STRENGTH CHARACTERISTICS OF FIBROUS CONCRETE

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Abstract: Concrete is an important construction material used in our daily life. Industrial by-products (fly ash) have become burden for disposal. In this study, two grades of concrete namely M30 and M50 have been investigated for plain and fiber reinforced concrete. Compressive and split tensile strength tests were performed with different aspect ratios of corrugated steel fibres of two lengths 2cm, 4 cm and three percentages of fibers 0.5,1, 1.5 by volume of concrete. The water cement ratios used was 0.45. The main objective of this study is to study the behavior of plain and Fibre reinforced concrete at different aspect ratios and at different volume fractions of steel fibres. The effect of fibres on strength properties of concrete at different temperatures is highlighted in this research to analyze the behavior of concrete.

By the addition of 1.5% by weight, steel fiber reinforced concrete showed a better overall residual strength and better crack resistance than non-fibrous concrete. The carbonation process for concrete with steel fiber is a little influenced by temperature compared to concrete without steel Fibre. Researchers has done extensive work on replacing cement with mineral admixtures in concrete obtained results by adding these mineral admixtures as substitute of cement decreases the emission of carbon dioxide in concrete. When the concrete is subjected to fire, the performance of concrete is evaluated in terms of compressive strength, flexural strength and density. In this study the mechanical properties of concrete were studied. Engineering structures in the city environment surrounded with combustible materials are prone to be in the danger of combined effects of blast-induced impact loading and fire. Steel-fiber reinforced concrete (SFRC) beams were tested after pre-impact loading to explore their fire-resistance. The beams were first subjected to impact loadings and then exposed to fire with a constant load.

Keywords: fiber reinforced concrete, Steel-fiber, fire-resistance, admixtures, combustible materials

I.INTRODUCTION

Concrete is widely used as a primary structural material in construction due to numerous advantages, such as strength, durability, ease of fabrication, and non-combustibility properties, it possesses over other construction materials. To increase the performance of the conventional concrete, we introduced the steel corrugated fibres. Because of this the performance of concrete during fire and impact loads has been increased. This fibrous concrete will arrest the cracks and restrict the formation of minor cracks in concrete.

Concrete structural members when used in buildings must satisfy appropriate fire safety requirements specified in building codes. This is because fire represents one of the most severe environmental conditions to which structures may be subjected. Therefore, provision of appropriate fire safety measures for structural members is an important aspect of building design. Exposure to high temperatures mainly caused by the fires is severe damage to buildings and structures. Fire resistance and thermal behavior after exposure to a fire in the concrete structure depends on thermal and mechanical properties of concrete materials. Elasticity is one of the major material properties which have an important influence in the structural behavior of reinforced concrete structures both before and after high temperatures exposure. The compressive strength of nominal concrete usually between 20 to 50MPa, which is classified as normal-strength concrete (NSC). In recent years,

concrete with a compressive strength in the range of 50 to 120MPa has become widely available and is referred to as high-strength concrete (HSC). When compressive strength exceeds 120MPa, it is often referred to as ultrahigh performance concrete (UHP). Concrete compressive strength will decline with the effect of temperature rise, and the rate of decline is largely due to the strength of concrete compressive strength. The use of steel fiber wires can be considered as a solution to control cracking and to increase the strength and ductility of concrete. Exposure to high temperatures causes a change in the concrete that causes a lot of cracks, this study is directed to determine the effect of steel fibers in concrete elasticity modulus after obtaining exposure to high temperatures

Fiber-reinforced concrete is concrete that is made by adding fibers to the mix. The purpose of the addition of fiber is to increase the tensile strength of concrete, so that the concrete can withstand ensile strength due to weather, climate and temperature changes that usually occur in the concrete with a large surface. Types of fiber used in fiber-reinforced concrete can be of natural fibers or artificial fibers. Slurry-infiltrated fibrous concrete (SIFCON) can be considered as a special type of fiber concrete with high fiber content. The matrix usually consists of cement slurry or flowing mortar. The fiber content of FRC generally varies from 1to3 percent by volume, but the fiber content of SIFCON varies between 5 and 20 percent. Unlike FRC, for which the fibers are added to the wet or dry concrete mix, SIFCON is prepared by infiltrating cement slurry into a bed of fibers preplaced and packed tightly in the moulds. The research studies found that SIFCON surpasses conventional FRCC in its ductility and energy absorption capacity. Because of these characteristics SIFCON is used for important structures including military facilities, runway precast pavements, and subterranean shelters. In the last few decades, the behavior of construction materials under blast loading has been a subject of growing interest because of the huge increase in the number of nuclear power plants, terrorist threats, and military threats. With the above-described features, SIFCON has considerable promise as a blast-proof material and fireproof material.

II. LITERATURE SURVEY

GunavantK.Kate, et al 1998: In this study six types of concrete mixtures were mixed. These mixes were made with W/C ratio of 0.33. One mix with O.P.C alone as binder and other five mixes with O.P.C replacing by weight of 15, 30, 45, 60 and 70% of fly ash. Application of Super Plasticized dosage for concrete mix 0 to 45% fly ash 1% by weight of cement is recommended and the dosage increased to concrete mix 60% to 70% fly ash is 2%. Tests like compressive strength, Modulus of elasticity, spilling tensile and Shrinkage Strain are conducted and from the test results it is observed that the rate of increase of shrinkage strain with increase in fly ash content is relatively at 90days rather than 28 & 56 days

Mini Soman, et al 2012: In this study, chemical properties of fly ash were mentioned by providing constituents and their percentage. Physical properties like Fineness residue, Moisture content, Soundness were also mentioned. 20%, 30%, 40%, 50% and 60% replacement of cement with fly ash is done. It is observed that minimum 50% cement could be replaced with fly ash without effecting its fresh and hardened properties. Four beams were casted providing under reinforcement for two beams and balanced reinforcement for other two beams.

Jayashree et al. (2013): In this work they used a composite beam (SIFCON-RC) comprises of two layers with RC as the top and SIFCON as the bottom layer. Materials used are cement-sand slurry, short, crimped fibers (NOVOCON 1050). Flexural strength test is made on beams of size 1m length x 0.1m breadth x 0.2 height, with varying percentages of RC and SIFCON. ANSYS software is used to analytical investigations. The crack pattern diagonal tension failure is noted in all the specimens. The diagonal crack starts from the last flexural crack and turns gradually into a crack more and more inclined under the shear loading. The results obtained are mainly flexural strength is more for 40% SIFCON - 60% RC beam. 40%

SIFCON – 60% RC and 50% RC – 50% SIFCON beams have lesser displacement than rest of the beams. It is observed that there is a gradual increase in modulus of elasticity with increase in

SIFCON volume from 20% to 40% At 50% by volume of SIFCON there is a sudden drop in the young's modulus When tested in ANSYS software the results are reasonable and the difference is less than 10%.

Dr. Kv. Ramesh et al 2016: In this paper, he performed tests on normal concrete mix, fly ash replacement (30,40,50%). He mainly deals change in color, cracks, weight loss and residual compressive strength. No change in color up to 600^0C in all mixes but at 800^0C the fly ash replaced members color changes to orange red. No visual cracks observed up to 400^0C, at 600^0C surface cracks are observed and at 800^0C are pronounced. Gradual decrease in weight loss with increase in fly ash content is observed. After exposure to heat from 200^0C to 800^0C with an internal of 200^0C cubes were cooled to room temperature then compressive strength is of all of fly ash replacement is decreases with increase in replacement percentage and increase in temperature and it is maximum at 7 days for normal concrete mix and at 28 days C70 and F30.

KuldeepDagar et al. (2012): The proportions of cement and sand are 1:1, 1:1.5, and 1:2. Fly ash or silica fume equal to 10-15% by weight of cement is used in the mix with water cement ratio in between 0.3 and 0.4 percentage of super plasticizer used is in between 2 to 5% by weight of cement. Unlike the cracks which form in continuous reinforced cementitious composites such as Ferro cement, the cracks in SIFCON do not extend through the whole width of the specimen. The ultimate tensile strength of SIFCON typically varies from 20 to 50 MPa, depending on the percentage of steel fibers and the mix proportions used. SIFCON exhibits an extremely ductile behavior under compression. The results thus obtained are mainly ultimate tensile strength varies between 20 and 50 MPa depending upon the percentage of steel fibers and mix proportions. Good properties are achieved by incorporating fibers to the mix.

VijayaKumar.M et al. (2017): Durability deals with the safety against dynamic loads like earthquake, any sudden abnormal loads and resists the acid and sulphate attack and abrasion. Materials used are PPC type cement, fly ash, super plasticizer CONPLAST SP 430, steel and glass fibers. All the cubes were tested in saturated condition after wiping out the surface moisture from the specimen. For each trial mix, cubes were tested at the age of 28 days. Tests conducted are compression strength test, durability test, acid attack test, sulphate attack test, abrasion test. The results thus obtained are the compressive strength of SIFCON increased about 28% in compared to M30, Ductility of SIFCON is high and can resist abnormal loads. Resistance to acid attack and sulphate attack is better than conventional concrete.

Mahmoud Nili et al. (2010): Impact resistance was studied by using concrete with water content 0.46 and 0.36 with steel fibers content 0.5% and 1% without adding silica fume. In the present work, the impact resistance, and mechanical properties of fibrous and non-fibrous concrete specimens with and without silica fume addition were experimentally assessed. The tests used are drop weight test (reported by the ACI committee [23]), explosive test, projectile impact test, constant strain rate test. Tests were conducted on six-150 x 64mm discs cut from 150 x 300mm cylindrical specimens with diamond cutter. The results obtained are Higher the volume of the fibers (0.5%-1%) more is the compressive strength (14%-19%) and the variation is linear, when water content is less split tensile strength is more among the specimens of same water content one with silica fume shows better results, Less W/C ratio with silica fume gives more flexural strength, using fibers and low W/C ratio one can attain more impact strength. Failure in the case of plain concrete is confined to a plane, when fibers are used the probability of failure in a single direction is reduced, thereby increasing the strength.

Pang-jo Chun et al. (2013): The research found that SIFCON surpasses conventional FRCC in its ductility and energy absorption. This research employed loose steel fibers which were not bonded at the ends so that the fibers dispersed well during the fabrication process. The explosive used is gelignite. An experiment was conducted to produce a high strength concrete with nil natural sand content by replacing it with M sand. Materials used are Ordinary Portland cement of 53 grades .M sand (Manufactured sand) passing through 4.75 mm sieve was used. Hooked end steel fibers having a diameter of 1.00mm and length of 30 mm with aspect ratio of 30was used. Random orientation of fibers was carried out. The test used is contact blast loading test. It is observed that surface if SIFCON heaved less than that of high strength concrete. This also indicates the remarkable ductility and blast resistance of SIFCON. Hence it is reasonable to say that SIFCON is suitable for structures which may subject to blast loading.

Prithvi Raj. B.S et al. (2014): The main objective of this research programme is to find out the shrinkage characteristics of Slurry Infiltrated Hybrid Fiber Reinforced Concrete (SIHFCON). Along with GGBFS (30% replacement to cement), variety of fibers with combination of more than one fiber are also used. In this work they used hybrid fiber reinforced concrete in which more than one fiber types are used as secondary reinforcement. The brittle nature of concrete results in sudden unpredictable failure. By using hybrid fiber combinations of steel and polypropylene fibers or others the explosive failure behavior of high strength concrete (HSC) may be avoided. The main objective is to find out Maximum length of crack, Maximum width of crack, Total number of cracks, Area of cracks of SIFCON For various combinations of fibers.

III. MATERIALS USED

3.1 Ordinary Portland Cement:

In the experimental investigations, 53-grade of ordinary Portland cement of ULTRATECH Brand is used. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1968 and found to be conforming various specifications of IS 12269-1987.

3.2 Fine Aggregate:

In the present investigation, fine aggregate used is obtained from local sources. The sand is made free from clay matter, silt, and organic impurities and sieved on 4.75mm IS sieve. The physical properties of fine aggregate like specific gravity, bulk density, gradation, and fineness modulus are tested in accordance with IS: 2386 and the results are shown in table 1 and 2. Grain size distribution of sand shows it is close to Zone II of IS 383-1970.

3.3 Coarse Aggregate:

The crushed angular aggregate of 12mm, 20mm size obtained from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, gradation, flakiness, elongation index and sieve analysis are tested in accordance with IS: 23861963.

3.4 Fly Ash:

In the present study of work, the Class F-fly ash is used, which is obtained from Vijayawada thermal power station in Andhra Pradesh.

3.5 Water:

Water free from chemicals, oils and other forms of impurities has been used for mixing of concrete as per IS: 456:2000.

3.6 Steel fibers:

Steel fibers are reinforcements materials that are made of cold drawn wire and then shaped to as desired to improve concrete mechanical properties. It is widely used in highway, bridge, tunnel, airport runway, basic structure.Tenstile strength : minimum 1200 N/mm2.

Usage: Construction of tall building, as well as shock resistance structure and high temperature kiln stove construction and military purposes.

3.6.1 Steel Fiber Reinforced Concrete and Applications:

During recent years, steel fiber reinforced concrete has gradually advanced from a new, rather unproven material to one which has now attained acknowledgment in numerous engineering applications. Lately it has become more frequent to substitute steel reinforcement with steel fiber reinforced concrete. The applications of steel fiber reinforced concrete have been varied and widespread, due to which it is difficult to categorize. The most common applications are tunnel linings, slabs, and airport pavements. Many types of steel fibers are used for concrete reinforcement. Round fibers are the most common type and their diameter ranges from 0.25 to 0.75 mm. rectangular steel fibers are usually 0.25 mm thick.

Below are some properties that the use of steel fibers can significantly improve: Flexural Strength Flexural bending strength can be increased of up to 3 times more compared to conventional concrete, Fatigue Resistance Almost 1 1/2 times increase in fatigue strength, Greater resistance to damage in case of a heavy impact, Permeability is low, the material is less porous, More effective composition against abrasion and spalling, Shrinkage cracks can be eliminated, Corrosion may affect the material, but it will be limited in certain areas.

*3.6.2 Effect of Fibers Utilized with Concrete***:**

Fiber reinforced concrete is a composite material comprised of Portland cement, aggregate, and fibers. Normal unreinforced concrete is brittle with a low tensile strength and strain capacity. The function of the irregular fibers distributed randomly is to fill the cracks in the composite. Fibers are generally utilized in concrete to manage the plastic shrink cracking and drying shrink cracking. They also lessen the permeability of concrete and therefore reduce the flow of water. Some types of fibers create greater impact, abrasion and shatter resistance in the concrete. Usually, fibers do not raise the flexural concrete strength. The quantity of fibers required for a concrete mix is normally determined as a percentage of the total volume of the composite materials. The fibers are bonded to the material and allow the fiber reinforced concrete to withstand considerable stresses during the post-cracking stage. The actual effort of the fibers is to

IV. TESTS AND PROCEDURES

In this study we have performed tests on cement (OPC 53 grade), fly ash (class F).

Tests on cement:

Standard Consistency Test
Initial setting time
Specific gravity of cement

Tests on Fly ash:

Fineness
Standard consistency test
Initial setting time
Specific gravity

4.1 Standard Consistency Test:

Apparatus required:

Weighing balance of 1000g with accuracy 1g and Measuring cylinder of 200ml, VICAT apparatus, VICAT Mould, Glass plate, the plunger of 10mm dia and Hand Trowel.

Procedure:

Take 400g of cement and place it in a bowl or tray.
Now Assume standard consistency of water is 28% and add the same quantity of water in cement and mix it.
Mix the paste thoroughly within 3-5 minutes. The time taken to obtain cement paste after adding water is called gauging time.
Now fill the paste in Vicatmould correctly any excessive paste remained on Vicatmould is taken off by using a trowel.
Then, place the VICAT mould on Glass plate and see that the plunger should touch the surface of VICAT mould gently.
Release the Plunger and allow it to sink into the test mould.
Note down the penetration of the plunger from the bottom of mould indicated on the scale.
Repeat the same experiment by adding different percentages of water until the reading is in between 5-7mm on the Vicat apparatus scale.

Standard Consistency Test

4.2 Standard Consistency Test Initial Setting Time:

Apparatus Required:

Weighing balance of 1000g with accuracy 1g and Measuring cylinder of 200ml, VICAT apparatus, VICAT Mould, Glass plate, the plunger of 10mm dia and Hand Trowel, stopwatch.

Procedure:

Take 400g of cement and place it in a bowl or tray.
Now add water of Start the stopwatch now water is added to the cement. Water of quantity 0. 85P.times (Where P is the Standard consistency of cement) is considered.
Now fill the mix in Vicat mould. If any excessive paste remained on Vicatmould is taken off by using a trowel.

Then, place the VICAT mould on non-porous plate (Glass plate) and see that the plunger should touch the surface of VICAT mould gently.
Release the Plunger and allow it to sink into the test mould.
Note down the penetration of the plunger from the bottom of mould indicated on the scale.
Repeat the same experiment at different positions on the mould until the plunger should stop penetrating 5 from the bottom of the mould.
The time period elapsed between the moment water is added to the cement and the time, the needle fails to penetrate the mould of 5mm when measured from the bottom of the mould**,** is the initial setting time of cement.
Now replace the needle (plunger) by the one with an annular attachment. The cement is assumed as finally set When, upon applying the needle gently to the surface of the test mould, the needle makes an impression therein, while the attachment fails to do so. The time period between the moment water is added to the cement and the time at which needle makes an impression on the surface of the mould, while the attachment fails to do so, is the final setting time of cement.

Initial Setting Time Test

4.3 Specific Gravity:

Apparatus Required for Le Chatelier's Principle: -

1. Cement
2. Kerosene
3. Specific Gravity Bottle capacity of 250 ml with stopper.
4. Weighing balance with 0.1 gm accurate

Procedure for finding Specific gravity in cement: -
The Lechatlier flask should be free from moisture content, that mean flask is thoroughly dried.
Now, weigh the empty flask and note it as $\mathbf{W_1}$.
Take 50gm of cement and add it in Flask. Now weight the Flask with the stopper as $\mathbf{W_2}$
Now pour kerosene in the sample up to the neck of the bottle. Mix thoroughly and see that no air bubbles left in the flask. Note down the weight as $\mathbf{W_3}$
Empty the flask and fill the bottle with kerosene up to the tip of the bottle and record the weight as $\mathbf{W_4}$.

SPECIFIC GRAVITY = (W2 – W1)/(W2 – W1) – (W3 – W4) * 0.79

WHERE, 0.79 = Specific Gravity of Kerosene oil.

where, Specific gravity of Kerosene = 0.79 g/cc.

A good cement should have the Specific gravity of 3.1-3.6 g/cc.

4.4 Properties Of Ingredients:
Cement:
Specific gravity: 3.15
Consistency limit: 28%

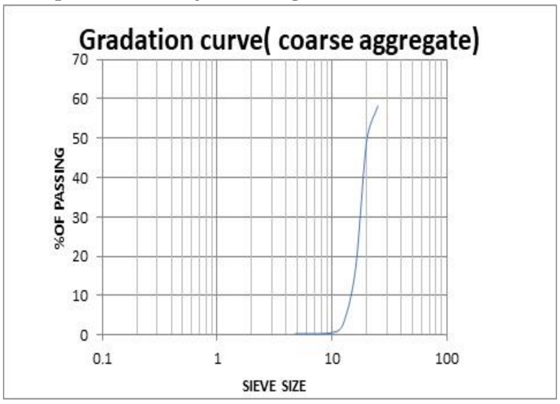
Moulding Cube

Initial setting time: 42 min
Final setting time: 420 min
Cube strength - 3 days: 35MPa
- 7 days: 47MPa
- 28days: 59MPa

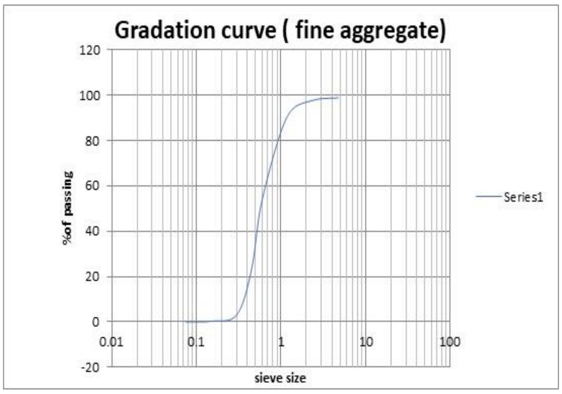
Fly ash:

Specific gravity: 2.35
Consistency limit: 30%
Initial setting time: 46 min
Final setting time: 470 min
Cube strength - 3 days: 32MPa
- 7 days: 43MPa
- 28days: 52MPa

Coarse aggregate:
Specific gravity: 2.81
Loose density: 1429kg/m3
Compacted density: 1575kg/m3



Fine aggregate:
Specific gravity: 2.69
Loose density: 1560kg/m3
Compacted density: 1680kg/m3



SUPER PLASTICIZER:
Conplastsp 430.
Specific gravity :1.20
Replacement: 5-10 percent of water content.

4.5 Design Stipulations For Mix Design:

Type of cement: OPC 53 grade
Maximum nominal size of aggregate: 20mm
Minimum cement content not including fly ash: 320kg/m3
Water- cement ratio: 0.45

Specific gravity:
Fine aggregate: 2.69
Coarse aggregate: 2.81
Cement: 3.15

Mix Design procedure (As per IS 10262-2019):
The mix design is adopted after conducting several conventional trails. The final mix design procedure is tabulated as follows

Calculation of Cement Content:
Water-Cement ratio: 0.45
Cement Content: 148/0.45 =328.88kg/m3

Proportion of volume of coarse aggregate and fine aggregate content:
Volume of Coarse aggregate: 0.63
Volume of fine aggregate: 0.37

Mix calculation:
Type of cement: OPC 53 grade
Maximum nominal size of aggregate: 20mm, 12mm
Minimum cement content: 320kg/m3
Water- cement ratio: 0.45
Specific gravity
Fine aggregate: 2.69
Coarse aggregate: 2.81
Cement: 3.15

M30:
Cement: 353kg/m^3
Water: 148kg/m^3
Fine aggregate: 712kg/m^3
Coarse aggregate: 1300kg/m^3
Chemical admixture: 3.53kg/m^3

Free water- cement ratio: 0.42

M30 (with fly ash and steel fibers):
Cement: 253kg/m^3
Fly ash :100kg/m^3
Water: 148kg/m^3
Fine aggregate: 712kg/m^3
Coarse aggregate: 1300kg/m^3
Chemical admixture: 3.53kg/m^3
Free water- cement ratio: 0.42

M50:
Cement: 394kg/m^3
Water: 177.3kg/m^3
Fine aggregate: 812.57kg/m^3
Coarse aggregate: 1034kg/m^3
Chemical admixture: 7.88kg/m^3
Free water- cement ratio: 0.45

M50 (with fly ash and fiber content):
Cement: 294kg/m^3
Fly ash: 100kg/m^3
Water: 177.3kg/m^3
Fine aggregate: 812.57kg/m^3
Coarse aggregate: 1034kg/m^3
Chemical admixture: 7.88kg/m^3
Free water- cement ratio: 0.45
Fiber content: 1% by total weight

V. RESULTS

Cubes Compressive Strength:

MIX CONSTITUENTS	M30[AVG]		M50[AVG]	
	7 days	28 days	7 days	28 days
MIX WITH FLY ASH	16 Mpa	33Mpa	27Mpa	54Mpa
MIX WITH FLY ASH AND FIBRES-1%	21 Mpa	41Mpa	32Mpa	60Mpa

Split Tensile Strength Results:

MIX CONSTITUENTS	M30[AVG]		M50[AVG]	
	7 days	28 days	7 days	28 days
MIX WITH FLY ASH	2.8 Mpa	4.4Mpa	3.2Mpa	5.2Mpa
MIX WITH FLY ASH AND FIBRES-1%	3.0 Mpa	4.8Mpa	3.8Mpa	6.1Mpa

V. CONCLUSION

From this study finally we can conclude that inclusion of fibers into concrete has provided more strength, crack resistance, fire resistance, durability**.** Use of fly ash improves workability, which is the major concern for fibrous concrete. Shape and dimensions of fibers has crucial role in arresting cracks. Steel fibres are less bound to corrosion in the same way as reinforcement in reinforced concrete, only when steel fibers are present at the surface of the member. Fibrous concrete is far better PCC.

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