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Behaviour of Ultra - High Performance Glass Concrete confined with High Carbon Steel Wire under Axial load

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Abstract - *This work proposes an idea on experimental investigations with a new type of ultra- high performance concrete with external lateral confinement. As an approach towards a sustainable development, glass powder is used which deals with an evolution of indexes related to hydration of concrete. Five cylinders were tested with the variation of confinement pressure that was achieved by changing the winding spacing of high carbon steel wire (HCSW). An addition of external lateral reinforcement in the form of steel wires improves the toughness of the specimens. This technique plays a vital role in structural repairs, seismic strengthening and retrofitting of the structure. The results of the experimental study such as the ultimate load strength, stress – strain curve, effect of confinement and failure modes of the specimen are ascertained. These results showed that winding of HCSW is an effective and efficient methods of jacketing that can enormously enhance the strength and gives abundant warning compared with control specimen.*

Key Words: **ultra – high performance glass concrete, high carbon steel wire, jacketing, confinement, compressive strength**.

1.INTRODUCTION

Ultra- high performance glass concrete has a very low water – to – binder ratio (W/B), high fineness admixtures, high energy absorption capacity and durability. Test results indicates that the addition of 2% of steel fibers significantly enhance the load carrying capacity and post cracking stiffness. In recent years, the usage of external lateral confinement has become enormously popular for the repair and rehabilitation of concrete structures.

Various strengthening methods such as strips, strands, hoops, spiral, wires etc. utilize the benefits produced by the lateral confinement of RC specimens to enhance structural integrity. For existing structures, the conventional steel bars and wires of low yield strength are used. This technique for RC cylinder improves both bearing capacity and ductility, reduces risk of buckling of main reinforcement bars under compression, thus enhance bonding action with concrete.

The results of earlier research work conducted by the J. Li et al, this paper experimentally investigates the performance of externally confined high strength concrete columns subjected to eccentric loading and determines the effectiveness of two confinement materials carbon fiber and glass fiber. A significant amount of research has been done by Mender et al. his work long stress strain behavior of confined concrete with spiral reinforcement was done both by experimentally and analytically. According to the latest research work that was conducted by Yang Wei et al investigates the HSW circular confined concrete columns with various spacing of wire under compressive load. With these conclusions comparison with ordinary steel spiral confinement was done. This model work proposed provide a better prediction of stress – strain curve for both specimens. In this current paper, high- carbon steel wire (HCSW) with strength more than 1500N/mm^2 are preferred. These wires of smaller diameter are used for specimen jacketing. compared with FRP, HCSW is with high malleable, ductile and less sensitive to high climatic condition.

The objective of this paper is to experimentally investigate the axial compression behaviour of Ultra-High performance glass concrete using high carbon steel wire as an external lateral confinement.

2.RESEARCH SIGNIFICANCE

The experimental results denote that the fresh Ultra-High Performance Glass Concrete (UHPGC) properties were gradually enhanced when the cement was replaced with non-absorptive glass powder particles. The strength improvement can be attributed to glass powder pozzolanicity and its mechanical performance. In order, to produce concrete economical and greener than the conventional UHPC.

3.EXPERIMENTAL INVESTIGATION

The following section describes the material characteristics, mix proportions, strengthening procedure, testing program and specimen design.

3.1 MATERIAL CHARACTERISTICS

Cement is desired as material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a whole compact. Ordinary Portland cement of grade 53 conforming to IS 12269:2013 with a specific gravity of 3.13 was used (Initial setting time 30minutes and Final setting time 453 minutes). River Sand is used as fine aggregate which passes in sieve 4.75mm sieve and retained in 2.36mm sieve are preferred confirming to zone II of IS 383-1970 was used (Specific gravity 2.72, fineness modulus 2.93). Crushed angular granite stone of size 20mm which passes through 25mm sieve and retained in 20mm sieve are preferred. Laboratory tests were conducted to determine the different physical properties (specific gravity 2.64, flakiness index 4.58% and elongation index 3.96) confirming to 383-1970.

The mixture was prepared with the cement content of 654.72 Kg/m^3 and water to cement ratio of 0.2. Reinforcement steel of high yield deformed steel bar (HYSD) with diameter of 10mm (longitudinal reinforcement) and 8mm (lateral ties) are provided. Usually the replacement levels of cement, glass powder were used in terms of 10%, 20%, 30% and 40% in concrete. In this paper 20% was preferred (Specific gravity is 2.4 – 2.8). Hooked type steel fiber with an aspect ratio of 50mm was preferred (specific gravity 7.89). Silica fume (highly reactive pozzolanic additives) and Conplast SP430 of specific gravity 2.2 and 1.21 respectively confirming to IS 456 and BS: 5075 was used to enhance early strength, durability and integrity enhancer for Ultra-High Performance glass concrete.

3.2 MIX PROPORTION

The UHPC mixture was prepared with the silica fume of 10% addition to cement, Glass powder particles with a replacement of 20% of cement. Designed with 2% of steel fiber addition to the concrete mix along with HRWR of 1.5% with a W/B of 0.2 respectively. This mix is denoted as a cost relative index indicator.

Table -1: Mix Proportions

Grade of Concrete	Cement (Kg/m^3)	Silica Fume (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)
M80	654.72	81.84	148.8	496.99	1025.06

3.3 STRENGTHENING PROCEDURE

Addition of glass powder reduces carbon di-oxide emission and cost. Glass powder in UHPC improves the concrete rheological properties, enhancement of long – term performance and long service life.

External lateral confinement of High carbon steel wire (HCSW) was done to eliminate the unwanted properties of concrete such as brittle behavior particularly useful for strengthening the concrete specimens. HCSW is made by twisting high strength steel filaments in a helix. The surface of wire is galvanized in order to prevent corrosion compared with FRP, it is more ductile, malleable and less expensive. The nominal diameter and cross-sectional area of a single steel filament is 3mm and 5.37mm^2 shown in fig 1. Tensile tests were conducted to measure mechanical properties of wire are shown in fig 2.

Fig 1: High carbon steel wire (HCSW)

Fig 2: Tension test on steel wire

Table -2: Mechanical Properties of HCSW

Specimen No	Nominal area (mm^2)	Max Load (kN)	Ultimate Strength (Mpa)	Yield Load (Gpa)	Breaking Load (KN)
1	5.37	3.05	442.72	2.5	0.91
2	5.37	3.08	436.64	2.9	0.93
3	5.37	3.01	426.08	2.36	1.01
Average Value	5.37	3.05	435.15	2.587	0.95

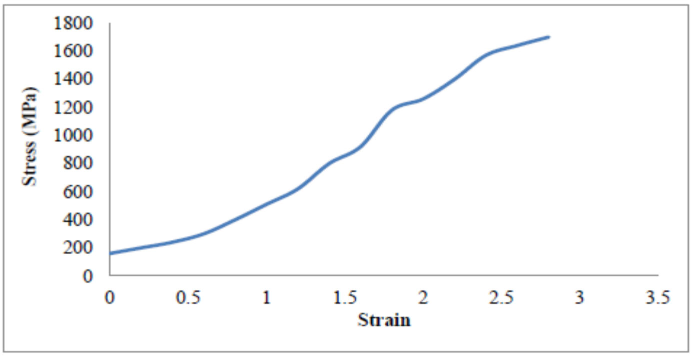


Fig 3: High carbon steel wire graph

3.4 TESTING PROGRAM

To determine the workability of the fresh concrete, tests such as slump cone and flow table test were done. All the tests were done as per IS codes. Experiment includes axial compressive tests on both control and UHPGC specimens. Several parameters were considered in experimental and analytical studies:

(a) Parameters for reference specimens:

3 cubes and 3 cylinders were tested on 28th day and acquired a result of 82N/mm^2 and 65N/mm^2 respectively are shown in fig 4.

(b) Parameters for cylinder specimens:

5 circular concrete cylinders with diameter of 150 mm and height 300mm were made as test specimens with external lateral confinement. The diameter of main reinforcement is 10mm of 4 in numbers and lateral ties is 8mm of 3 in numbers with a spacing of 100mm each are made for internal reinforcement are shown in fig 4. One day after casting, the cylinder specimens were removed from the moulds and cured for 28 days shown in fig 6.

Fig 4: Cube and Cylinder specimens

Fig 5: Reinforcement detailing

Fig 6: Unconfined cylinder specimens

3.5 SPECIMEN DESIGN

This paper deals with the compression behavior of Ultra-High performance glass concrete columns, which are confined by high carbon steel wires. To study the behavior, 5 Ultra- High Performance Glass reinforced concrete cylinders are cast using M80 grade concrete. After 28 days curing, the specimens are wound with high carbon steel wires of 3mm diameter. High carbon steel wires are wound on the specimen by rotation and very suitable for column jacketing.

One column remains unconfined, and remaining four columns are confined by high carbon steel wires.

To ensure good anchoring and to avoid de- bonding of the high carbon steel wires from concrete specimen, three to five added circles are provided at the top and bottom ends of the specimen. The main parameter in this investigation is the winding spacing of High carbon steel wire (HCSW) that varies from 10mm – 40mm by an increment of 10mm. The severity of concrete crushing varies with the winding spacing. The windings embrace the specimen integrity shown in fig 7.

Fig 7: Confined Cylinder specimens

Spec No	Winding Spacing (mm)	Ultimate Load (KN)	Peak stress (N/mm²)	Peak strain	Peak stress ratio (N/mm²)	Peak stain ratio
1	-	1130.9	64	0.16	-	-
2	10	1278.4	72.34	0.42	8.34	0.26
3	20	1233.7	69.81	0.5	2.53	0.08
4	30	1186.1	67.12	0.6	2.69	0.1
5	40	1171.9	66.32	0.8	0.8	0.2

3.6 EXPERIMENTAL SETUP

The specimen was tested under axial compressive load using a 3000KN capacity high stiffness compression machine for cylinder specimen are shown in fig 8. While high carbon steel wire (HCSW) was tested using 1000KN capacity of high stiffness compression machine. Both ends of the cylinder are kept in fixed condition. In top of cylinder mild steel plate is placed for applying axial load and also to avoid movement of specimen. Load should be directly applied axially to cylinder in order to prevent bending.

Fig 8: Test Setup

4 EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1 ULTIMATE LOAD STRENGTH

Ultimate load strength is the capacity of a material or structure to withstand the loads tending to elongate, as opposed to compressive strength, which withstands the load tending to reduce size. The experimental results show the ultimate load strength, which enhances its strength when the winding spacing decreases.

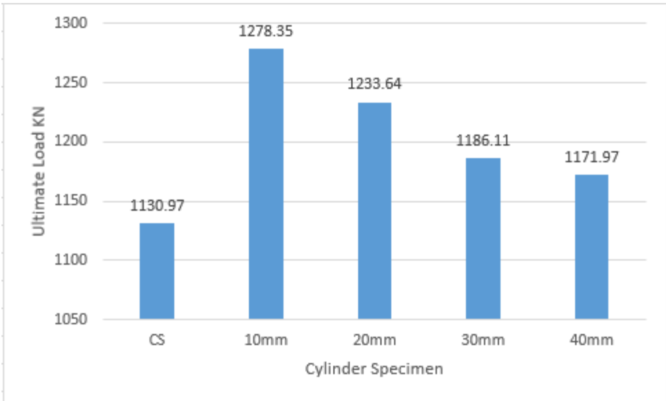
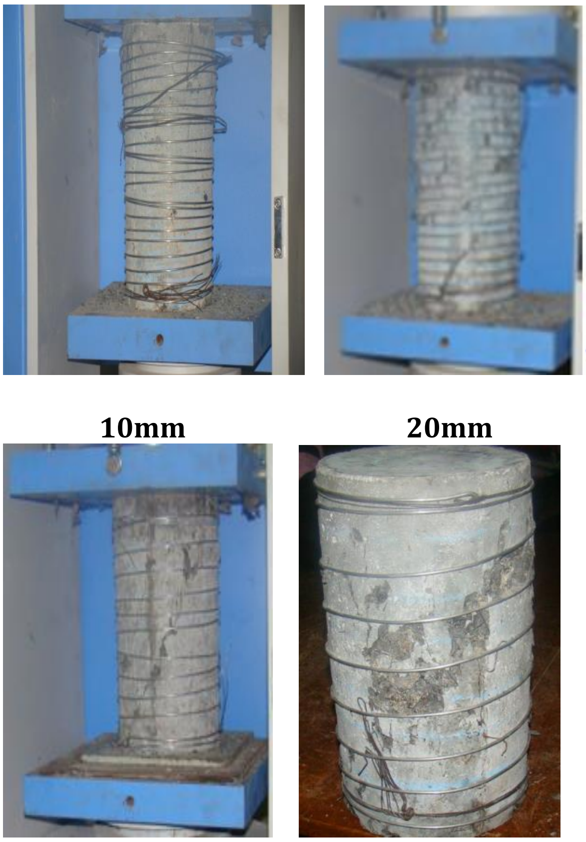


Fig 9: Ultimate load carrying capacity for cylinder specimen

The proposed work provides reasonably a close predictions of the test results. It can be seen from the above cases that at the high confinement levels, the 10mm confined cylinder performs better than other specimens in terms of both strength and ultimate load.

4.2 FAILURE MODES

The failure modes for the test specimens of spacing of windings with 10mm,20mm,30mm and 40mm respectively are shown in fig10.



10mm **20mm**

30mm **40mm**

Fig 10: Failure modes

All specimens failed with successive amount of fracture of high carbon steel wire, thus HCSW was fully developed before failure. At the time of peak load application, the surface of longitudinal area commences to crack accompanied with an eminent cracking sounds. HCSW fracture gives clear warning before final fracture.

After HCSW fracture, the wire jacket opened up and the concrete core crushed in the failure region. Severity of concrete crushing develops, when the winding space reduces. For specimen with 10mm spacing of wire, concrete core was crushed into powder, while for 40mm spacing of specimen, concrete core was crushed into bulks.

4.3 STRESS – STRAIN CURVE

The typical experimental stress–strain curve of HCSW confined concrete is illustrated in fig 11.

The first phase before the peak point is similar to that of an ordinary cylinder specimen. The second phase after the peak point is generally shorter than that of the reference specimen but after that the load commenced to improve gradually with an external lateral confinement of the cylinder.

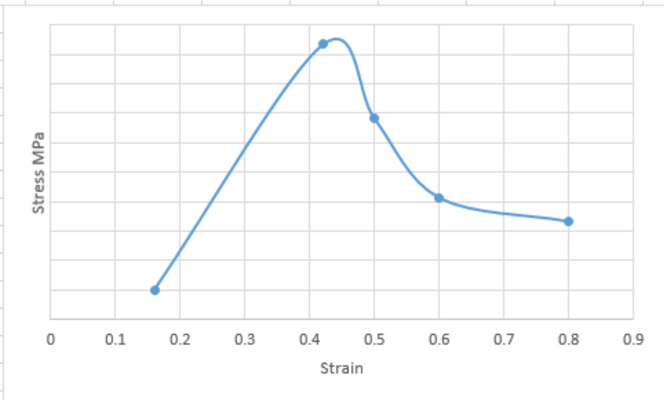


Fig 11: Stress – Strain curve

6. CONCLUSIONS

In this paper, HCSW circular confined concrete cylinders with different winding spacing were tested under axial compression. Based on the test results existing stress – strain model behavior for both control specimen and confined concrete circular cylinder specimen under monotonic loadings are determined.

The following conclusions are drawn from this study results

1. The replacement of cement by glass powder shows a gradual improvement in the compressive strength, flexural strength and fracture energy of UHPGC.
2. The concrete mixtures prepared with 20% GP had an average of 8.0% and 3.4% increase in the compressive and fracture strength compared to the control mixture.
3. The unconfined specimens failed by crushing at top and bottom with severe spalling and disintegration around the base of the cylinder. The cracks are concentrated at the end portions and crushing of concrete occurred eventually.
4. Progressive rupture of HCSW causes final failure of the concrete specimen. Compared with reference specimen, HCSW confined concrete cylinders are more ductile with a yield plateau from the peak point to rupture of the first HCSW and abundant warning before the collapse of the cylinder.
5. The development of the tensile properties of the UHPGC was slower, when compared to the compression properties.

6. The load-carrying capacity of the core concrete strengthened with the external lateral confinement (HCSW), which increases even after the spalling of the cover and beyond peak strength of core. While unstrengthen concrete shows a slower decreasing rate of the strength.
7. The axial load carrying capacity of strengthened cylinders was higher than that of unstrengthen cylinders by 5-20%.

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