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 0.5%, 1%, 1.5% and 2% with concrete grade of M40., 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
SNFRC –	Synthetic Fibre Reinforced 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

Ronald F. Zollo (1997)" presented an overview regarding the history and development of Fibre Reinforced Concrete 30 years ago. According to this report, in the early 1960s, the works on fibre reinforced concrete had been started. A lot of research work has been conducted by many researchers on different fashions. But these projects have studied about steel fibres alone. So far, there were only a few works which have studied the other fibres like nylon, plastic, rubber and natural fibres. But those researches are completely different from the current study, since they have concentrated along the material strength properties not on their structural behaviour.

"Jayaprakasan and Divya (2015") have investigation was to experimentally study the mechanical properties of steel and polyester fibre. The present study is steel and polyester hybrid fibre concrete and a comparison of which with conventional concrete mix and also find out the optimum dosage of steel fibre in the hybrid reinforced concrete. The strength properties are studied for the conventional concrete. A combination of mineral admixtures like steel fibre, Recron 3S Polyester fibre OPC is used. Use M30 mix and using coarse aggregate of 20mm maximum size. From the present experimental study the following conclusions are arrived. Optimum dosage of steel fibre is found to be 0.2% by weight of cement. Introduction of hybrid fibre into the concrete reduce the workability of the mix. Addition of hybrid fibre is found to be increased 28th day strength, impact strength and better modulus of elasticity of concrete. Addition of fibre in concrete reduces the formation of internal micro cracks.

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. Glass fibers can also occur naturally, as Pele's hair.

Properties

Properties of Glass Fibre

Fiber type	Tensile strength (MPa)[10]	Compressive strength (MPa)	Density (g/cm^3)	Thermal expansion (µm/m·°C)	Softening T (°C)
E-glass	3445	1080	2.58	5.4	846
S-2 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 = 40N/mm^2
- 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

FIBRE PROPORTION

Glass fibres of 0.5%, 1%, 1.5% and 2% 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.

Compressive strength (% of Glass fibre added)

Mix ratio	**Compressive strength (N/mm^2)**				
M40	Conventional concrete	0.5%	1.0%	1.5%	2%
7 Days	27.47	28.89	30.56	33.67	31.34
14 Days	38.07	40.87	43.23	45.54	44.78
28 Days	45.07	46.25	47.45	49.45	47.45

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)

Mix ratio	Split Tensile Strength (N/mm^2)				
M_{40}	Conventional concrete	0.5%	1.0%	1.5%	2%
7 Days	2.10	2.18	2.54	2.97	2.67
14 Days	2.67	2.86	3.45	3.76	3.56
28 Days	3.44	3.74	3.84	4.67	3.98

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)

Mix ratio	Flexural Strength (N/mm^2)				
M_{40}	Conventional concrete	0.5%	1.0%	1.5%	2%
7 Days	3.45	3.51	3.58	3.64	3.60
14 Days	6.98	7.13	7.36	7.45	7.40
28 Days	7.45	7.87	7.98	8.55	8.34

DISCUSSIONS ON RESULTS

The experiments are carried out by adding fibres separately with different percentages in normal concrete. The fibres are added by 0.5%, 1%, 1.5% and 2% conducted on M_{40} 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.

It is found that, at the age of 28 days, maximum compressive strength (49.64 N/mm^2) is observed for 1.5% 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 (4.67 N/mm^2) is observed for 1.5% addition of glass fibre and it is 26% 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 (8.55 N/mm^2) is observed for 1.5% addition of glass fibre and it is 12% 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 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF after immersion were 43.26N/mm^2, 44.34 N/mm^2, 45.39 N/mm^2, 47.85 N/mm^2, 42.86 N/mm^2 respectively. Thus the addition of fibre is found to have increased the durability against Acid solution.

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 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF 0.63%, 0.56%, 0.64%, 0.59%, 0.53%, 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 0.63%. 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 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF were 43.26N/mm^2, 45.14 N/mm^2, 46.67 N/mm^2, 47.97 N/mm^2, and 43.16 N/mm^2 respectively. It is observed that GFC mix containing 1.5% 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), with 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF are 1.38%, 1.10%, 1.03%, 0.96%, 0.84%, 0.94% and 0.71% respectively. It indicate that 1.5% 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 mix. Comparing the strength corresponding to 90 days Sulphate exposure the rate of strength and weight loss was found to be minimum for 1.5% 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 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF were 43.86N/mm^2, 44.74 N/mm^2, 45.26 N/mm^2, 47.19 N/mm^2, and 43.48 N/mm^2 respectively. It is observed that GFC mix containing 1.5% 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 0.5% GF, 1.0% GF, 1.5% GF, 2.0% GF were 43.86N/mm^2, 45.26N/mm^2, 46.47 N/mm^2, 48.25 N/mm^2, and 43.79 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

The results from this research aimed at development of beam-column joints with higher ductility and energy absorption capability for the structures constructed in active seismic zones through the use of hybrid fibers have been reported.

Based on the experimental results the following conclusions are drawn.

1. The optimum percentage addition of glass fibre is found 1.5%,
2. The compressive strength increase with increase of percentage of GFC upto certain limit. The average compressive strength of GFC is 9%, 21% and 10% higher than the conventional concrete and is obtained in CC, 0.5% AND 1.0% respectively..
3. The average split tensile strength of GFC is 13%, 21% and 10% higher than the conventional concrete and is obtained in CC, 0.5% AND 1.0% respectively.
4. The average flexural strength of GFC is 8%, 15% and 9% higher than the conventional concrete and is obtained in CC, 0.5% AND 1.0% respectively..
5. The durability study shows that GFC of 1.0% replacement concrete is more resistant to acid attack and chloride attack tests.
6. Water resistance capacity of GFC of 1.5% replacement concrete is also better than the conventional concrete.
7. Chloride penetration is also minimum in GFC of 1.5% replacement concrete when compared to the conventional concrete
8. The failure of GFRC and Glass Fibre joints occurred after the formation numerous cracks in the beam region and crushing at the junction of beam and column. The mode of failure of FRC joint is more ductile than RCC joint.

In general, the hybrid fibre reinforced concrete for beam-column joints is highly advisable and recommended for cyclic loading when compared to beam-column joints with mono fibre (Glass Fibre) and without fibres.

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