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EXPERIMENTAL STUDY ON DURABILITY PROPERTIES OF GLASS FIBRE REINFORCED CONCRETE

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ABSTRACT

Concrete is the most widely used construction material because of its specialty of being cast into any desired shape. Concrete has low strength, low ductility and energy absorption. In fibre reinforced concrete the fibre are uniformly distributed and randomly oriented. It is an economical method for overcoming micro-cracks, increase tensile and compressive strength. Fibre is used as a reinforcing material because it is strong in tension. The characteristic of fibre reinforced concrete depends upon fibre material, geometries, distribution, orientation and densities.

In this project work, Glass fibre is added individually in varying percentage of 0.01%, 0.02%, 0.03% and 0.04% with concrete grade of M30, the effective utilization is step to eco-friendly construction, advantages of crack control, reduction in water permeability and rebound loss, increase in flexibility it had been chosen in this project. The strength related properties are determined to find out optimum dosage of each fibre. The test results showed that the addition of fibre will contribute to increase in strength.

FIBRE REINFORCED CONCRETE

Fibres are, most generally discontinuous and randomly distributed throughout the cement matrices. According to the terminology adopted by the American Concrete Institute (ACI) Committee 544, in Fibre Reinforced Concrete, there are four catagories:

SFRC	–	Steel Fibre Reinforced Concrete
GFRC	–	Glass Fibre Reinforced Concrete
SNFR	–	Synthetic Fibre Reinforced

C Concrete

NFRC – Natural Fibre Reinforced Concrete

The term fibre reinforced concrete (FRC) is defined by ACI 116R - Cement and Concrete Terminology, as "concrete containing dispersed randomly oriented fibres". The addition of fibre in concrete increases the impact and shatters resistance, fatigue endurance, shear strength, cracking resistance, long - term ductility, energy absorption capacity and toughness of concrete. It also provides the multi-directional concrete reinforcement, compatible with admixtures, in all types of cement and concrete mixtures. Another important advantage of adding fibre is the reduction of plastic shrinkage cracking.

OBJECTIVE OF THIS STUDY

The main objective of this study is as follows:

To study the Workability, Mechanical property and durability.

LITERATURE REVIEW

"Khale and Choudhary (2007)" studied the chemical reaction, the source materials, and the factors affecting Geopolymerization. Geopolymers possess excellent mechanical strength due to high degree of polycondensation. It is emerging technology for utilization of by-products like fly ash, slag, and kiln dust and also for the immobilization of toxic metal in the wastes. The pH range 13 - 14 is the most suitable for the formation of the Geopolymers with good mechanical strength. Activators are NaOH, Na_2So_4, Na_2Co_3, K_2Co_3, KOH, and K_2So_4. Curing temperature is an important factor in Geopolymerization. Alkali concentration in the range of 5 – 10N plays important role in the formation of Geopolymer.

"Duxson et al (2007)" reviewed the technology and the vast categories of materials that may be synthesized by alkali- activation of Aluminosilicates. Fly ash based Geopolymers are generally more durable and stronger. The Geopolymer concrete derived from fly ash, where the cost of the material is generally lower than OPC by a factor of about 10 -30%. The technological characteristics of Geopolymer concrete show the promising improvements.

"Filho et al (1999)" reported the chronological development of Sisal fiber reinforced cement composites. The Sisal fibers are reliable materials to be used in practice for the production of structural elements. The influence of Sisal fibres on the minimizing of plastic shrinkage in the pre-hardened state and Tensile, Compressive and bending strength in hardened state mortar mixes improved. Compressive strength is essentially unaffected by the inclusion of a low fraction of low modulus fibers. It improves the toughness and the post cracking performance.

"Ilamvazhuthi and Gopalakrishna (2013)" studied the Geopolymer concrete performance with PolyPropylene fibers. Low calcium fly ash obtained from thermal power plant is used and the ratio of alkaline solution kept as 2. Fiber diameter varies as 10 micron to 10mm and length as 6mm to 48mm. Napthalene Sulphonate based Super-Plasticizer by 4% of fly ash is used. The slump of fiber Geopolymer concrete was about 110 mm. Heat curing is done at $64^{o}C$ for 36 hours was done. The usage of fiber will be regulated as stipulated in IRC45/456. Dosage of fiber content vary from 0.23 – 0.6%. It has excellent Compressive strength and suitable for structural application.

Glass fiber

Glass fiber is a material consisting of numerous extremely fine fibers of glass.

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. This was first worn by the popular stage actress of the time Georgia Cayvan.

Properties

Properties of Glass Fibre

Fiber type	Tensile strength (MPa)	Compressive strength (MPa)	Density (g/cm^3)	Thermal expansion (µm/m·°C)	Softening T (°C)
E-glass	3445	1080	2.58	5.4	846
S2 glass	4890	1600	2.46	2.9	1056

Glass Fibre

Uses of Glass Fibers

Uses for regular glass fiber include mats and fabrics for thermal insulation, electrical insulation, sound insulation, high-strength fabrics or heat- and corrosion-resistant fabrics. It is also used to reinforce various materials, such as tent poles, pole\ vault poles, arrows, bows and crossbows, translucent roofing panels, automobile bodies, hockey sticks, surfboards, boat hulls, and paper honeycomb. It has been used for medical purposes in casts. Glass fiber is extensively used for making FRP tanks and vessels.

MIX DESIGN

DESIGN STIPULATIONS

- Characteristic compressive strength = 30N/mm^2

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- Maximum size of aggregate = 20 mm
- Degree of quality control = Good
- Type of Exposure= Mild

TEST DATA FOR MATERIALS

- Specific gravity of cement = 3.15
- Specific gravity of coarse aggregate = 2.7
- Specific gravity of fine aggregate = 2.6

Sieve analysis conforming to grading zone –III of sand.

Cement	Fine aggregate	Coarse aggregate	Water – cement ratio
1	2.03	3.87	0.40

The same mix was used for Polyester and coir fibre reinforced concrete.

Mix Proportion

Cement	= 350 kg/m^3
Water	= 140 kg/m^3
Fine aggregate	= 710kg/m^3
Coarse aggregate	= 1355 kg/m^3
w/c ratio	= 0.40

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FIBRE PROPORTION

Glass fibres of 0.01%, 0.02%, 0.03% and 0.04% are used in this project in order to find out the optimum dosage of fibre based on its compressive, tensile and flexural test result.

CASTING AND CURING

A laboratory type concrete mixer machine was used to mix the ingredients of concrete. To avoid balling of fibers, the following procedure was followed in casting. First, aggregates and cement were mixed for one minute, water being added within two minutes. Then fibres were manually added and dispersed throughout the mass in slow increment. Now the materials were allowed to mix thoroughly for three more minutes. The fibrous concrete was manually placed in the respective moulds. All the specimens were well compacted using a table vibrator. The specimens were demoulded after 24 hour.

RESULTS AND DISCUSSION

For M40 grade conventional concrete and fibre reinforced concrete the compressive strength, tensile strength and load deflection test results are conducted.

EXPERIMENTAL RESULTS

Compressive Strength

The results of compressive strength of cubes are obtained and are presented in Tables The variation of compressive strength with respect to type of concrete cube made by using different combination of adding fibre by weight of cement. Result Shows that the mixes with the different combination gives consistently higher strength than the normal concrete.

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Compressive strength (% of Glass fibre added)

% of Fibres	Average Compressive strength (N/mm2)	
	7 days	28 days
0	17.88	25.42
0.01	18.34	27.79
0.02	18.64	29.46
0.03	17.26	27.97
0.04	16.99	26.01

Split Tensile Strength

The results of split tensile strength of cylinder are obtained and are presented in Tables. The variation of compressive strength with respect to type of concrete cube made by using different combination of adding fibre by weight of cement. Result Shows that the mixes with the different combination gives consistently higher strength than the normal concrete.

Split tensile strength (% of glass fibre added)

% of Fibres	Average Split tensile strength (N/mm2)	
	7 days	28 days
0	1.46	3.14
0.01	1.58	3.27
0.02	1.77	3.56
0.03	1.61	3.24
0.04	1.48	3.16

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Flexural Strength

The results of flexural strength of prism are obtained and are presented in Tables. The variation of compressive strength with respect to type of concrete cube made by using different combination of adding fibre by weight of cement. Result Shows that the mixes with the different combination gives consistently higher strength than the normal concrete.

Flexural strength (% of glass fibre added)

% of Fibres	Average Flexural strength (N/mm2)	
	7 days	28 days
0	2.68	4.56
0.01	3.24	5.64
0.02	3.78	6.24
0.03	3.56	6.10
0.04	3.39	5.32

DISCUSSIONS ON RESULTS

The experiments are carried out by adding fibres separately with different percentages in normal concrete. The fibres are added by 0.01%, 0.02%, 0.03% and 0.04% conducted on M_{30} grade normal concrete to determine the optimum dosage.

Compressive Strength

The fibres were added separately to normal concrete to determine the maximum compressive strength. The test results for optimum percentage of each fibre were compared with conventional concrete and discussed. The figure shows the compressive strength value of conventional concrete (CC) and various percentage additions of fibres.

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It is found that, at the age of 28 days, maximum compressive strength (18.64 N/mm^2) is observed for 0.02% addition of glass fibre and it is 10% more than the conventional concrete.

Split Tensile Strength

The fibres were added separately to normal concrete to determine the maximum split tensile strength. The test results for optimum percentage of each fibre were compared with conventional concrete and discussed.

It is found that, at the age of 28 days, maximum split tensile strength (1.77 N/mm^2) is observed for 0.02% addition of glass fibre and it is 12% more than the conventional concrete.

Flexural Strength

The fibres were added separately to normal concrete to determine the maximum flexural strength. The test results for optimum percentage of each fibre were compared with conventional concrete and discussed.

It is found that, at the age of 28 days, maximum flexural strength (3.78 N/mm^2) is observed for 0.02% addition of glass fibre and it is 10% more than the conventional concrete.

Acid attack on concrete

The Compressive strength of M_{40} grade of Conventional Concrete, Glass Fiber concrete and with fibre specimens subjected to Acid resistance tests is as:

After immersion in Acid solution, the Compressive strength of M_{40} grade of concrete was reduced. The strength of the specimens prepared by using Conventional Concrete, Glass fiber concrete (GFC), with 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF after immersion is 16.57N/mm^2, 17.46 N/mm^2, 17.68 N/mm^2, 16.12 N/mm^2 and 15.37 N/mm^2 respectively. Thus the addition of fibre is found to have increased the durability against Acid solution.

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The loss of weight of M_{40} grade of concrete and Glass fiber concrete subjected to acid test, prepared by using the Conventional Concrete, Glass fiber concrete (GFC), with 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF are 1.08%, 1.06%, 1.05%, 1.08% and 1.11% respectively.

As expected, the conventional concrete showed the least resistance to Sulphuric Acid attack, where the loss in weight was measured and found to be 0.52%. The loss in weight of the samples that were exposed to Sulphuric Acid was smallest because Calcium Sulphate (gypsum) is less soluble in water. These results can be attributed to the formation of soluble Calcium salts due to the reaction of acids with fly ash. Due to this fact, the amount of weight loss of samples that are kept in H_2SO_4 was lowest.

Sulphate attack on concrete

The Compressive strength of M_{40} grade of Conventional Concrete, Glass Fiber concrete and with fibre specimens subjected to sulphate resistance tests is as:

After immersion in Sulphate solution, the Compressive strength of M_{40} grade of concrete was reduced. The strength of the specimens prepared by using Conventional Concrete, Glass fiber concrete (GFC), with 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF, after immersion were 15.48N/mm^2, 16.02 N/mm^2, 16.96 N/mm^2, 15.46 N/mm^2 and 14.34 N/mm^2 respectively. It is observed that GFC mix containing 0.02% glass fibre an increase in strength as compared to conventional mix after immersing the cubes in Sodium Sulphate solution.

The loss of weight M_{40} grade of Conventional Concrete, Glass Fiber concrete subjected to Sulphate test, prepared by using the Conventional Concrete, Glass fiber concrete (GFC), 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF are 1.15%, 1.14%, 1.06%, 1.16%, and 1.18%, respectively. It indicate that 0.02% of Glass fibres is considered optimum from the consideration of resistance to Sulphate attack as observed from the experimental results. It was clear that compared to all other mixes, the strength and weight loss was maximum for the conventional

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mix. Comparing the strength corresponding to 90 days Sulphate exposure the rate of strength and weight loss was found to be minimum for 0.02% addition of glass fibers.

Alkaline attack on concrete

The Compressive strength of M_{40} grade of Conventional Concrete, Glass Fiber concrete and with fibre specimens subjected to alkaline resistance tests is as:

After immersion in Alkaline solution, the Compressive strength of M_{40} grade of concrete was reduced. The strength of the specimens prepared by using Conventional Concrete, Glass fiber concrete (GFC), with 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF, after immersions were 16.08 N/mm^2, 16.76 N/mm^2, 17.46 N/mm^2, 15.86 N/mm^2, and 14.68 N/mm^2 respectively. It is observed that GFC mix containing 0.02% glass fibre an increase in strength as compared to conventional mix after immersing the cubes in Alkaline solution.

The addition of alkali in the form of NaOH, which is commonly done when evaluating aggregates for potential alkali-silica reactivity and the effect of ASR on the mechanical properties of concrete, can causes reduction in Compressive strength of conventional as well as Glass Fiber concrete concrete.

Chloride attack on concrete

The Compressive strength of M_{40} grade of Conventional Concrete, Glass Fiber concrete and with fibre specimens subjected to chloride resistance tests is as:

After immersion in chloride solution, the Compressive strength of M_{40} grade of concrete was reduced. The strength of the specimens prepared by using Conventional Concrete, Glass fiber concrete (GFC), with 0.01% GF, 0.02% GF, 0.03% GF and 0.04% GF after immersions were 15.23 N/mm^2, 16.76 N/mm^2, 17.12 N/mm^2, 14.98 N/mm^2, and 13.68 N/mm^2, respectively. It is observed that GFC mix containing 1.5% glass fibre, reduce in strength as compared to conventional mix after immersing the cubes in chloride solution.

CONCLUSIONS

Fly ash is a waste material therefore it is very important from economical point of view. Using of fly ash in concrete decreases the air pollution. By using fibres in concrete provides economical benefits and environmental friendly. Based on the experimental results the following observations are made.

- Geopolymer concrete can be widely used in theϖ manufacture of precast structures.
- It can be used in areas where faster strengthϖ achievement is needed.
- Fibre reinforced geopolymer concrete completely eliminates the use of cement in concrete and helps to prevent global warming and to utilize the fly ash effectively.
- The density of geopolymer concrete composites¬ was found approximately equivalent to that of conventional concrete.
- It is concluded that 0.02% addition of Glass fibre in Geopolymer concrete induces higher strength and durability characteristics compared to conventional concrete.
- The increase in flexural strength of Geopolymer concrete with fibres is due to increased area of bonding at interfacial region of the matrix and fibre.
- Beyond the optimum, the strength is reduced due to more voids formation in concrete and improper bonding of materials.
- The minimum loss of weight and loss of compressive strength of Geopolymer concrete in all durability aspects due to addition of fibres.
- The work can be further extended to reinforced beams, slabs and columns to check their behavior in terms of deflection, crack pattern, and failure of members.

REFERENCES

1. ASTM C 1018-97, “Standard test method for Flexural Toughness and First crack strength of Fibre Reinforced Concrete”, American Standard for Testing Materials, Pennsyluvia, USA.

2. ASTM C 1202-05, "Standard Test Method for Electrical Indiction of concrete's ability to resist Chloride Ion Penetration", ASTM International, West Conshohocken.
3. Abdul Aleem M.I. and Arumairaj P.D. (2012), "Optimum Mix for the Geopolymer Concrete", International Journal of Science and Technology, Vol. 5, No. 3, pp 2299-2301.
4. Anuradha R., Sreevidya V., Venkatasubramani R. and Rangan B.V. (2011), "Modified Guidelines for Geopolymer Concrete Mix Design using Indian Standard", SID, pp353-364.
5. Athiappan K. and Vijaychandrakanth S. (2014), "Experimental study on flexural behavior of sisal fiber in reinforced concrete beam", International Journal of Engineering Research and Technology, Vol. 3, No. 5, pp 1500-1505.
6. Divya Khale and Rubina Choudhary (2007), "Mechanism of Geopolymerization and factors influencing its development", Journal of Material Science, pp 729 – 746.
7. Duxson P., Fernandez-Jimenez A., Provis J.L., Lukey G.C., Palomo A. and Van Deventer J.S.J. (2007), "Geopolymer Technology: the current state of the art", Journal of Material Science, pp 2917-2933.
8. Ganesan N., Ruby Abraham and Deepa raj S. (2015), "Durability characteristics of steel fibre reinforced Geopolymer concrete", Construction and Building Materials, Vol. 93, pp 471-476.
9. IS 383-1970, "Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete", Bureau of Indian Standards, New Delhi, India.
10. IS 516-1959, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, India.
11. IS 10262-2009, "Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standards, New Delhi, India.
12. Romildo Dias Toledo Filho, Kuruvilla Joseph, Khosrow Ghavami and George Leslie England (1999), "The use of Sisal Fiber as Reinforcement in Cement based Composites", Revista Brasileira de Engenharia Agricola e Ambiental, Vol. 3, No.2, pp 245-256.