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MECHANICAL CHARACTERISTICS OF FIBER REINFORCED GEOPOLYMER CONCRETE

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Abstract - This project is all about the use of class-f flyash in concrete as a partial and full replacer. The partial replacement of cement with flyash results in a concrete called Geopolymer composite concrete. And the complete replacement of cement with the flyash is called Geopolymer concrete .

The Pozzolana Portland cement concrete is considered as a control concrete. Addition of steel fibre is made in order to check the cracking strength of the concrete. It is added in the percentage of 0,0.5 & 1.5 to the concrete. A special mix design for the flyash based concrete was made in the ratio of 1:1.21:1.95 as per the guidelines provided in the Asian Journal of civil Engineers. GPC and GPCC were made for the grade of M25 and the specimens was casted for 28 days and have been tested. In order to achieve the strength in the GPC and GPCC sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions was used instead of water in the ratio of 1:2.5.

The alkaline liquid to flyash ratio was determined as 0.42 from the consistency test. Oven curing was done for the Geopolymer mix for 24 hours followed by 28 days of atmospheric curing. Fresh concrete test –slump cone and hardened concrete tests like compressive test, split tensile test and flexural strength were done and the results were discussed. Future Durability test the obtained results it is clear that GPC and GPCC both gives the required strength for M25 grade with 10 molecular concentration..

***Key Words*:** Geopolymer Concrete(GPC), Geopolymer Composite Concrete (GPCC), steel fiber(SF), Fine Aggregate (FA), Coarse Aggregate (CA), Compressive Strength, Split Tensile Strength, Flexural Strength, Durability.

1. INTRODUCTION

TheConcrete makes a substantial contribution to society, from its use in large scale infrastructure projects and also serves one of the basic needs of living of the human, the shelter. Use of concrete is also the major contributor to generate greenhouse gases. Among the greenhouse gases CO_2 contributes 65% of global warming. Its contribute nearly 6% of the CO_2 emissions worldwide because one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere. Portland cement is currently exceeding 2.6 billion tons per year worldwide and growing at a rate of 5% per year.

Although the use of Portland cement is still unavoidable many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilization of supplementary cementing materials such as flyash, silica fume, granulated blast furnace slag, rice husk and metakaoline and finding alternative binders to Portland cement.

Other major need is energy. Different forms of energy and their production has generated different types of wastes. One of such waste is flyash. A huge volume of flyash is generated around the world and most of the flyash is not effectively used .large part of it is disposed in landfills which affects the aquifers and surface bodies of the fresh water.

This flyash abundance and disadvantages of Portland cement usages together has contributed in the generation of the idea of using flyash in concrete.Initially certain percentages like 10%, 20%, and 30%...of flyash has been tested and also succeeded. But now research are going on to use larger proportion of flyash in concrete and also attaining the same strength and durability of ordinary concrete.

Researches are also going on to completely replace the cement with the flyash. One of such contribution is what the project we have done.

In this project we have compared the strength properties of Geopolymer concrete, Geopolymer composite concrete with the ordinary concrete along with the addition of the steel fibre.

Generally fibre in any concrete increases the cracking strength of the concrete at the time of collapse. Though the crack is formed it do not allow the element or structure to undergo sudden collapse and disintegration of the structure.

Normally flyash do not bind with other materials with the addition of water. A mixture of solution has to be given in order to indent the binder property in the concrete made of Geopolymer. In the ordinary Portland cement the binding material is limestone and silica which forms calcium silica hydrate (C-S-H) gel and calcium hydroxide $Ca(OH)_2$ which are very important component in binding. Cement, without the addition of the water do not produce the gelatinous substance. Hence water is the important stirrer for binding.

But in flyash based concrete a mixture of sodium silicate and sodium hydroxide is used to carry out the binding process along with the provision of 60˚-80˚c temperature.

Compression test, split tensile test, flexural strength test have been tested for normal concrete ,Geopolymer concrete(GPC) ,Geopolymer composite concrete (GPCC) with the addition of steel fibres and their 28th day strength are compared and the results were given.

2. OBJECTIVE

To develop a alternative concrete for cement which have the same or even higher strength characteristics to that of ordinary Portland cement concrete.

To impart the steel fibre in concrete and to determine the cracking pattern through which the concrete specimens fails.

To identify and study the following properties of low calcium flyash based Geopolymer concrete (GPC) and Geopolymer composite concrete (GPCC)

Compressive strength

Split tensile strength

Flexural strength

Workability

To compare the properties and cost analysis of conventional concrete with Geopolymer concrete (GPC) and also with Geopolymer composite concrete (GPCC).

3. MATERIAL PROPERTIES

The materials used for making fibre reinforced Geopolymer concrete (GPC) are

Low calcium dry flyash as a substitute for cement

Alkaline liquid

Coarse aggregates

Fine aggregates

3.1 Steel fibre

The materials used for making fibre reinforced Geopolymer composite concrete (GPCC) are as same as the materials as before but additionally certain percentage of cement as a substitute for flyash is been used.

3.2 Flyash

Flyash is a residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases of thermal power plants

There are about 75 thermal power plants in India and the total production of flyash is nearly as much as that of cement (75 tonnes). But our utilization of flyash is only about 5% of the production.

Most of the flyash available globally is low calcium flyash formed as a by- product of burning anthracite or bituminous coal. Although coal burning power plants are not considered to be eco-friendly, the extent of power generated by these plants is on the increase due huge reserves of good quality coal available worldwide and the low cost of power produced from these sources. Therefore, huge quantities of flyash will be available for many years in the future. Since flyash is produced by rapid cooling and solidification of molten ash, a large portion of components comprising flyash particle's are in amorphous state. The amorphous characteristics of flyash are the spherical form of the particles. This shape of particles improves the flow ability and reduces the water demand. ASTM broadly classified into two classes.

Class F: Flyash normally produced by burning anthracite of bituminous coal, usually has less than 5% CaO. Class F flyash has pozzalonic properties only.

Class C: Flyash is normally produced by burning lignite or sub- bituminous coal. Some class C flyash may have calcium oxide content in excess 10%. In addition to pozzalonic properties class C flyash also possesses cementitious properties.

In this experimental work, low calcium, class F (American Society for Testing and Material) dry flyash obtained from the silos of Ennore Thermal Power Station(ETPS), Chennai , was used as the base material.

3.3 ALKALINE LIQUID

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react i.e. (polymerisation takes place) it liberate large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent

3.4 Sodium hydroxide (NaOH)

Generally the sodium hydroxides are available in solid state by means of pellets and flakes.

The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our Geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used.

3.5 Sodium silicate (Na_2SiO_3)

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na_2O to SiO_2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of Geopolymer concrete.

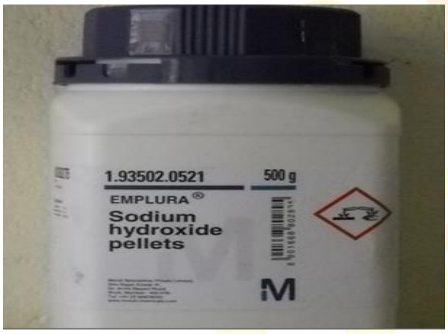

Fig.1 sodium hydroxide pellets

Fig.2 sodium silicate solution

4. AGGRAGATES

4.1 Fine aggregate

The fine aggregate or sand may be natural or crushed. It may be available in a riverbed or in a quarry. The size of sand particles varies from a maximum of 4.75 mm down to 150 micron. Good sand must contain all the particles within the above

range, that is, it should be graded sand. The sand may be sieved through the following Indian Standard Sieves 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron, and 150 micron. The sand may be classified as very coarse (zone I), medium coarse (zone II), coarse (zone III), and fine (zone IV) depending upon its grain size distribution. Only well graded or uniformly graded sand must be used for good concrete

4.2 Aggregate (coarse aggregate)

Aggregate is the solid particles that are bound together by the cement paste to create the synthetic rock known as concrete. Aggregates can be fine, such as sand, or coarse, such as gravel. The relative amounts of each type and the sizes of each type of aggregate determine the physical properties of the concrete .

Sand + Cement Paste = Mortar

Mortar + Gravel = Concrete.

Amongst all the materials, which are used, aggregates are very important. The quality of aggregates is very important since they make up about 60 to 80% of the volume of the concrete. Since we use steel fibre here it is recommended to use aggregates of 10mm only (as recommended in concrete technology by M.S Shetty)

4.3 FIBRES

Types of fibres Steel

Steel fibres have been used in concrete since the early 1900s.The early fibres were round and smooth and the wire was cut or chopped to the required lengths. The use of straight, smooth fibres has largely disappeared and modern fibres have either rough surfaces, hooked ends or are crimped or undulated through their length. Typically steel fibres have equivalent diameters (based on cross-sectional area) of from 0.15 mm to 2 mm and lengths from 7 to 75 mm. Aspect ratios generally range from 20 to 100. Carbon steels are most commonly used to produce fibres but fibres made from corrosion-resistant alloys are available. Stainless steel fibres have been used for high-temperature applications.

Steel fibres have high tensile strength (0.5 – 2 GPa) and modulus of elasticity (200 GPa), a ductile/plastic stress-strain characteristic and low creep. Steel fibres have been used in conventional concrete mixes, concrete and slurry-infiltrated fibre concrete. Typically, content of steel fibre ranges from 0.25% to 2.0% by volume. Fibre contents in excess of 2% by volume generally result in poor workability and fibre distribution, but can be used successfully where the paste content of the mix is increased and the size of coarse aggregate is not larger than about 10 mm. Steel-fibre-reinforced concrete containing up to 1.5% fibre by volume has been pumped successfully using pipelines of 125 to 150 mm diameter.

Fig.3 steel fibre

5.RESULTS AND DISCUSSIONS

5.1 TEST RESULTS FOR CONTROL CONCRETE (CC)

Types of specimens	Percentage of fibre	Results for 28 days water curing in N/mm²	Average value in N/mm²
Cube1 Cube2	0%	28 27.55	27.78
Cylinder 1 Cylinder 2	0%	3.183 3.5	3.34
Beam 1 Beam 2	0%	7.5 7.375	7.74

Table 1: Test result for CC with 0% fibre

Types of specimens	Percentage of fibre	Results for 28 days water curing in N/mm²	Average value in N/mm²
Cube1 Cube2	0.5%	36.88 39.11	37.99
Cylinder 1 Cylinder 2	0.5%	3.82 4.45	4.135
Beam 1 Beam 2	0.5%	7.625 8	7.812

Table 2: Test results for CC with 0.5%

Types of specimens	Percentage of fibre	Results for 28 days water curing in N/mm²	Average value in N/mm²
Cube1 Cube2	1.5%	52.44 52.44	52.44
Cylinder 1 Cylinder 2	1.5%	4.138 4.615	4.37
Beam 1 Beam 2	1.5%	8.125 8.5	8.31

Table 3:Test results for CC with 1.5% fibre

5.2 TEST RESULTS FOR GEOPOLYMER COMPOSITE CONCRETE (GPCC)

Types of specimens GPCC	Percentage of fibre	Results for 28 days atmospheric curing in N/mm²	Average value in N/mm²
Cube1 Cube2	0%	25.77 24.88	25.32
Cylinder 1 Cylinder 2	0%	2.864 2.864	2.864
Beam 1 Beam 2	0%	5.25 5.375	5.312

Table 4: Test result for GPCC with 0% fibre

Types of specimens GPCC	Percentage of fibre	Results for 28 days atmospheric curing in N/mm²	Average value in N/mm²
Cube1 Cube2	0.5%	25.77 25.33	25.55
Cylinder 1 Cylinder 2	0.5%	3.501 3.183	3.342
Beam 1 Beam 2	0.5%	6.75 6.625	6.68

Table 5: Test result for GPCC with 0.5% fibre

Types of specimens GPCC	Percentage of fibre	Results for 28 days atmospheric curing in N/mm²	Average value in N/mm²
Cube1 Cube2	1.5%	27.55 28.44	27.995
Cylinder 1 Cylinder 2	1.5%	4.138 4.456	4.297
Beam 1 Beam 2	1.5%	7.125 7.25	7.187

Table 6: Test result for GPCC with 1.5% fibre

6. RESULTS OF CONCRETESPECIMENS
6.1 COMPRESSIVE STRENGTH TEST RESULT

Compressive strength test is done as Per IS 516-1959. The test is conducted on Compression testing machine of capacity 2000 KN. Mechanical behaviour of concrete was studied for M30 grade of cubes were casted and cured for 7,14 and 28davs.The compressive strength is computed from following formula.

Compressive Strength (f) = (P/A)N/mm^2

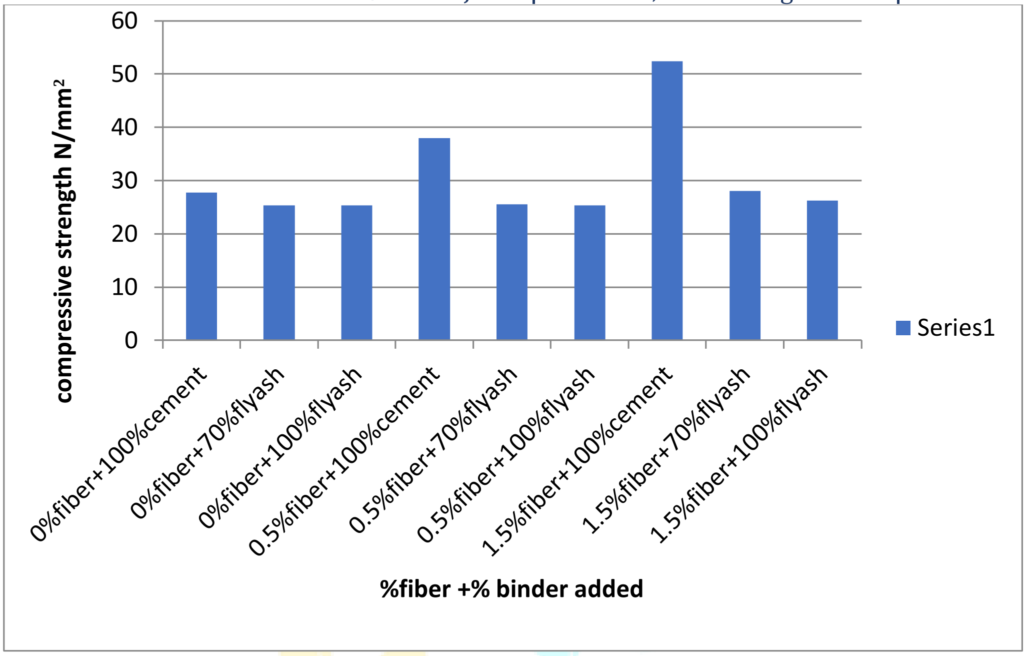

Fig 7: Comparison of compressive strength between control,GPCC and GPC

6.2 SPLIT TENSILE STRENGTH TEST RESULT

split tensile strength is done as per IS 5816-1999. The test is conducted on Compression testing machine of capacity 2000 KN. The Split tensile strength is computed from the following formula.

$$T= (2P/ \pi LD)\ N/mm^2$$

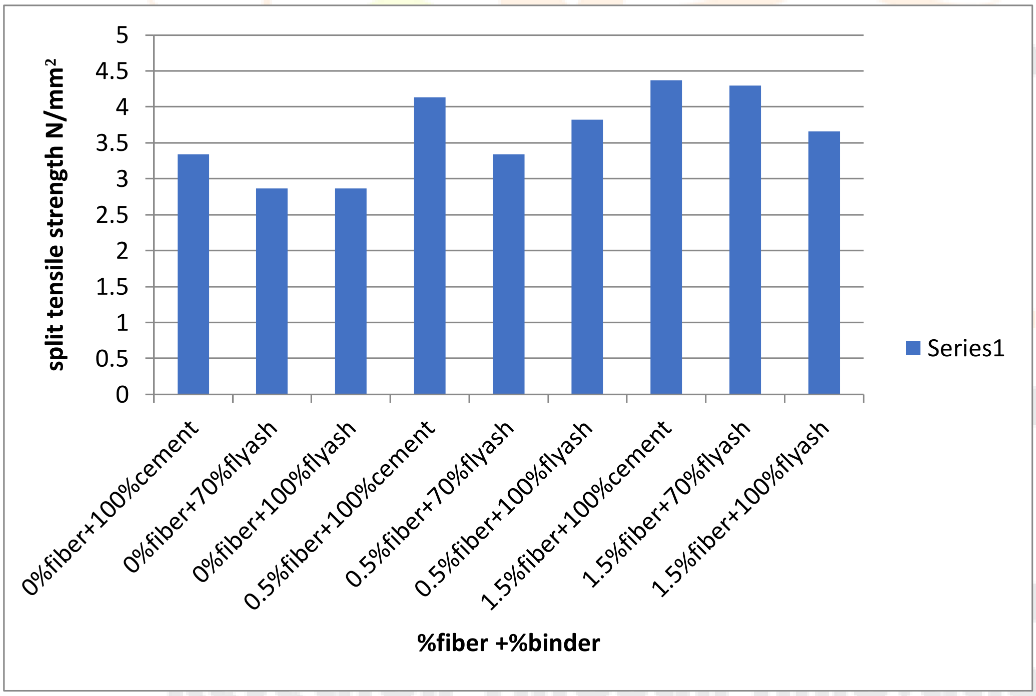

Fig 8:Comparison of split tensile strength between control,GPCC and GPCC

6.3 FLEXURAL STRENGTH TEST RESULT

In order to determine the flexural strength of concrete, prismatic specimens of a size 100 mm x 100 mm x 500 mm were cast with various proportions of all the concrete mixtures. then calculated using the formula and procedure given in IS: 516-1959.

The bearing surface of the supporting and loading rollers was wiped clean. The specimen was then placed on the rollers in such a way that the load will be applied to the upper most surface as cast in the mould along two lines spaced 13.3cm apart. The axis of specimen was carefully aligned with the axis of the loading device. The load was applied without shock and increasing continuously. The load was increased until the specimen failed and the maximum load applied to the specimen was recorded. Unusual fractures were recorded.

(fb) = Pl/bd^2

For 'a' is less than 133 mm but greater than 110 mm for a100mm specimen, then modulus of rupture is calculated from the formula.

(fb)=3Pa/bd

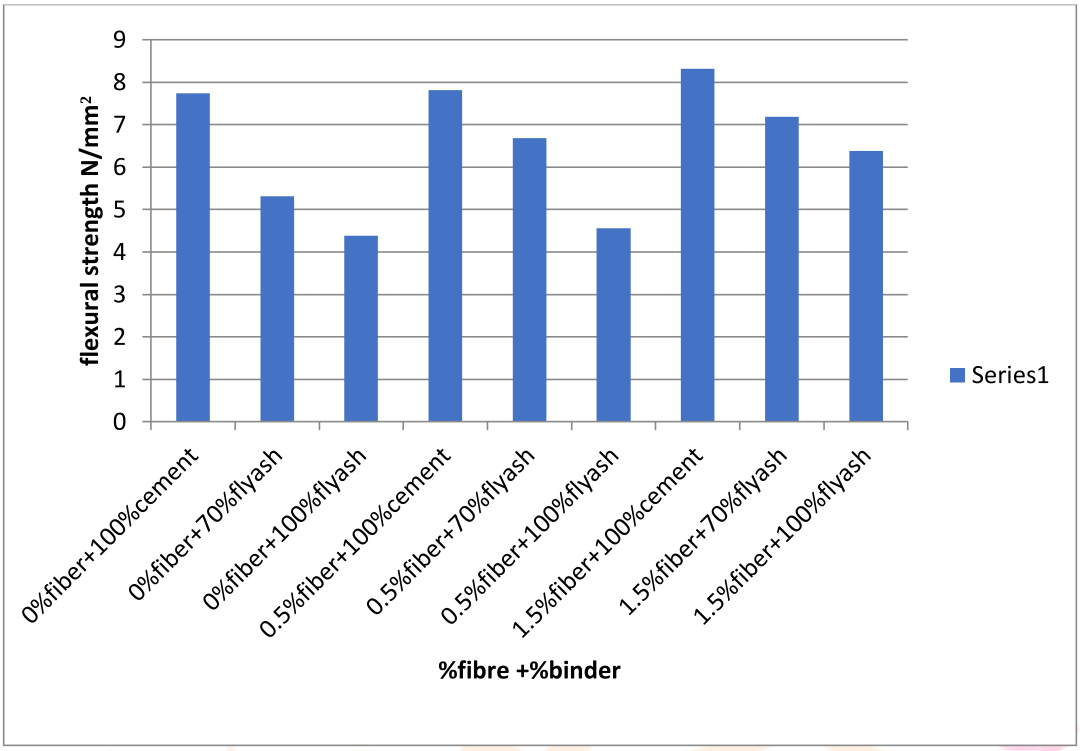

Fig 9: Comparison of flexural strength between control,GPCC and GPC

7. CONCLUSION

- Trial specimens were made for GPC with 1:1 ratio of NaOH and Na2SiO3 and were subjected to water curing which concluded that 1:1 ratio should not be adopted since it gave very very poor result for 7 days.
- The slump value of the fresh fly ash based GPC and GPCC increases with the increase in addition of water.
- The fresh flyash based GPC can be handled upto 120 minutes without any sign of setting.
- Incorporation of fibre shows increased strength in GPC and GPCC.
- Increase in % of fibre increased the strength of the concretes.
- GPC and GPCC had attained required (M25 grade) strength with 10 M concentration itself. But in comparison with control concrete values it is less only.
- In comparing GPC and GPCC, GPCC has higher strength .
- GPCC showed 6.35% increase in compressive strength when compared to GPC with 1.5% fibre.
- Replacement of flyash with 30% of cement showed quick setting time while experimentation.
- Replacement of flyash with 30% of cement showed very low workability.
- GPCC showed 10.52 % increase in flexural strength when compared to GPC with 1.5% fibre.
- GPCC with 1.5% incorporation of fibre showed the same result as what the control concrete gives with the same 1.5% percentage.

Researches are going on in order to produce high strength GPC and GPCC by increasing the concentration of NaOH to 12M, 14M ,16M etc. and also by increasing the duration of curing in oven. Increase in the concentration of NaOH increases the strength abruptly. Hence if cost aspect is the main consideration besides high performance then GPC and GPCC can be used without any doubt in consideration with the above results.crete.

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