparing concrete as it constitutes about 50-55% of concrete and the main constituent responsible for the strength of the concrete. The aggregate used in this study were of the size of 12mm and and 20mm of the maximum size If the size is more the workability of the concrete will get reduced and will pose difficulty in compaction. According to IS 383-1970 standards angular shaped aggregates were used.

Table 4.3 Physical Properties of Coarse Aggregate

S.no	Test particulars	Result obtained
1	Fineness	7.1
2	Specific gravity	2.69
3	Water absorption	0.5%
4	Moisture content	Nil

4.1.4 Fine aggregate

Sand here used is of zone-II fine sand ,fine aggregate passing through 4.75mm sieve and retained on 2.36mm sieve conforming is 383-1970.

Table 4.4 Physical Properties of Fine Aggregate

S.no	Test particulars	Result obtained
1	Fineness	2.4
2	Specific gravity	2.50
3	Water absorption	1%

4.1.5 Water

Water which is available in the laboratory premises and was used in mixing of concrete and curing of specimens Water content depends on cement unit weight, grade of concrete, shape of coarse aggregate, type of sand etc. by using IS- 456-2000.

4.1.6 Sodium hydroxide

Sodium hydroxide is a strong base. It is in pellet form. Its soluble in water. Since it has better binding property when mixed with fly ash and water so in the form of

Solution. Here sodium hydroxide is used in 100% replacement of fly ash of cement which is not possible without any chemical reaction.Sodium Hydroxide was brought from national scientific laboratory Guntur.

4.1.7 Sodium silicate

Sodium silicate is also known as water glass. It is white powdered substance which having good solubility in water and it is alkaline in nature. So 2.5 times sodium hydroxide solution was considered to that of the sodium silicate. Formula for sodium silicate is Na_2SIO_3.It is combined with sodium hydroxide which forms the cement like binding property. Sodium silicate is brought from national scientific laboratory Guntur.

4.1.8 Super plasticizer

Super plasticizer is used to increase the workability of concrete.In this study since it was not possible to alter the water cement ratio as it will effect the process of Geo Polymerization. In this project the total quantity of super plasticizer that was used was 1.515kg.

4.2 Preparation of Normal Concrete

- In case of normal concrete, based on grade of concrete mix proportion of cement, sand and coarse aggregate should be taken.
- The mix design has been done by using american concrete institute method based on number of moulds and unit weight of concrete here M30 grade concrete is used so 1:2:2.5 proportion mix is used.
- First take coarse aggregate according to the proportion in the tray and measure the weight in the weighing machine pour it in the pan mixer and then take sand according to the proportion in the tray and measure the weight in weighing machine Pour it in the pan mixer on the machine mix it for a while.
- By using indian standard codes IS 456-2000 water proportion should be taken based on grade of concrete and also cement weight now mix the cement, sand, and coarse aggregate in the pan mixer adding water into the pan mixer on the machine mix it properly.
- While mixing drop water from flask slowly thus it will mix properly. After mixing take the mixture into a tray after completing the task clean machine four to five times such that particles are not present in the machine. Do not put your

hands in the machine while machine is on be safe hand injury may happen please be safe .

- Do not cross the water/cement ratio such that it will become self compacting concrete.

Thus with some safe precautions do the experimental work of normal concrete properly.

4.2.1 Casting

- While casting cube moulds take mix in the cube in three layers in a cubical shape. compact the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs in the mould. compact properly otherwise honeycombing will be occurred.
- While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape compact the mix with tamping rod 4 to 5 times per layer keep this cylinder for 24 hrs in the mould .
- In case of big cylinder moulds take mix in the big cylinder in five to six layers in the big circle shape compact the mix with tamping rod 5 to 6 times per layer keep this cylinder for 24 hrs in the mould .
- In case of prism moulds take mix in the prism in the three to four layers in the rectangular shape. compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer keep the prism for 24 hrs in the mould.

4.2.2 Curing of Normal Concrete

After 24 hours remove the Specimen from the moulds keep the specimens for curing upto 7 day and 28 day more the curing more the strength will occur in the specimen thus we can observe the strength from 7 day to 28 day after curing dry the moulds for some time upto one hour then it is dried now it is ready for testing.

4.2.3 Mixture of Normal Concrete

American concrete institute method is used for these mix design as more material will be obtained when compared to IS- 10262:2009 based on grade of concrete used and no of moulds used to know the total weight of concrete to be used.

1.cement-30kg.

2.sand-60kg.

3.coarse aggregate -75kg.

4.water-13.5kg.

4.3 Concrete Preparation Of 30% Cement Replacement With Fly Ash.

- In case of 30% cement replacement with fly ash. in this process we are just replacing cement with fly ash as per the mix design specified per concrete grade.
- 30% cement replacement with fly ash and cement and sand, coarse aggregate in 1:2:2.5 american concrete institute method is used for determining total quantity for this trail.
- In this experiment small mixer was used first pour coarse aggregate which is properly weighed in a tray and then pour sand which is of weight measured According to mix design and mix both of them properly.
- Then add fly ash on it because it is more heavier in weight then fly ash according to indian standard code IS 456-2000 water cement ratio is taken based on the grade of concrete and unit weight of cement.
- On the switch from the current board mixture rotate anticlockwise take water according to mix design in a volumetric flask pour the water while mixing then see that mixing is proper or not.
- After the mixture is done switch off the machine lift the machine from the right pour the concrete mixture into the tray properly.
- Clean the machine properly no particle should be remained on the machine so that it will be not create problem for future use.

4.3.1 Casting

- While casting cube moulds take mix in the cube in three layers in a cubical shape. compact the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs. compact properly otherwise honeycombing will be occurred.
- While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape. compact the mix with tamping rod 4 to 5 times per layer keep this cylinder for 24 hrs in the mould.

- In case of big cylinder moulds take mix in the big cylinder in five to six layers in the big circle shape compact the mix with tamping rod 5 to 6 times per layer keep this cylinder for 24 hrs in the mould.
- In case of prism moulds take mix in the prism in the three to four layers in the rectangular shape. compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer keep the prism for 24 hrs in the mould.

4.3.2 Curing

After 24 hours Remove the specimens from moulds then keep the specimens for curing up to 7 day and 28 day more the curing more the strength will occur in the specimen thus we can observe the strength from 7 day to 28 day after curing dry the specimens for some time up to one hour after drying it is ready for testing.

4.3.3 Mixture Of 30% Cement Replacement With Fly Ash

American concrete institute method is used for these mix design as more material will be obtained when compared to IS 10262:2009 based on grade of concrete used and no of moulds used to know the total weight of concrete.

1.Cement-4.1kg.

2.Flyash-1.7kg

3.Sand-11.6kg.

4.Coarse Aggregate -14.5kg.

5.Water-2.38kg.

4.4 Preparation of 70% cement replacement with fly ash Concrete.

- In case of 70% cement replacement with fly ash, in this process we are just replacing cement with fly ash as per the mix design specified per concrete grade.
- 70% cement replacement with fly ash and cement and sand, coarse aggregate in 1:2:2.5 use american concrete institute code for determining total quantity for this trail.
- In this experiment small mixer was used first pour coarse aggregate which is properly weighed in a tray and then pour sand which is of weight measured according to mix design and mix both of them properly.

- Add fly ash on it because it is more heavier in weight then fly ash according to indian standard code IS 456-2000 water cement ratio is taken based on the grade of concrete and unit weight of cement.
- On the switch from the current board mixture rotate anticlockwise take water According to mix design in a volumetric flask pour the water while mixing then see that mixing is proper or not.
- After the mixture is done switch off the machine lift the machine from the right pour the concrete mixture into the tray properly.

Clean the machine properly as such that no particle will be remained on the machine so that it will not create problem for future use.

4.4.1 Casting

- While casting cube moulds take mix in the cube in three layers in a cubical shape. compact the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs. compact properly otherwise honey combing will be occurred.
- While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape compact the mix with tamping rod 4 to 5 times per layer keep this cylinder for 24 hrs in the mould .
- In case of big cylinder moulds Take mix in the big cylinder in five to six layers in the big circle shape compact the mix with tamping rod 5 to 6 times per layer keep this cylinder for 24 hrs in the mould .
- In case of prism moulds Take mix in the prism in the three to four layers in the rectangular shape. compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer keep the prism for 24 hrs in the mould.

4.4.2 Curing of 70% cement replacement with fly ash

After 24 hours remove the specimen from the moulds keep the specimens for curing upto 7 day and 28 day more the curing more the strength will occur in the mould thus we can observe the strength from 7 day to 28 day after curing dry the moulds for some time upto one hour then it is dried now and ready for testing.

4.4.3 Mixture of 70% cement replacement with fly ash

American concrete institute method is used for these mix design as more material will be obtained when compared to IS- 10262:2009 based on grade of concrete used and no of moulds used to know the total weight.

1.cement-1.7 kg.

2.flyash-4.1kg

3.sand-11.6 kg.

4.coarse aggregate -14.5 kg.

5.water-2.38 kg.

4.5 Preparation of Geo Polymer Concrete

Trail no:-1

Geo polymer concrete has been done using hand mixing and prepared a solution of sodium hydroxide solution which is 20% of water content used for mix design and then added sodium silicate which is 2.5 times of sodium hydroxide in a flask and Kept the solution for 24 hrs after 24 hrs did mix design with 100% fly ash replacement and sand, coarse aggregate and added the solution to it mixed it with trowel then added water to it thus the mix was prepared. immediately poured the mix into the moulds.

4.5.1 Casting

- While casting cube moulds taken mix in the cube in three layers in a cubical shape. compacted the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs compact properly otherwise honeycombing will be occurred.
- While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape compact the mix with tamping rod 4 to 5 times per layer keep this cylinder for 24 hrs in the mould.
- In case of prism moulds take mix in the prism in the three to four layers in the rectangular shape compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer keep the prism for 24 hrs in the mould.

4.5.2 Curing of geo polymer trail no-1

After 24 hours remove the specimen from THE mould keep the specimens for curing upto 7 day and 28 day more the curing more the strength will occur in the

specimen. Thus we can observe the strength from 7 day to 28 day. After curing dry the moulds for some time upto one hour then it is dried now it is ready for testing.

4.5.3 Mixture of geo polymer trail no-1

Here american concrete institute method is used for these mix design as more material will be obtained when compared to IS- 10262:2009 based on grade of concrete used and no of moulds used, we will know the total weight.

1.flyash-5.8kg

2sodium chloride-0.476kg.

3.sodium silicate-1.19kg

4.sand-11.6 kg.

5.coarse aggregate -14.5 kg.

6.water-2.38 kg.

4.5.4 Failure Of Geo Polymer Trail No-1

Due to water curing strength decreased and also using the metallic moulds not keeping in oven under temperature for 24 hrs.

4.6 Preparation of Geo Polymer Concrete

Trail no:-2

Geo polymer concrete is done using hand mixing. then prepared a solution of sodium hydroxide solution which is 20% of water used for mix design and then add sodium silicate which is 2.5 times of sodium hydroxide solution in a flask . Kept the solution for 24 hrs. After 24 hrs we can do mix design with 70% cement replacement with flyash and 30% lime, sand, coarse aggregate and added the solution of flask to it. Mixed it with trowel. Then added water to it . Thus the mix is prepared. Immediately poured the mix into the moulds.

4.6.1 Casting

While casting cube moulds take mix in the cube in three layers in a cubical shape. Compact the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs. Compact properly otherwise honeycombing will be occurred. While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape. Compact the mix with tamping rod 4 to 5 times per layer. Keep this cylinder for 24 hrs in the mould. Compact properly.in case of prism moulds take mix in the prism in the three to four

layers in the rectangular shape. Compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer. Keep the prism for 24 hrs in the mould. Compact properly.

4.6.2 Mixture of geo polymer trail no-2

Here American concrete institute method is used for these mix design as more material will be obtained when compared to is 10262:2009. Based on grade of concrete used and number of moulds used, we will know the total weight.

1.Fly ash-4.1kg.

2.Lime-1.7kg.

3.Sodium Chloride-0.476kg.

4.Sodium Silicate-1.19kg

5.Sand-11.6 Kg.

6.Coarse Aggregate -14.5 Kg.

7.Water-2.38 Kg.

4.6.3 Failure of geo polymer trail no-2

Using the metallic moulds. not keeping in oven under temperature for 24 hrs.

Fig 4.6 Failure of Geo Polymer Specimen -1

4.7 Preparation of Geo polymer concrete

Corrected procedure

Finally third trail got the right mix with much more precautions. Metallic moulds were used as it is active and reacts with the mixture and in chemical mixture for stirring also use non reactive metal.here wooden moulds are used as it is non reactive metal. After mixing and mould preparation. moulds along with cubes, cylinders and prisms are be kept at a 60 degree temperature for 24hrs to attain strength. The aggregate using here like coarse aggregate should pass through 10mm sieve. fine aggregate like sand should pass through 90mm sieve. Chemical mixing of sodium hydroxide of 14 molar solution and sodium silicate solution which is 2.5 times of sodium hydroxide. super plasticizer used for binding the concrete. should be done properly by molarity of the solution. Otherwise the procedure will be failure, if neither of the precautions are not taken. We have to do multiple number of trails to get the correct strength by changing the molarity. Thus by following all the mentioned precautions we got the final outcome.

Fig 4.7 Geo polymer concrete cube

4.7.1 Casting

While casting cube moulds take mix in the cube in three layers in a cubical shape. Compact the mix with tamping rod 4 to 5 times per layer keep this cube for 24 hrs. Compact properly otherwise honeycombing will be occurred. While casting short cylinder moulds take mix in the short cylinder in four layers in circle shape. Compact the mix with tamping rod 4 to 5 times per layer. Keep this cylinder for 24 hrs in the mould. Compact properly. In case of prism moulds take mix in the prism in the three to four layers in the rectangular shape. Compact the prism every corner and at the centre with the tamping rod 5 to 6 times per layer. Keep the prism for 24 hrs in the mould. Compact properly. Compact it with wooden tamper.

4.7.2 Mixture of geo polymer concrete

Here American concrete institute method is used for these mix design as more material will be obtained as compared to IS 10262:2009 based on grade of concrete used and number of moulds used, we will know the total weight.

Fly Ash = 10.70kg.

Sodium Hydroxide

Solution = 1.02kg.

Sodium Silicate = 2.57 Kg.

Coarse Aggregate = 22.71 Kg.

Fine Aggregate =17.35 Kg.

Super Plasticizer = 1.515 Kg.

Water=4.28kg.

4.7.3 Mixture proportions

The following shows the Mixture proportions for $1m^3$ of concrete and is calculated as per ACI method. The control mix was denoted as normal concrete. the Mixing of 30%,70% of cement with fly ash and also geopolymer mix trails -1,trail-2,and trail-3 . After iterative trial mixes the water-cement ratio was fixed as 0.45. The detailed mixture as shown figure 4.7.3.

Table 4.7 Mix Proportions of Following Concrete

Concrete mix	Cement in kg/m³	Fly ash in Kg/m³	Lime In kg/m³	Coarse aggregate In kg/m³	Fine aggregate In kg/m³	Water content in kg/m³	Sodium hydroxide In kg/m³	Sodium silicate In kg/m³
Normal concrete	392			992	786	176.4		
30% flyash	274.4	117.6		992	786	176.4		
70% flyash	117.6	274.4		992	786	176.4		
Geopolymer-1		392		992	786	176.4	35.28	88.2
Geopolymer-2		335	57	992	786	176.4	35.28	88.2
Geopolymer-3		392		992	786	176.4	44.91	112.28

4.7.4 Sample mix design for 70% replacement of cement with flyash

F_{ck} = 30+1.64×5 = 38.20 MPA.

Based on the grade of concrete is M-30 take standard deviation 5.

Water content based on maximum coarse aggregate size .

Required cement content = 185 kg/m^3/0.45= 392 kg/m^3.

w/c ratio is considered by grade of concrete and unit weight of cement

Weight of coarse aggregate = 0.62×1600 kg/m^3= 992 kg/m^3.

Based on bulk volume of dry rodded coarse aggregate per volume of concrete for fineness modulus of sand

Weight of water = 185 kg/m^3.

Weight of fine aggregate = 2355-(392+992+185) = 786 kg/m^3.

Fly ash content = 274.8kg/m^3.

Cement content = 117.2 kg/m^3.

Absolute volume of cement = 132kg/m^3/3.15 = 41×10^{3}cm^3.

Absolute volume of Water =185 /1= 185×1000 cm^3.

Absolute volume of Coarse aggregate = 992kg/m^3 /2.4 = 392×1000 cm^3.

Absolute volume of Fly ash = 274.2/2.5= 109.68×1000 cm^3.

Volume of fine aggregate = (1000-728.36)×$1000cm3$.=272×1000 kg/m^3.

Weight of fine aggregate = 272 × 2.65 = 720.8 kg/m^3.

Weight of coarse aggregate = 392 × 2.65 = 953 kg/m^3.

4.8 Difficulties in geo polymer concrete preparation

In geo polymer concrete each and every step in geo polymer concrete preparation is very important any minute mistake causes failure of geo-polymer concrete. Metallic cubes can't be used because these are more reactive they react with alkalis in the mixture and wooden cubes should be prefarably. Coarse aggregate should be less than 10mm size. Oven temperature should be strictly maintained at 60°c for 24hrs.Other wise

Geo-polymer doesn't get enough strength. Class F fly ash should be used because it has low calcium content it doesn't react with alkalies. Chemical mixing with water should be done properly based on the molar solution. Whereas normal concrete preparation is easy because cement has more strength has fly ash. Preparation of Geo polymer needs skilled labour.

4.8.1 Economic constrains in preparing geo polymer concrete

While preparing geo polymer concrete fly ash is not available outside like cement. we have to contact dealer agencies and lignite and coal industries travel charges will be more and bag costs more than five hundred rupees. Chemical also costs more sodium hydroxide (500g) costs around three hundred rupees. sodium silicate (500g) also costs three hundred rupees. Per each trail along sand and coarse aggregate it costs nearly five thousand rupees. After doing various no of trails success comes.it is like trail and error method. In case of molar solution in order to get the final solution. Coming to normal concrete two trails cost will be around thousand rupees which is very cheaper in costs. Practically if the contractor wants to use geo polymer concrete he will have to spent more money and delay in construction because it needs more number of trails to prepare geo polymer concrete.

4.8.2 Side effects of geo polymer concrete

The materials used in geo polymer are very harmful chemicals while preparing the solution. If you touch the chemical mixture with hands or it touches any of the body part there will be many side effects such as face swelling which occurs due to tasting the mixture or in halation of the chemical.it is mainly noticeable in lips eyes and mouth. This

is a disorder in which eyes and lips, mouth becomes bigger the face gets a great change from normal face to monster face swelling will remain upto 4 to 5 days. Skin irritation also occurs while handling with hands irritations like itching sensation of the whole body, skin redness etc . Skin allergy like pimples which will later on become darkspots due to chemical falling on stomach or hands etc.The chemical causes burning sensation if it comes in contact with the skin.

4.8.3 Practical problems in construction field

While preparing geo polymer concrete surface should be smooth. A separate room should be constructed for casting geo polymer beams, columns and should be maintained at elevated temperatures for 60̊c for 24hrs.every shuttering should be made with wood and silica no metal shutters should be used as making shutters itself costs lot of money and lot of labour should be used .Skilled and efficient labour should be used with proper engineering guidance in the preparation of geo polymer concrete.other wise beam columns fail major losses of money and human life can occur labour also gets medical problems while preparing geo polymer concrete.So compared to normal concrete beams and columns geo polymer concrete beams and columns is more difficult in casting and care need to be taken while casting.

4.8.4 Precautions

People should be care full while preparing wear gogles to eyes and wear lab uniform and wear gloves to hands while preparing geo polymer concrete. Maintain distance while preparing geo polymer concrete. Carefully take the sample from the oven. If it fails it will break suddenly and also maintain strictly 60°Cfor 24 hrs. Apply water immediately on the swelling part so that we can prevent swelling and burning sensation.

4.8.5 Advantages of Geo Polymer Concrete

The following are the advantages of the Geo polymer concrete

- Curing is not required
- Geo polymer concrete attains it 90% of its strength within 3 days.
- It is eco friendly concrete
- It helps in Reduction of Solid waste produced from Thermal power plants.

4.9 Specimens casted

As we have done tests for engineering properties for split tensile strength, flexural strength, compressive strength, modulus of elasticity etc. the table shows no of samples used per trail and days taken for each trail.

Fig 4.9 Specimens Casted

Tests	**Compressive strength**	**Split tensile strength test**	**Flexural strength**	**Modulus of elasticity**
No of specimens casted per day	3	3	3	3
No of days strength	7 day,28 day	7day,28 day	7day,28 day	7day,28 day
Normal concrete	10	8	6	4
30% flyash	6	4	2	3
70%flyash	6	4	2	3
Geopolymer trail-1	6	3	3	-
Geopolymer trail-2	6	3	3	-
Geopolymer trail-3	6	4	5	
Total	40	30	21	10

Fig 4.9 Samples done per each trail

4.9 Tests on Concrete

The following tests were conducted on concrete

4.9.1 Compressive strength

Introduction

Compressive strength test **is** used to the check whether the specimen is able to with stand target strength. Thus this test is helpful in several concrete applications before the structural members are casted in the field.Compressive strength is checked for 7 day, 28 day strength normally.

Methodology

Various mixes have been tested in this machine. First put the cube in the compression testing machine. Apply the load vertically. the load should be applied on the smooth surface so that load calculation comes accurately. After putting the cube on the testing surface. Now tighten with the clamp downward . Now ON the green button reading will slowly increase set the loading rate 2.5KN/sec. Now slowly load increases as the specimen breaks note down the reading when failure load occurs. Now switch on red button and the machine stops and automatically untighten the clamp downward. thus remove the sample .Thus all the mixes normal concrete, 30% flyash,70% fly ash , Geo polymer are Calculated. the sample size is of 100×100×100mm cubes.

Compressive strength in N/mm^2 = load/area.

Load in KN as shown in the machine,

area in mm^2.

Fig 4.10. Compressive strength testing

4.9.2 Split tensile strength

Introduction

Split tensile test is used to check the horizontal side of the concrete to check whether the Sample is able to handle the tensile forces from outside. Split tensile strength is checked for 7 day, 28day strength normally.

Methodology

Cylinder specimen is kept on the horizontal direction in this machine. Apply the load from the vertical direction. Tighten the clamp such that the engine allows the working. On the green button and then set the loading rate to 2.5KN/sec. Now slowly load increases.At one point failure load at which the specimen breaks. Note down the

load reading. switch on the red button and untighten the clamp such that the working stops. The sample size 100dia×200mm cylinder.

Split tensile strength=P/A

P=load obtained on the machine.

A= area of short cylinder =π×D×L.

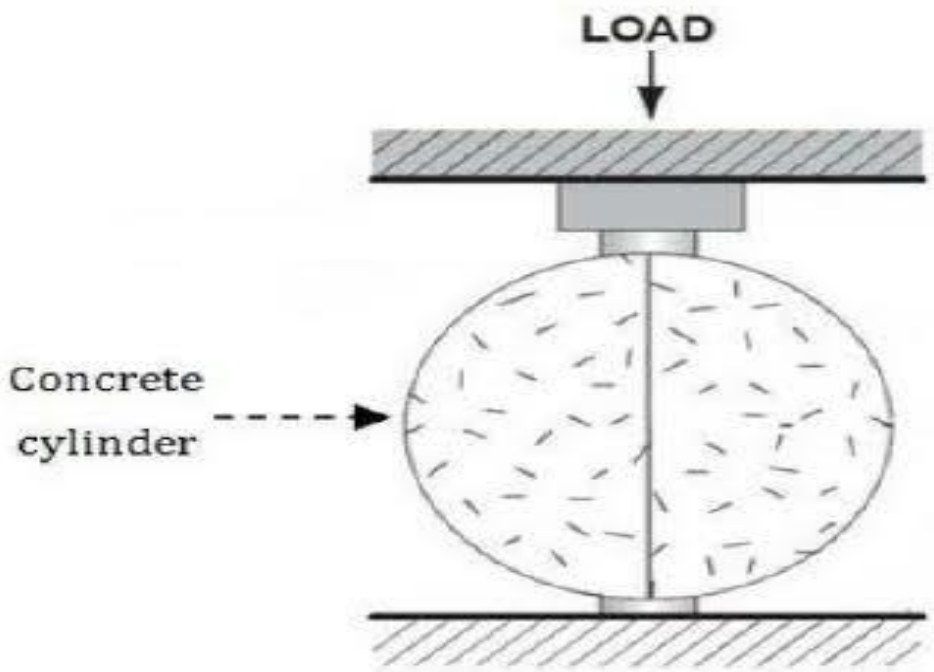

FIG 4.11 Split Tensile Strength Testing Machine

4.9.3 Flexural test on concrete

Introduction

Flexural strength test is done on a prism which is placed horizontally.

Methodology

Prisms after casting and curing .they are tested in a universal testing machine under two pointing loading. Prism is kept at the centre of plywood strip. with the support of two rollers at both 1/3rd ends of prism. Distance in between the two rollers should be 2/3rd of prism. Fit the screwing jack tightly from top. Then On the switch load is applied then the prism fails at the maximum load. note the readings. Calculate the

flexural strength by the following formulas, based on where the crack occurs. Specimen of dimension 100×100×500mm.

At 1/3rd of the span, flexural strength =$3pa/bd^2$.

At 2/3rd of the span, flexural strength=pl/bd^2.

p = load applied. a= distance from end point to the crack formation point

l=length of prism.

b=breadth of prism.

d= depth of prism.

Thus all the 6 prisms are tested in this way at 7day,28 day flexural strength respectively.Thus flexural strength graph is plotted.

FIG 4.12 Flexural Testing Machine

4.9.4 Modulus of elasticity

Introduction

This test is done in compression testing machine for checking out the stress at any point strain.by this test we will find out elastic modulus of a material. The sample used here is a big cylinder which is kept under compression. Hooke law is tested based on the stress/strain ratio upto stress/strain ratio changes where failure slowly starts. Thus tangent modulus of elasticity is calculated which is slope of stress/strain curve. and also secant modulus is stress/strain At any point.by knowing youngs modulus, poisons ratio of concrete we can get bulk modulus k and also shear modulus G.

Fig 4.13 Modulus of Elasticity Testing Machine

Methodology

Modulus of elasticity is calculated by compression testing machine by calculating stress applied on a big cylinder at a loading rate of 1.25 kN/sec by using a Extensometer fitted on the cylinder. Adjust the extensometer properly and calibrate it properly.

Calibrameter should touch bottom screw so that readings will come exact and strain value is shown properly. Note down strain for every 10 kN reading. Such that we can find exact stress/strain ratio from all the readings. And plot the graph stress v/s strain from given values.

Stress=load/area.

Area of big cylinder =π×R^2.

Calculate the stress-strain values for all the three values 30%,70%,0% cement replacement with flyash is determined using their big cylinder specimens of 150dia ×300mm.

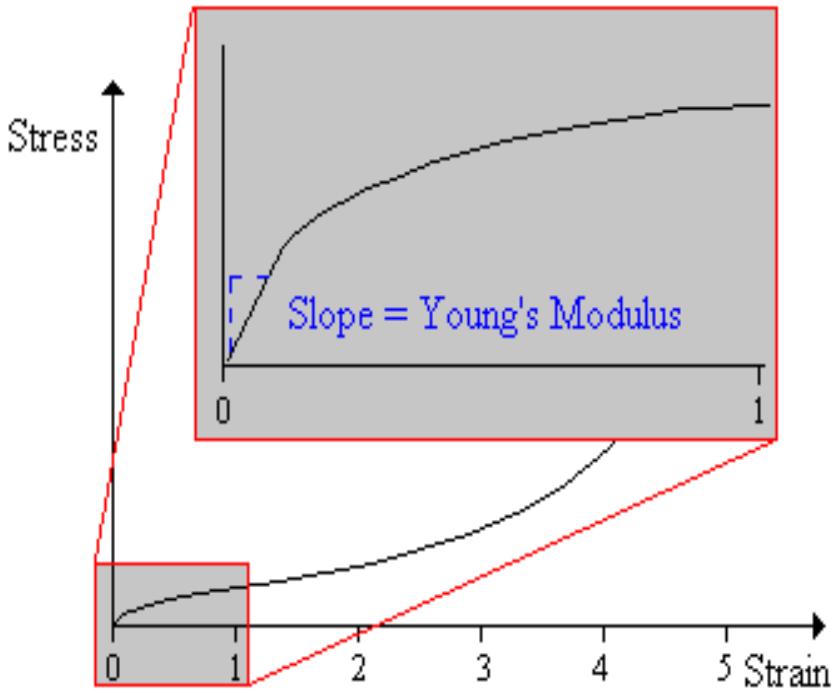

Fig4.14 Calculation of Youngs Modulus

Chapter 5

RESULTS AND DISCUSSION

5.1 Compressive Strength of Concrete

These are the following results of the six mixes of 7day, 28day compressive strength. The compressive strengths have been shown in the following table :-

Table 5.1 Compressive Strength Test Results

Type of concrete	7 day strength in N/mm^2	28 day strength in N/mm^2
Normal concrete	17	30.2
30% flyash replacement	22	30.4
70% flyash replacement	11.7	15.3
Geopolymer-1	1.7	3
Geopolymer-2	3	5.2
Geopolymer -3	15	22

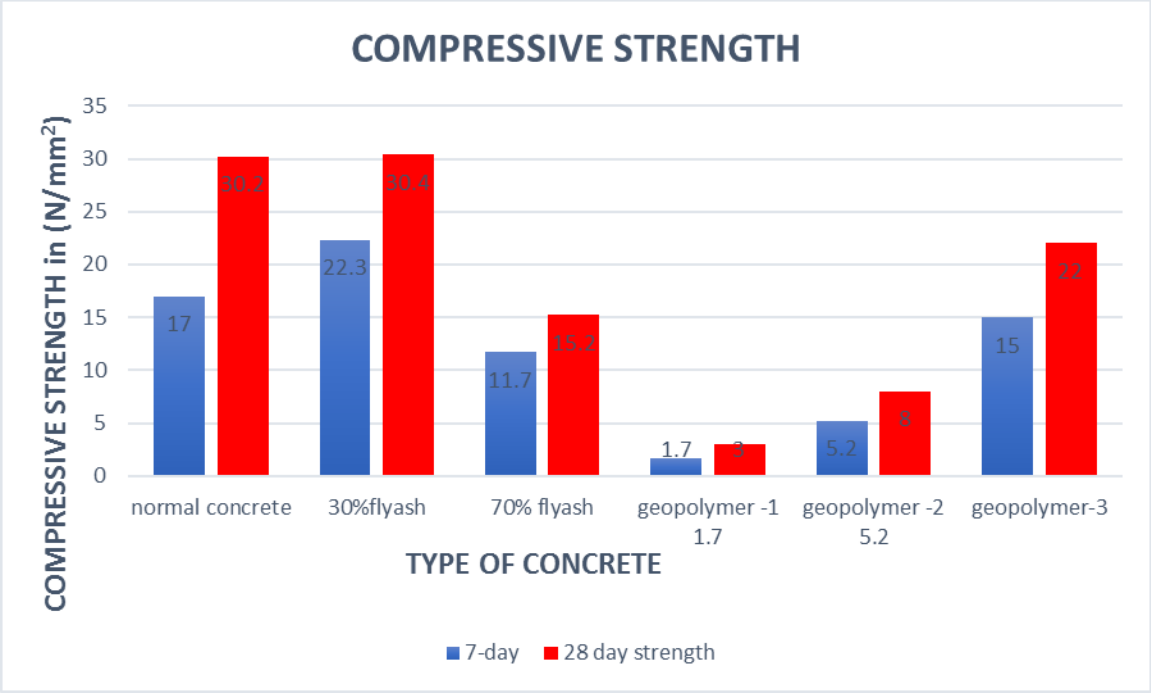

Fig 5.1 Compressive Strength Graph

5.1.1 Inference of Compressive Strength Of Following Concrete Specimens

Inference

Compressive strength of normal concrete is similar to 30% cement replacement with fly ash but the increase in percentage strength from 7day to 28day is more for normal concrete with 39.44% more than 30% flyash replacement. Thus normal concrete gains an edge over 30% cement replacement with fly ash. On comparison with 70 % cement replacement with fly ash, normal concrete has double strength than normal concrete. Percentage gain from 7 day to 28 day is more for normal concrete than 70% cement replacement with fly ash with a difference of 46.88%. Now increasing the replacement to 100% cement replacement which is Geo polymer concrete the first two trails of geo polymer concrete are a damn failure which is not satisfying basic 7day strength of normal concrete. After the two trails here comes the third trail of geo polymer which has satisfied basic strength parameters of normal concrete. Normal concrete has strength gain 37.27% over Geopolymer-3. Geopolymer-3 28 day strength is 5N/mm^2 more strength than normal concrete 7day strength. And also percent strength gain from 7 day to 28 day is 30.98% more than normal strength. The following results show normal

concrete has higher strength than all the values by but similar to 30 % cement replacement with fly ash. Geo polymer concrete has lesser compressive strength compared to normal concrete but higher strength when compared with 70% cement replacement with fly ash. Percentage gain of strength from 7 day to 28day is more for normal concrete is 77.64% compared to all concretes next is geo polymer with percent gain of 46.66%. Thus results conclude geo polymer has produced satisfactory results when compared to other concrete specimens but somewhat lesser strength than normal concrete.

5.2 Split Tensile Strength of Concrete

Split tensile strength results of the following six mixes of 7day, 28 day strength are shown in the table. Split tensile strength results are displayed below.

Table 5.2 Split Tensile Strength results

Type of Concrete	Split Tensile Strength For 7 days	Split Tensile Strength For 28 days
Normal Concrete	1.9	2.22
30% cement replacement	1.43	1.9
70% cement replacement	1.13	1.43
Geopolymer-1	0.169	0.3
Geopolymer-2	0.519	0.62
Geopolymer-3	1.443	1.62

5.2.1 Inference of Split Tensile Strength of Following Concrete Specimens

Inference

Normal concrete has highest split tensile strength than all the other specimens with a split Tensile strength 2.22N/mm^2.When compared with 30% cement replacement with fly ash. normal concrete has higher strength. difference between their strengths is just 0.32N/mm^2. But percent gain of strength from 7 day to 28 day is more for 30% cement replacement with fly ash with a difference of 22.31%. Comparison with 70%

cement replacement with fly ash. Here also normal concrete has a More gain in strength compared to before one with a difference 0.77N/mm^2.But percent gain of strength from 7day to 28 day is more for 70% cement replacement with fly ash with a difference of 16.31%. Now comparing with geo polymer concrete the first two trail values are very less compared to all the concrete specimens.so there values are not suitable for comparison with normal concrete. Coming to geo polymer third trail. here also normal concrete dominates with a difference of 0.5771N/mm^2 which is better than 70%cement replacement with fly ash but less when compared to 30%cement replacement with fly ash. and also percent gain from 7 day to 28 day is more for geopolymer-3 with a difference of 2.7%. From the above results it is clearly mentioned that geo polymer has better split tensile strength but not similar to normal concrete. Thus these results proved that geo polymer concrete can satisfy the split tensile strength requirements of normal concrete geo polymer concrete can be used for walls constructed with normal concrete.no need for curing

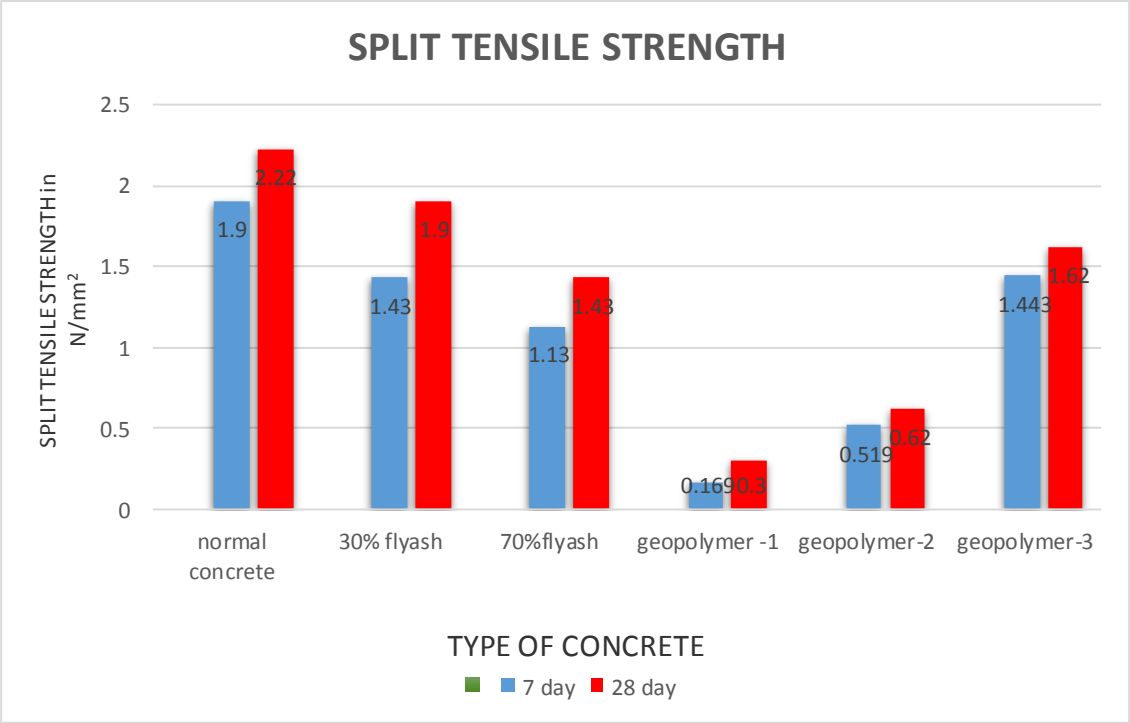

Fig 5.2 Split Tensile Strength Graph

5.3 Flexural Strength of Concrete

Flexural strength of six mixes of 7day, 28 day strength are shown in the table. The results of the following mixes are shown in table

Table 5.3 Flexural Strength of Concrete

Type of concrete	7 day strength in N/mm^2	28 day strength in N/mm^2
Normal concrete	3	4.25
30% fly ash	2.5	3.75
70% fly ash	1.125	1.5
Geo polymer -1	0.168	0.264
Geo polymer-2	0.434	0.818
Geo polymer-3	2.886	3.75

5.3.1. Inference Of Flexural Strength Of Following Concrete Specimens

Inference

Normal concrete when compared to all the samples has the highest flexural strength of 4.25N/mm^2.it has strength gain from 7day to 28day of 41.66%. Which is compared to 30% cement replacement by fly ash is low by 8.33%but the compressive strength of 30% cement replacement by fly ash is low by 0.5 N/mm^2.When compared with 70% cement replacement normal concrete is far a head in flexural strength for 28 days and also in aspect of strength gain from 7 day to 28 day by 8.66%.This proves normal concrete has better flexural strength. now coming to geo polymer concrete geo

polymer first two trails were a total failure of flexural strengths 0.264N/mm^2 and 0.818N/mm^2 which are not even fit for comparison with normal concrete. While coming to the geo polymer third trail which is done with so many precautions has got much more better value but less compared to normal concrete. It has got slightly less strength than 30% cement replacement with fly ash.

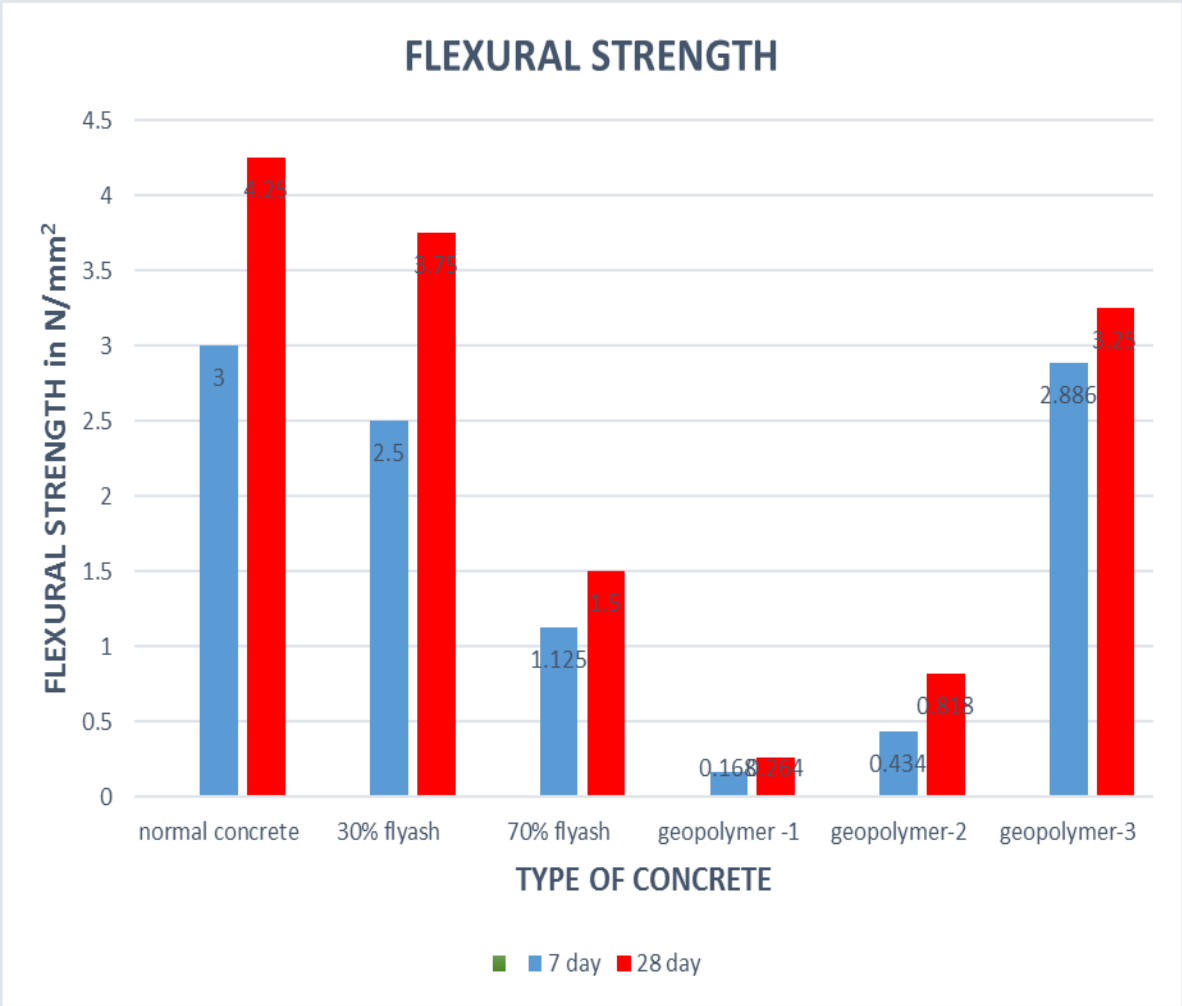

Fig 5.3 Flexural Strength of Concrete

5.4 Modulus OF Elasticity Of Concrete

Here following stress-strain curve graphs of following three concrete big cylinder mixes are shown in figure.

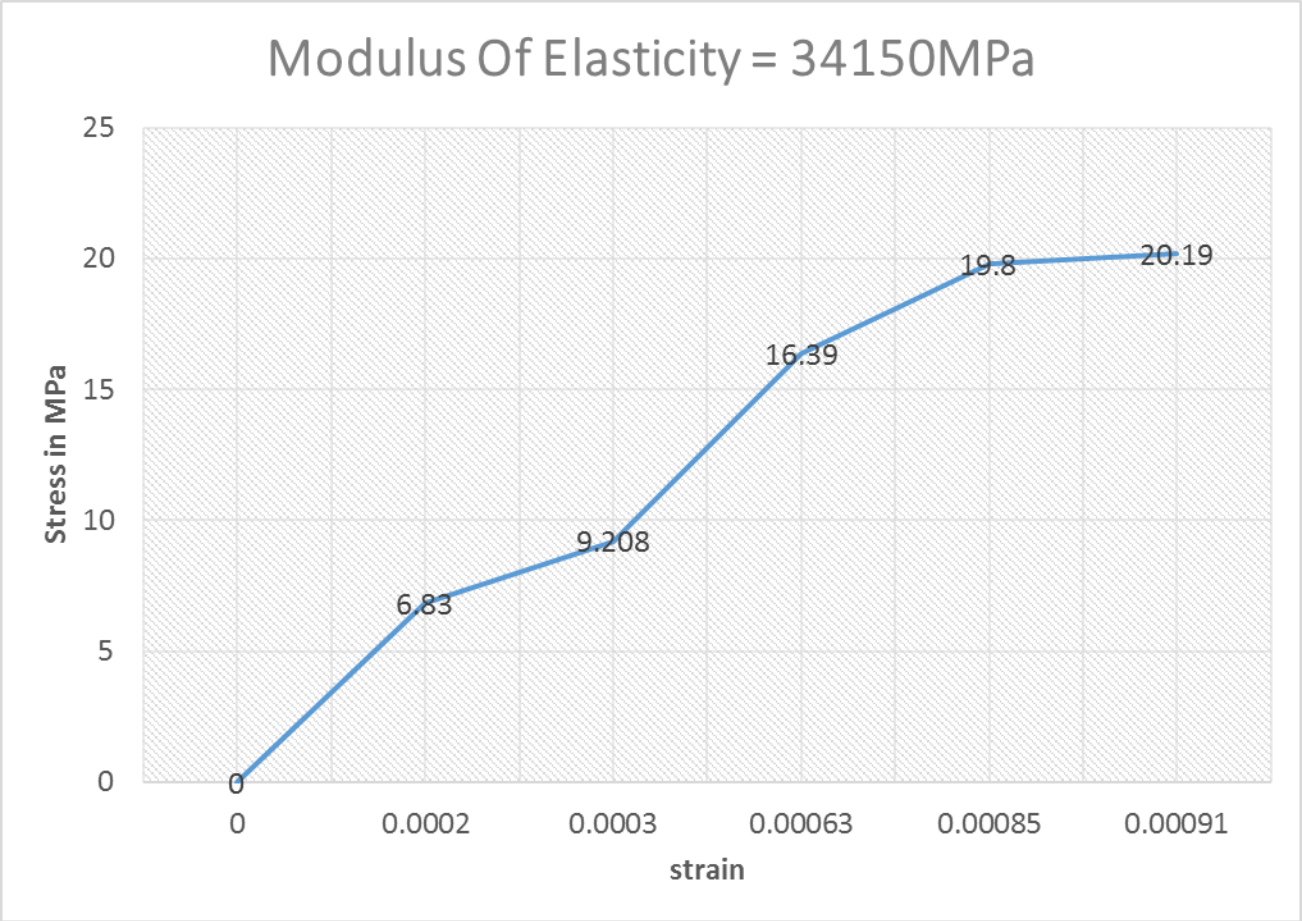

FIG 5.4 Stress strain curve for normal concrete

Stress/strain ratio in MPa	Stress in MPa	Strain
34150	6.83	0.0002
30670	9.209	0.0003
26000	16.39	0.00063
23000	19.80	0.00085
21000	20.19	0.00091

Table 5.4 Stress Strain Table for Normal Concrete

5.4.1 Graph Explanation

Here in case of normal concrete, proportionality limit is from zero to 9.208 N/mm^2.Elastic limit upto 6.83 N/mm^2 at a strain of 0.0002.

This means modulus of elasticity is calculated upto that point which is 34150 mpa by using tangent method.

After that point failure load occurs and slowly at upper yield point crack forms at 9.208 N/mm^2 which happens to occur at a strain 0.0003. At this point stress/strain ratio is 30670mpa.

After that lower yield point occurs at 19.80 N/mm^2 which happens to occur at a strain 0.00085. At this point stress/strain ratio is 23000MPa.

Ultimate stress occurs at 20.19N/mm^2 where full breakage of specimen occurs at a strain 0.00091. At this point stress/strain ratio is 21000MPa.

Fig 5.5 Stress strain curve for 30% cement replacement with flyash

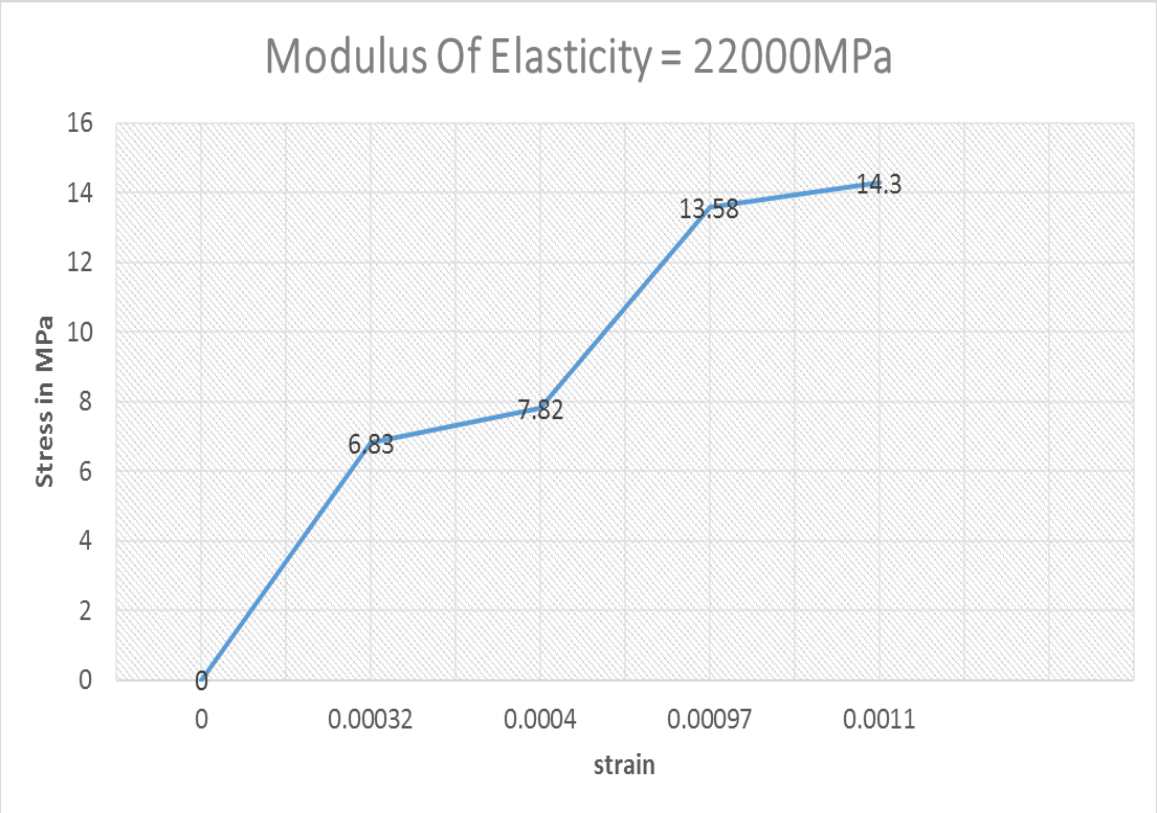

Table 5.5 Stress Strain Curve Table for 30% Cement Replacement

Stress/strain ratio in MPa	Stress in MPa	Strain
22000	6.889	0.00032
15600	7.82	0.00050
14000	13.58	0.00097
13000	14.32	0.00110

5.4.2 Graph Explanation

Here in case of 30% cement replacement with flyash Elastic limit occurs at 6.889N/mm^2 at a strain 0.00032.propotionalty limit occurs from 0 to 6.889N/mm^2.By using tangent method modulus of elasticity is obtained as 22000mpa.Upper yield point occurs at 7.82N/mm^2 at a strain 0.0004. at this point stress/strain ratio is 19500mpa.Crack slowly occurs at the point . Lower yield point occurs at 13.58N/mm^2 at a strain 0.00097. at this point stress/strain ratio is 14000mpa. Crack full formation at this point. Ultimate failure stress occurs at 14.32N/mm^2 at a strain 0.00110.at this point stress/strain ratio is 13000mpa.Full failure of specimen occurs at this point.

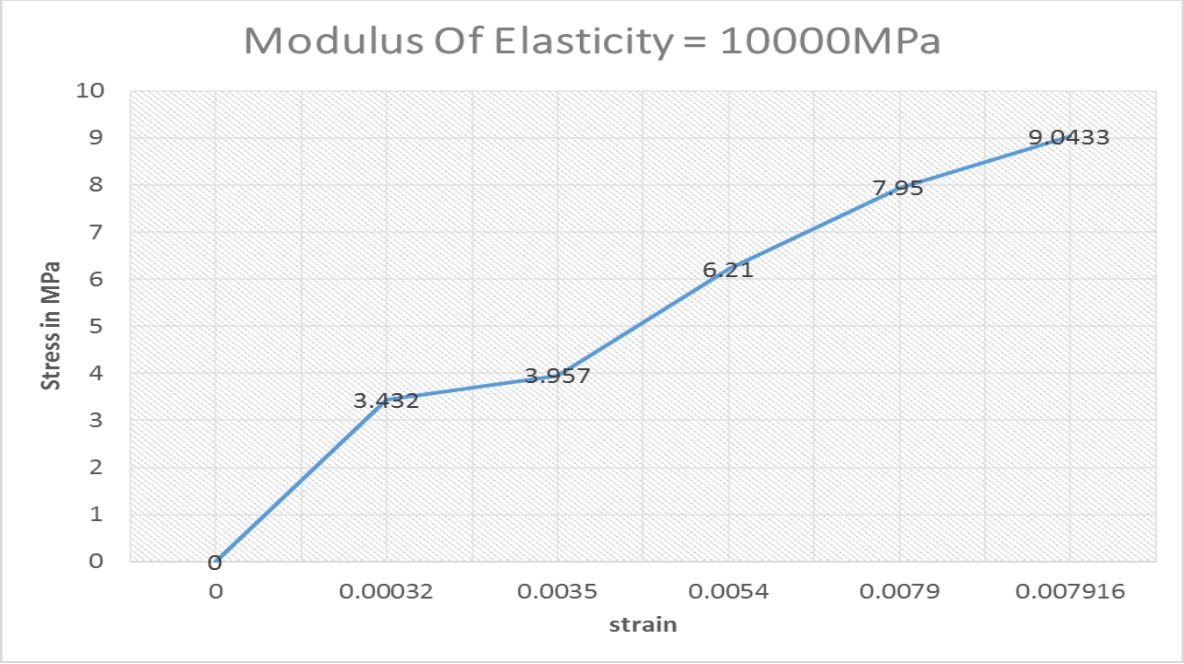

Fig 5.6 Stress strain curve for 70%cement replacement with flyash

Table 5.6 Table for stress strain curve for 70% cement replacement

Stress/strain ratio in MPa	Stress in MPa	Strain
10000	3.432	0.000325
11000	3.957	0.00035
10000	7.914	0.00079
11000	9.0433	0.0007916

5.4.3 Graph Explanation :-

Here in case of 70% cement replacement with fly ash concrete, proportionality limit is from zero to3.432.elastic limit up to 3.432 N/mm^2 at a strain of 0.000325.This means modulus of elasticity is calculated up to that point which is 10000 mpa by using tangent method. After that point failure load occurs and slowly at upper yield point crack forms at 3.957 which happens to occur at a strain 0.00035. At this point stress/strain ratio is11000mpa.After that lower yield point occurs at 7.914N/mm^2 which happens to occur at a strain 0.00079. At this point stress/strain ratio is 10000mpa.Ultimate stress occurs at 9.0433N/mm^2 where full breakage of specimen occurs at a strain 0.0007916. At this point stress/strain ratio is 11000mpa.

The below results of all the three concretes best modulus of elasticity is normal concrete as it is zero percent replacement of fly ash. Fly ash is being weak material the more the replacement the less will be modulus of elasticity for 28 days

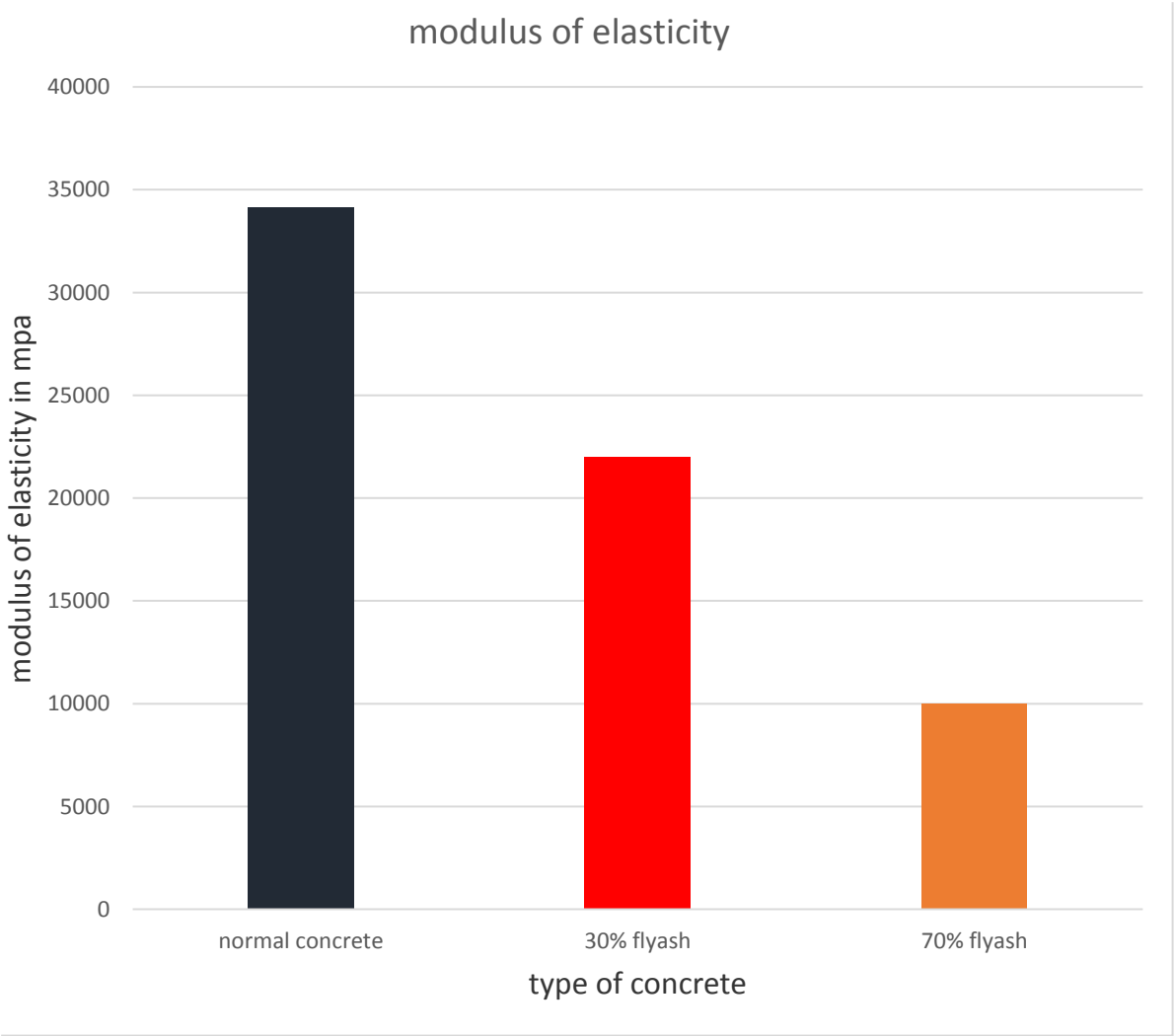

Fig 5.5 Stress strain graph

5.6 Cost analysis

Cement

Cost of cement per kg = Rs8.

Total cost of cement = Rs446.4.

Flyash

cost of fly ash per kg = Rs 20.

Total cost of fly ash = Rs330.

Fine aggregate

Cost of sand per kg = Rs 0.346/kg.

Total cost of sand = Rs6.04199.

Coarse aggregate

Cost of coarse aggregate per kg = Rs 0.428/kg.

Total cost of coarse aggregate = Rs 9.63.

Sodium hydroxide

Cost of sodium hydroxide per 500g = Rs300

Total cost of sodium hydroxide = Rs1200

Sodium silicate

Cost of sodium silicate per 500g = Rs330

Total cost of sodium silicate = Rs 1650.

Wooden mould

Cost of plywood =Rs250

CHAPTER 6

FUTURE SCOPE OF THE RESEARCH STUDY

Till today researchers have tried so many alternative replacements of cement with fly ash and slag, solid waste in percentages of cement. Some how they got success. but till now 100% replacement of cement had not been done. Till now researchers in case of getting high strength concrete as aim have tried geo polymer concrete. Which attains faster strength to that of the normal concrete some how it is very hard to prepare geo polymer concrete but with some precautions and after doing multiple trails got success based on molarity etc.As per this study 30%,70% fly ash and 100% replacement of cement three trails confirmed that geo polymer can't get strength only by molarity but also by so many factors in preparation.in the first two trails used a different method taken 20% of water as sodium hydroxide.in the next trail using same method but with 30% replacement of cement with lime and rest with fly ash . failure of these two trails was due to usage of metallic moulds , and also temperature failure, water curing. Now the third trail success came by using wooden moulds using turpentine oil for oiling and which passes through 10mm aggregate of coarse aggregate and fine sand which passes through 90 mm sieve. And also should do mix carefully water shouldn't be more in content. Upto now this paper determined mechanical properties of geo polymer concrete.

The future scope of the study is that researchers can go for the design of structural components such as beam,column and pave a way to bring the Geo Polymer concrete use into the day to day life. As it will reduce the cost of the dwellings.

Chapter 7

CONCLUSION

- From the test results we conclude normal concrete is better in all the tests along with highest modulus of elasticity of 34000MPa.

- The Replacement of 30% Fly Ash showed the same results as that to controlled concrete samples.

- Geo polymer Concrete showed comparably better results with respect to that of the convention concrete.

- The Geo polymer attained its 90% of Strength within 3 days that makes the structure available for early occupancy.

- Geo polymer doesn’t require any curing.

- It is cost effective.

- Geo polymers require skilled labour as the mixing is very difficult.

- Geo polymer concrete should be handled with care as it poses various health threats.

Chapter 8

REFERENCES

Behrooz Saghafi, M.ASCE1; Hassan Al Nageim2; and William Atherton3 “Mechanical Behavior of a New Base Material Containing High Volumes of Limestone Waste Dust, PFA,and APC Residues” journal of materials in civil engineering © asce / april 2013 /.

Pattanapong Topark-Ngarm1; Prinya Chindaprasirt2; and Vanchai Sata3 “Setting Time, Strength, and Bond of High-Calcium Fly Ash Geopolymer Concrete”
Journal of. Materials Civil. Engineering © ASCE/JULY 2015/.

Partha Sarathi Deba,, Pradip Natha,, Prabir Kumar Sarkera“Drying shrinkage of slag blended fly ash geopolymer concrete cured at room temperature”. Partha Sarathi Deb et al. / Procedia Engineering 125 (2015) 594 – 600.

Les Vickers∗, William D.A. Rickard, Arie van Riessen “Strategies to control the high temperature shrinkage of fly ash based geo polymers”. Thermochimica Acta 580 (2014) 20–27.

Alireza Mohammadinia; Arul Arulrajala; Jay Sanjayan; Mahdi M. Disfani; Myint Win Bo;and Stephen Darmawan “Strength Development and Micro fabric Structure of Construction and Demolition Aggregates Stabilized with Fly Ash–Based Geo polymers”. Journal of Materials in Civil Engineering© 2016 American Society of Civil Engineers.

Shi cong kou; chi sun poon; and dixon chan“influence of fly ash as cement replacement on the properties of recycled aggregate concrete”. Journal of materials in civil engineering,2007© asce / september.

Aimin xu and shondeep l, sarkar ”micro structural development in High-volume flyash cement system”. J. Mater. Civ. Eng., 1994, 6(1).© asce / september.

Wenyi hu ronald d. Neufeld; luis e. Vallejo; christopher kelly
And martin latona ”strength properties of autoclaved cellular concrete with high volume fly ash” journal of energy engineering / august 1997.

Concrete technology published in 1982 , by M.S.Shetty.

IS 456-2000.

IS 10262-2009 mix design for normal concrete.

IS 2386(part-2)-1963 methods of test for aggregates for concrete.

IS 516 – 1959 methods of strength of concrete.

IS 383 -1979 methods of specification of coarse and fine aggregates from natural sources for concrete.

55