Experimental Study of Structural Behaviour of Beam using Ultra High Performance Concrete

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ABSTRACT
UHPC (ultra-high performance concrete) is a relatively new type of concrete that exhibits mechanical properties that are far superior to those of conventional concrete and high performance concrete. The main characteristics that distinguish UHPC from conventional reinforced concrete are the improved compressive strength, the tensile strength, the addition of steel fibres, and the resistance to corrosion and degradation. The mechanical properties of UHPC allow for smaller, thinner, lighter sections to be designed while strength is maintained or improved. The use of UHPC has been limited to a few structure applications due to the high cost of the materials and the lack of established design guidelines. As the construction of super-high structures and long span structures increases all over the world, strength and stiffness of structures are being improved by applying Ultra-high strength concrete. With such trends, demands to use 100Mpa or Ultrahigh strength concrete more than that are anticipated to spread out. Reinforced concrete is being used extensively in the construction industry all over the world. The use of Ultra high strength concrete has increased due to its obvious advantages like increased modulus of elasticity, chemical resistance, freeze thaw resistance, lower creep shrinkage and lower permeability.

Keywords: UHPC, Stiffness, Shrinkage , Corossion , Chemical Resistance .

1 INTRODUCTION

Concrete is the most used building material invented in last century. It has a very compressive strength but it is poor in tension. In IS/456-2000 code concrete is designated by its compressive strength of 150mm cubes at 28 days in N/mm2. The classification of grades has been done asM-10 to M-20 ordinary concrete, M-25 to M-55 standard concrete, M-60 to M-80 High Performance concrete and now a new grade has also developed as Ultra High Performance Concrete. High performance concrete is often called durable concrete because its strength and impermeability to chloride penetration makes it last much longer than conventional concrete. The concrete mix is engineered with the typical elements of water, Portland cement, and fine and course aggregates, but with admixtures which enhance performance. When strength of concrete is more than M 80 it is called Ultra high performance concrete. It is also called as reactive powder concrete (RPC). It is a high ductile material formulated by combining Portland cement, silica fumes, quartz flour, fine silica sand, high water reducing agent, water, and steel or organic fibres. The material provides compressive strength and flexural strength up to 50Mpa. Reinforced concrete is being used extensively in the construction industry all over the world.

2 OBJECTIVES

The main objectives of this dissertation are:

1. To investigate the structural behavior like flexural performance and modes of failure of ultra high strength RC beams.
2. This study intends to evaluate the behaviour of Ultra high performance concrete member in bending, shear and comparing the result with the conventional concrete.
3. Find out the flexural capacity and deflection of UHPC beams at the structural level.

Typical UHPC Composition

Material	Composition
Portland Cement	28.5
Fine Sand	40.8
Silica Fumes	9.3
Ground Quartz	8.4
Super Plasticizers	1.2
Accelerator	1.2
Steel Fibres	6.2
Water	4.4

3 LITERATURE REVIEW

Ultra-high performance concrete (UHPC) is a relatively new type of concrete that provides significant improvements in strength, ductility, workability, and durability when compared to reinforced concrete or conventional high- performance concrete (HPC). The distinguishing factor between UHPC and HPC is that these improved characteristics are inherent to UHPC, whereas HPC the mix is designed to meet special combinations of performance and uniformity requirement. When compared with high performance concrete (HPC), UHPC tends to exhibit superior properties such as advanced strength, durability, and long-term stability [2]. AFGC-SETRA group has authored the first recommendation of ultra high performance concrete material. It consists of cement, metallic fibers, polymeric fibers, super plasticizers aggregates and water etc.

The metallic fiber should ensure at least non-brittleness; it means the ultimate bending moment developed at first cracking of the matrix [1] .If the fiber is non brittleness then passive reinforcement can be avoided. Its compressive strength is generally 150MPa. Its tensile strength should be higher than 7MPa [1]. Mix proportion should be such that w/c Ratio may be between 0.13 to 0.22 and this can be achieved by use of super plasticizers. As the diameter of aggregate will increase compactness of mix also increase [1]. Maximum size of aggregate is limited to 6mm to 10mm. Sand must be free from harmful impurities. The limitation of maximum size of aggregate is depends on the structural element size and amount of fibers will be used in matrix. Good mix proportion will give minimum 130 to 180mpa characteristic compressive strength. The requirement of material ductility may in fact depend on the loadings and deformations applied to the elements. For beams or bridge components, steel fibers at 2 to 3 % can generally ensure non-brittleness under pure bending in the convenient directions. These fibers are 10 to 25 mm in length and 0.2 to 0.3 mm in diameter. They are anchored either by hooked or deformed ends, or by direct friction along their length. It must be noticed that under present knowledge, there is no guarantee of direct relationship between the type and fiber content of UHPFRC mixes, and the tensile hardening or softening behavior. Fiber orientation is mainly controlled by the casting and possibly vibrating processes.

· Compressive strength: UHPFRC has water binder ratio as 0.2. Its compressive strength ranges between 150MPa to 250MPa.Without heat treatment mean strength value will be 180 MPa to 200 MPa. Ductile material with heat treatment has 230MPa mean strength. · Young's modulus: It is from 48 to 67 GPa. This is depending on the coarse aggregate nature and content, and on the fiber content.

· Poisson ratio: It is 0.2 depends on the coarse aggregate content, the water and the fibre content.

·Tensile Strength/Flexural strength: The significant improvements in compressive strength are complimented by the fact that UHPC also exhibits tensile strength that has not been demonstrated in conventional concretes. The tensile strength allows the material to support both pre-cracking and post-cracking loads without experiencing the brittle failure that would be common in a conventional concrete. UHPC has demonstrated tensile strengths ranging from 6mpa-50mpa with various curing regimes and standard ASTM testing methods (Gray Beal and Hartmann 2003). These tensile strengths were achieved as a result of the interaction of the steel fibers on the microscopic level and their ability to sustain load after the onset of cracking. It is governed by fibers orientation, scatter, and non brittleness. In addition to the improvements in tensile strength, UHPC can also achieve flexural strengths ranging from 35mpa-50mpa (Perry and Zakariasen 2003). This combination of the tensile and flexural strength makes UHPC an extremely ductile material, capable of supporting significant loads beyond cracking and allows designers to create thinner sections, longer spans, and taller structures (Perry and Zakariasen 2003).

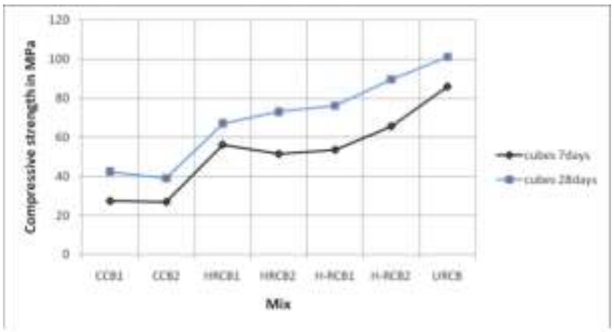
4 EXPERIMENTAL WORK

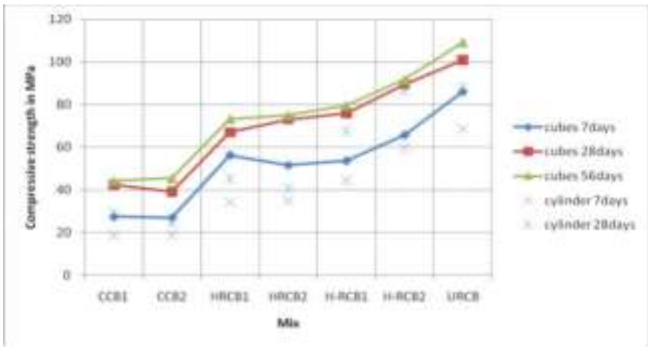
In the following section, the results obtained from testing of fourteen specimens of beams casted or flexure and shear is included in this experimental program is presented and discussed. The results recorded for each test included measurements of load, deflection, bottom Steel strains and strains at four points on the beam surface at the center of the span at various load stages. The observed crack pattern, load propagation and mode of failure at ultimate load are reported. The testing of the beam specimens were grouped into three series. Series-1 consisted of total 10-beam:8-beamswith dimension of150mm*200mm by 1600mmmade of a concrete grade of 2-beam of M-30, 2-beam of M-60 , 2-beam of M-80 and 2-beams with dimension of 150mm*300mm by 2100mm1beam is made of M-100 and 1-beam is made of M-80 and series-2 consisted of 4-beams with dimension of 150mm*200mm by2000mm2-beam is made of M-80. Mechanical properties of concrete from which the beam is made In this experiment, specimen was produced by using 100mm by 100mm mould for cube compressive strength test of ultra high strength concrete along with the other mix is done and the results are shown in the following table :

Table : 7 and 28 days Compressive strength and flexural strength

Mix Strength	7-days Compressive Strength cubes MPa	28- days Compressive Strength cubes MPa	Flexural Beams Strength 100x100x500 mm
CCB1	27.5	42.33	5.10
CCB2	27.5	39	4.70
HRCB1	56.33	67	10.60
HRCB2	51.55	73	9.30
H-RCB1	53.66	76	9.60

H-RCB2	65.75	89.5	12.20
URCB	86.00	101	15.30





7 days and 28 days compressive strength vs mix **Graphs of compressive strength**

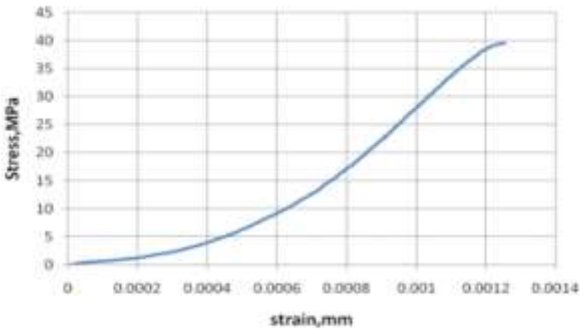
The following tables and graphs are detail test report of the mixes used. These values are results from test on new machine UTM-Helicon, capacity 300 tones. The compressive stress-strain responses of different concrete varies because concrete is a heterogeneous material and the test method used in some specimen are different i.e. load control mode and displacement control mode. In load control mode the loading rate IS-456-200 which is 140Kg/cm/min for cubes and 120 kg/cm/min for cylinder was adopted.

The compressive failure of UHPC was found to be similar to the compressive failure of any fiber reinforced concrete. In general terms, UHPC fails under axial compressive load through lateral tensile expansion. This lateral expansion is partially restrained by the internal steel fiber reinforcement, thus allowing for a more ductile failure than may be expected. As illustrated, fibers reinforced substantially enhance the toughness and ductility of concrete. If the materials were classical brittle, the loading curve would be linear till peak load and drop sharply, however cementations material are not classical brittle, rather, their response is quasi-brittle, exhibiting non-linearity prior to reaching peak load and gradually decrease after peak load. It can be also seen that with the decrease of water/cement ratio and the introduction of pozzolanic materials like fly as hand silica fumes strength tends to increase Plot of stress vs. strain of each mix are shown. From the graph, the stress versus strain behavior of concrete under axial compression is initially linear, in this stage, stress is proportional to strain and elastic strain is recovered at unloading. With the generation of micro-cracks, the behavior becomes nonlinear and inelastic.

After the specimen reaches the peak stress i.e. at failure load, the resisting stress decreases with increase in strain. For High strength and UHPC under axial compression, the ascending and descending branches are steep slopes. The slope of linear portion of the curve is the modulus of elasticity. The modulus of elasticity of UHPC is significantly higher than normal concrete and high strength concrete. If the materials were classical brittle, the loading curve would be linear till peak load and drop sharply, however cementations material are not classical brittle.

SAMPLE DESCRIPTION		TEST RESULTS
Test Type	CTM	Peak Load (KN) 524.6
Sample ID	H1	Max strain at Peak Load% 0.001405
Sample Type	Cuboidal	Compressive Strength (MPa) 59.03
Age Days	28 Days	Modulus (MPa) 6666.67
Sample Dimension 100*100*100(mm)		Area in sq.mm 10000

Stress-Strain curve of M60 concrete



Stress-Strain curve of M30 concrete

5 CONCLUSIONS

1) The first cracks were barely visible; their presence was clearly indicated by the available signal. As the test progressed after first cracking, new micro-cracks started to develop between the existing cracks. Most of the cracks continued to propagate toward the upper face, and the cracks did not visually widen.

2) The test showed that tightly spaced cracks formed perpendicular to flexural tensile stresses on the lower face of the beam. These results indicate the ability of UHPC to redistribute stresses and undergo multiple cracking before fiber pullout.

3) When the load carried by an individual fiber overcomes the ability of the UHPC to grip the fiber. Fibers that pulled out increase the load that other fiber nearby must carry. As the load on the beam increased, more cracks formed and the fibers bridging the existing cracks experienced more stress .

4) The beam's deflection until the initiation of cracks increased linearly and was proportional to load. After the initial cracking, deflection increased nonlinearly until the maximum load was reached. The initial cracking load for each beam ranges between 40 KN to 150KN. Beam CRCB-1 had smaller cracking load 40KN. While beam had the largest cracking load 150KN. The percent difference between these two extreme values is 73.33%.

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