INVESTIGATION ON STRESS STRAIN BEHAVIOR OF CONFINED CONCRETE

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ABSTRACT

In the present world, there is wide scope for strengthening the structural concrete elements which calls upon the use of confined concrete. The present study focuses on the stress-strain behaviour of confined concrete cylinders subjected to compression.

Nine specimens involving the use of carbon fiber reinforced polymer(CFRP) with varying wrap thickness of 1, 2, 3 layers are wrapped in the direction of fibers are adopted in the study. Nine specimens with the use of helical steel rings of pitch of 25mm,50mm and 75mm and nine specimens involving hook end steel fibers of 0.5%, 1% and 1.5% are undertaken in the present study. The stress-strain behavior for all above specimens are recorded and obtained results are compared.

Keywords*:* *CFRP, Steel fibers, Steel ring, Confinement, Compression*

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1. INTROUDUCTION

It is generally accepted that plain concrete exhibits a brittle failure when it is compressed which leads to a rapid loss of load carrying capacity. The concept of using confinement reinforcement is to restrain the concrete from expansion and prolongates the failure. The strength and durability of concrete has undergone continuous improvement over the years and these improved materials are now commonly used. In the past a lot of research has focused on using steel spirals and rings to confine concrete (Ahmad and Shah 1982, El-Dash and Ahmad 1995, and Mander *et al* 1988). The increase in ductility and strength were prominent. With the advent of composite materials, replacement of steel by confinement seems to be a rational method to solve the corrosion problems. In addition, due to the difference in the stress-strain behavior of steel, the induced confining pressure is also different when subjected to compression. The stress of steel remains virtually constant after its yield point so the induced pressure cannot increase after yielding. On the other hand, confinement concrete possesses linear elastic properties. The stress of the confinement keeps on increasing with strain, and thus a monotonically increasing confining pressure is produced. The maximum confining pressure is obtained when the ultimate strength of the confinement is reached. When further load is applied, failure of the confined concrete offen occurs as a result of fracture of the confinement reinforcement.

The use of fiber reinforced polymers (FRP) jackets as an external mean to the strengthening existing RC columns has emerged in the recent years with very promising results among others. Several studies on the performance of FRP wrapped columns have been conducted, using both experimental and analytical approaches. Such strengthening technique has proved to be very effective in enhancing their ductility and axial load capacity. However, the majority of such studies have focused on the performance of columns of circular cross section. This field remains in its development stage and more testing and analysis are needed to explore its capabilities, limitations, and design applicability. This study deals with the columns strengthened with carbon fiber reinforced polymer (CFRP) sheets.

In this experiment the number of CFRP layers are (1L, 2L and 3L), followed by the number of specimen. Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension.

2. MATERIALS USED AND PROPERTIES

2.1 Cement

The Birla super 53 grade Ordinary Portland Cement (OPC) which conforms to IS 12269-1987 is used in the present study.

2.2 Aggregates

The fine and coarse aggregates occupy about 60–75 per cent of the concrete volume (70–85% by mass) and hence strongly influence the properties of fresh as well as hardened concrete, its mixture proportions, and the economy. Aggregates used in concrete should comply with the requirement

Aggregates are commonly classified into fine and coarse aggregates.

2.3 Fine Aggregates

It is generally consisting of natural sand or crushed stone with particle size smaller than about 5 mm (materials passing through 4.75 mm IS sieve). The physical properties like specific gravity, bulk density are tested .

2.4 Coarse Aggregates

It consists of one or a combination of gravels or crushed stone with particle size larger than 5 mm (usually between 10 mm and 40 mm). The crushed coarse aggregate of 20mm maximum size as well as 12mm size are obtained from the local crushing plant at confirming to Zone II, is used in the present study, the physical properties of the coarse aggregate like specific gravity tested.

2.5 Water

Water plays an important role in the workability, strength, and durability of concrete. To much water reduces the concrete strength, whereas to little will make the concrete unworkable. The water used for mixing and curing should be clean and free from injurious amounts of oils, acids, alkalis, salts, sugars, or organic materials, which may affect the concrete or steel.

2.6 Steel

The helical reinforcement size of 6 mm diameter mild steel is used in the experiments.

2.7 CFRP composites

The carbon fiber fabric used in this study were the SikaWrap-230C/45 product, a unidirectional wrap. The resin system that was used to bond the carbon fabric

over the specimens in this work was the epoxy resin made of two parts, resin and hardener. The mixing ratio of the two components by the weight of 10:1 was field laminated using the epoxy to form a carbon fiber reinforced polymer wrap (CFRP) used to strengthen the concrete specimens.

2.8 Steel fiber

Steel fiber is one of the most commonly used fiber. Generally round fibers are Used. The diameter may varies from0.25 to 0.75mm.in this experiment using .60mm steel fibers.

Concrete mixtures

Three concrete mixtures were used to achieve the desired range of unconfined concrete strength (25 MPa) Mixtures were prepared in the laboratory using a mechanical mixer and were used to cast the concrete specimens.

3. SPECIMEN PREPARATION AND TESTING

Standard size of cylinders of 150mm diameter and 300mm length were cast for studying the compressive strength and stress-strain behaviour of concrete. The cylinder specimens were cast without any confinement for CFRP and with different percentages of confinement for steel fibers of 0.5%,1%,1.5% of volume of concrete and mild steel in the form of rings with various pitches of 25mm,50mm and 75mm . This specimens cast were cured for 28 days and tested as per BIS specifications. The cylinder specimens were tested in 1000kN strain control Universal Testing Machine under 0.002mm/s strain rate.

3.1 Fiber-Reinforced Polymer Wrapping

After 28 days of curing, the FRP jackets were applied to the specimens by hand layup of CFRP Wrap with an epoxy resin. The resin system used in this work was made of two parts, namely, resin and hardener. The components were thoroughly mixed with a mechanical agitator for at least 3 min. The concrete cylinders were cleaned and completely dried before the resin was applied. The fabric was carefully placed into the resin with gloved hands and smooth out any irregularities or air pockets using a plastic laminating roller. The roller was continuously used until the resin was reflected on the surface of the fabric, an indication of fully wetting. After the application of the first wrap of the CFRP, a second layer of resin at a rate of 0,5 kg/m2 was applied on the surface of the first layer to allow the impregnation of the second layer of the CFRP, The third layer is made in the same way. Finally, a layer of resin was applied on the surface of wrapped cylinders. Each layer was wrapped around the cylinder with an overlap of ¼ of the perimeter to avoid sliding or debonding of fibers during tests and to ensure the development of full composite strength The wrapped cylinder specimens were left at room temperature for 1 week for the epoxy to harden adequately before testing.

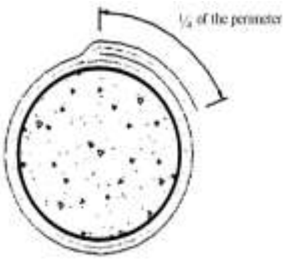

Fig.1 Wrapped cylinder specimens

Before starting the experiments, the top and bottom surfaces of test specimens were smoothed.

3.2 TESTING OF THE SPECIMEN

The axial displacement of the specimens was recorded over a gauge length of 200mm using two dial gauges were attached on the two opposite faces of the specimen. The experimental setup is shown in Fig.2. The specimens were loaded in 1000 KN capacity strain controlled universal testing machine. The monotonic concentric compression was applied at a very slow strain rate. The load was applied from zero to failure. The time taken to complete each test ranged from 30 minutes to 50 minutes depending on the degree of confinement

Fig 2. Experimental Set up

4. RESULTS AND DISCUSSIONS

All specimens behaved in a similar manner initially and exhibited relatively linear load deformation behavior in the ascending part. The plain SCC specimens had a brittle failure with very few readings could be taken in the descending portion. The behavior of confined specimens was comparatively ductile and complex unlike plain unconfined specimens. The specimens were characterized sequentially by the development of surface cracks cover spalling and crushing of core concrete. The specimens were analyzed to obtain the Stress-Strain curves of confined concrete. Fig.4 gives the appearance of specimens after the test.

Fig 3. Appearance of circular specimen after failure.

4.1 Compressive strength of plain concrete

NO. OF DAYS	CUBES	CYLINDERS
7 DAYS	23.68 MPA	18.50 MPA
28 DAYS	33 MPA	25.5 MPA

Stress-Strain Behavior Of Concrete: Stress-Strain curves and normalized curves of steel rings, steel fibers and CFRP confinement was drawn peak stress to peak strain. That the peak stress of steel rings in 25mm pitch confinement 40.33 N/mm2 and peak strain of 1.75%. Curves also plotted peak stress to peak strain for the different different pitch and other confinement material Graphs are shown below.

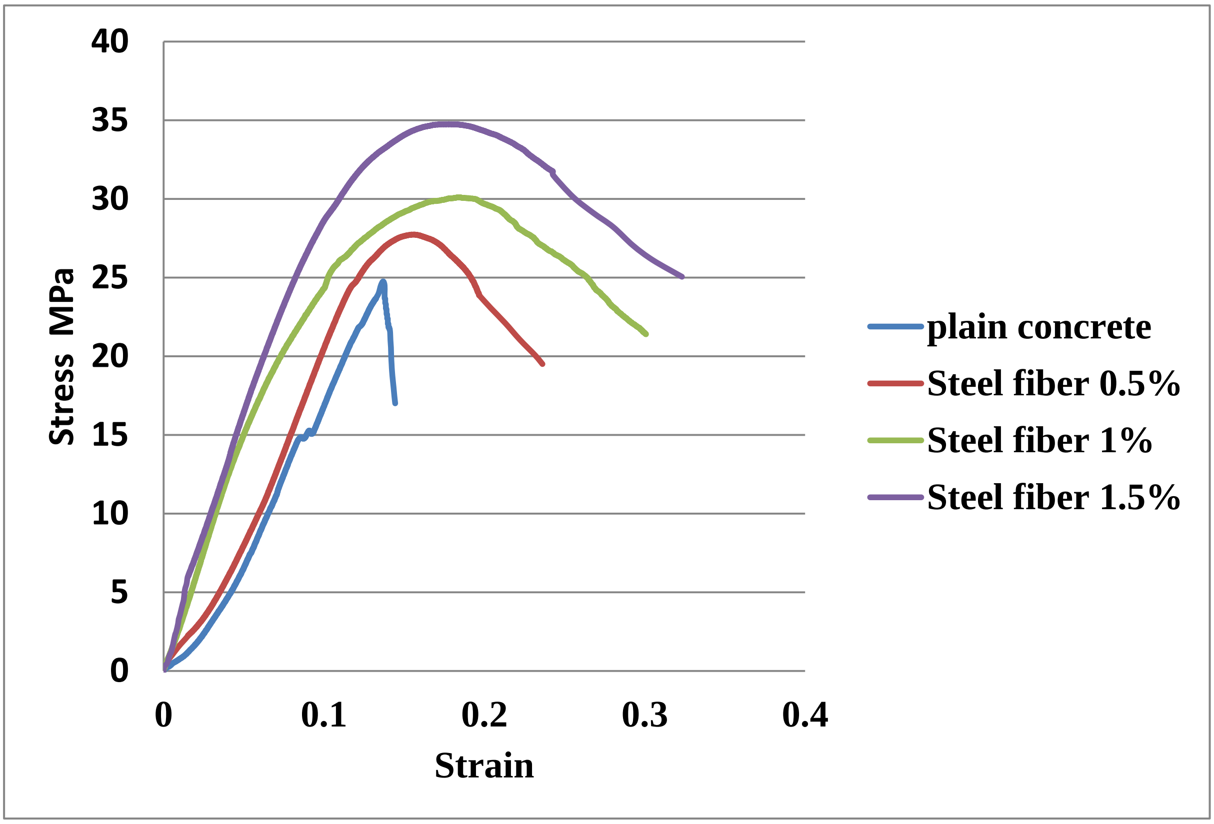

Fig.6 Plain concrete and steel fiber with various percentage

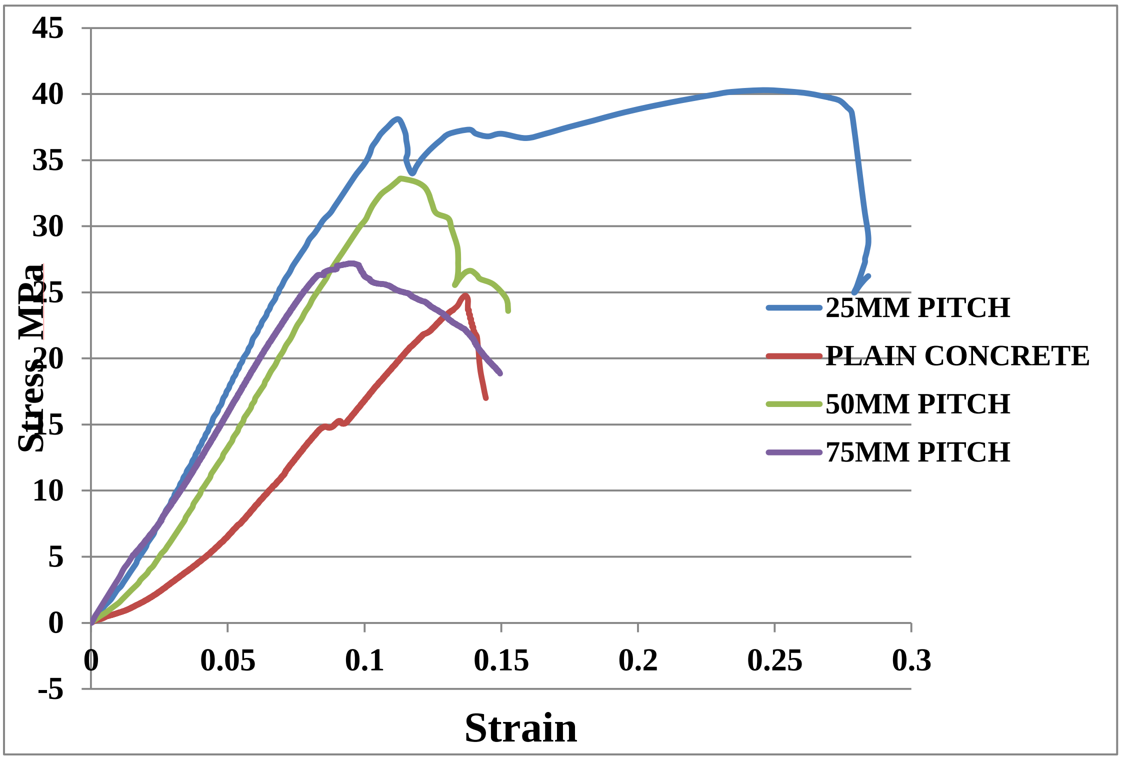

Fig.7 Plain concrete and Steel ring with varying pitch

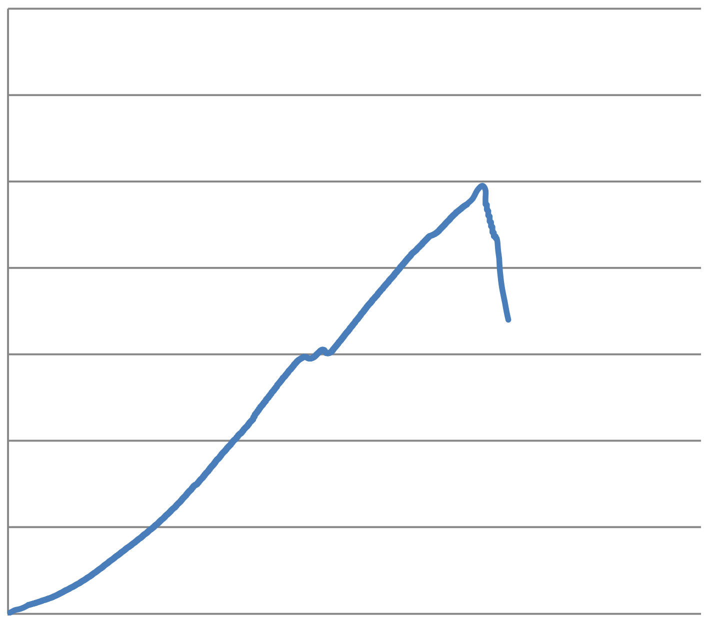

Fig.8 Plain concrete and CFRP wrap

4.4 Comparison of all confined materials

	peak stress N/mm^2	strain at peak stress	strain at 30% drop in peak stress	First crack strain
Plain concrete	24.75	0.1365	0.144	0.082
Steel Fiber				
0.50%	27.75	0.150	0.235	0.09
1%	30.1	0.175	0.30	0.08
1.50%	34.75	0.180	0.32	0.077
CFRP				
1 Layer	25.45	0.105	0.14	0.08
2 Layer	28.28	0.1	0.125	0.085
3 Layer	29	0.11	0.13	0.0875
Steel Ring				
25 mm	40.23	0.245	0.28	0.075
50 mm	33.61	0.12	0.16	0.065
75 mm	27.19	0.095	0.15	0.06

4.5 Calculation of toughness

4.5.1 Steel fibers with various percentage

percentage	First crack	Peak stress	30% drop	Total toughness
0.5%	0.566	1.617	2.084	4.268
1%	0.922	2.626	3.205	6.754
1.5%	0.969	3.053	4.521	8.543

4.5.2 Steel ring with various pitch

PITCH	First crack	Peak stress	30% drop	Total Toughness
25 MM	0.975	6.253	1.393	8.621
50 MM	0.535	1.532	0.896	2.964
75 MM	0.191	0.837	1.276	2.304

4.5.3 Carbon fiber reinforced polymer with various layers

NO. OF LAYER	First crack	Peak stress	30% drop	Total Toughness
ONE LAYER	0.721	0.596	0.564	1.882
TWO LAYER	0.971	0.652	0.337	1.960
THREE LAYER	1.045	0.625	0.490	2.161

5. CONCLUSION

Studies have been carried out on behavior of M25 grade concrete with confinement under compression. The parameters studied include compressive strength, and comparison of stress-strain calculations of concrete with confinement. Based on the study conducted the following conclusions are drawn

- Percentage of Confinement increases the strength of concrete also increased the strengths at 28 days.
- An increase in volume of confinement improves the ductility factor of confined concrete.
- Steel rings increases the strength up to 17% of steel fibers.
- Steel rings increases the strength up to 30% of FRP.
- In steel fibers strain is more compared to the helical ring and FRP.
- Toughness is more in steel fiber compared to the FRP for obtained results.
- Increase in percentage of steel fiber toughness also increases.
- Helical ring of 25mm pitch is gives the strength and toughness.

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