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Ultra High Performance Concrete- Next Generation Concrete

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Abstract

The research is about evaluation of the behavior of Ultra-high performance concrete (UHPC), it is a new class of concrete that has been developed in recent decades. When compared with High Performance Concrete (HPC), UHPC tends to execute superior properties such as advanced strength, durability, and long-term stability.

The main thing that makes it different from conventional concrete is the use of Steel Fiber Reinforcement, and some super plasticizers which give superior resistance to cracking and crack propagation.

During the experimental work with specimen testing UHPC gave us very high compressive strengths, regardless of the curing treatment applied. The average 28-day compressive strength of submerged and Air treated UHPC were found to be 180 MPa and 126.17 MPa.

Introduction

UHPC is a new class of concrete that has been developed in recent decades. The main thing that makes it different from conventional concrete is the use of Steel fiber Reinforcement, and some super plasticizers along with replacement of a part of cement with Fly Ash.

It is now well established that one of the important properties of steel forced reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading: and the fibers are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fiber composite pronounced post- cracking ductility which is unheard of in ordinary concretes. The transformation from to a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fiber composite and its ability to withstand repeatedly applied, shock or impact loading.

Fiber reinforced concrete may be defined as a composite material made with Portland cement, aggregate and incorporating discrete discontinuous fibers.

Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes fibers is to bridge across the cracks that develop some post cracking “ductility”. If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post- cracking stage.

There are of course, other (and probably cheaper) ways of increasing the strength of concrete. The real contribution of the fiber is to increase the toughness of the concrete. (defined as some function of area under the load vs. deflection curve),under any type of loading. That is, fibers tend to increase the strain at peak load, and provide a great deal of energy absorption in post-peak portion of the load vs. deflection curve.

Objective

The objective of this research is to evaluate the potential use of UHPC in various structures by characterizing material behaviors through small scale specimen testing.

Also we wanted to find its future aspects of being used in India for general construction by trying to reduce its cost.

Summary of Approach

The research included two experimental phases. The experimental phases focused on determining the material behavior from small-scale testing, the material characterization of UHPC included the testing of different specimens, with an emphasis toward determining the compressive and tensile behavior, the long term stability, and the durability of UHPC. Many of the material characterization tests were completed according to INDIAN standard test procedures.

Material Testing and Results

1) Cement

Preparation of cement

In order to achieve the desired setting qualities in the finished product, a quality gypsum is added to the clinker and the mixture is finely ground to form the finished cement powder.

This is achieved in a cement mill. The cement is conveyed by belt or powder pump to a silo for storage. The cement is delivered to end users either in bags or bulk powder blown from a pressure vehicle into the customer's silo.

In UHPC the cement I needed is a standard quality cement which can give best possible outcome, hence I tested the cement available for checking its quality.

The tests were performed in two ways-

1) Field Testing
2) Laboratory Testing

Field Tests

1) On visually observing there were no lumps ,Color of the cement was greenish grey
2) By thrusting hand into the bag ,it gave a cool feeling
3) By pinching it between fingers it gave a smooth feeling, nota gritty one.
4) Particles of cement when thrown in a bucket of water floated foe sometime before sinking.

Following are the tests conducted in the laboratory.

1) Fineness test- Performed by sieve analysis.
2) Standard consistency test

2) Aggregates

Test conducted on aggregates:

1) Specific gravity test

2) Test for bulk density and voids.

3) Aggregate crushing value.

4) Test of aggregate abrasion value.

3) Fly Ash

Fly ash is one of the residues generated in combustion, and comprises the fine particles. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the gases reach the chimneys of coal-fired plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (Cao), both being endemic ingredients in many coal-bearing rock strata.

Advantages of Fly Ash in Concrete

1) The permeability of carbon dioxide and to chloride ions which are responsible for the corrosion of steel is very low in the high volume fly ash concrete.
2) Mitigation of sulphate attack, corrosion, and attack from other aggressive chemicals.
3) Decreased moisture intrusion, less permeable concrete.
4) Increased durability
5) Low total life cycle costs, longer concrete life.
6) Slower speed of hydration, better structural integrity
7) Less water needed in concrete production, leading to water
8) conservation

4) Admixtures

A “Chemical Admixture” is any chemical additive to the concrete mixture that enhances the properties of concrete in the fresh of hardened state to reduce water requirement or accelerate/retard setting or improve specific durability characteristic.

A number of types of chemical admixtures are used for concrete. The general purpose chemical include those that reduce the water demand for a given workability (called “water reducers”), those entraining air in the concrete for providing resistance to freezing and thawing action (called “air entrainers”), and those chemicals that control the setting time and strength gain rate of concrete (called “accelerators and retarders”).

The five distinct classes of admixtures are as follows:

1) Air entraining admixtures.
2) Water reducing admixtures.
3) Retarding admixtures.
4) Accelerating admixtures
5) Super plasticizers

Batching, Casting and Curing Of UHPC

The first phase of material characterization study described in this chapter is to determine the properties of fresh UHPC. To achieve consistent results, a series of specific, standardized procedures were implemented for the creation of the specimens described in the previous section. The casting of these specimens allowed for the mixing, associated testing, and observation of different batches of UHPC.

The UHPC used in this study can be divided into three parts – **premix, fibers, and liquids**

1) The premix consists of all the cementitious, aggregate, and filler materials. The cement was batched and blended by the manufacturer and delivered in bulk to the researchers.
2) The liquids that were mixed with the UHPC included water, accelerator, and a high range water-reducing admixtures (HRWA). Hence the water to cement ration that I adopted was 0.3
3) The fibers included in the UHPC were cylindrical steel fibers which were 13mm long and had 0.2mm diameter. These fibers were included in the mix at a concentration of 2% by volume.

The mix proportion used throughout the study included the following:

1) Premix	2194.74kg/m3 of concrete
2) Water	3109.09kg/m3 of concrete
3) HRWA (including plasticizers)	30.75kg/m3 of concrete
4) Accelerator	29.95kg/m3 of concrete
5) Steel fibers	156.03kg/m3 of concrete

Key points in the mixing procedure for UHPC included the following steps:

1) Weighted all constituent materials, add ½ of HRWA to water.
2) Placed premix (contentious, aggregates, and filler materials) in mixer pan, and mix for 2 minutes.
3) Add water (with ½ of HRWA) slowly to the premix over the course of 2 minutes.
4) Wait 1 minute then add remaining HRWA to premix over the course of 30 seconds.
5) Wait one minute then add accelerator over the span of 1 minute.
6) Continue mixing as the UHPC changes from dry powder to a thick paste.
7) The time for this process will vary.
8) Add fibers to the mix slowly over the course of 2 minutes.
9) After the fibers have been added, continue running mixture for 1 minute to ensure that the fiber are well dispersed.

As soon as the mixing process was completed the casting of the specimen and the measurement of rheological properties of the UHPC commenced.

In the test that was implemented in this study, a mini slump cone was filled then removed to allow the concrete to flow outward. Once concrete reaches steady state, average diameter is determined by measuring concrete at three locations. Next, the flow table is dropped 20 times in 20 seconds. Again concrete in allowed to settle and again the diameter is recorded. The casting of all UHPC specimens used in this study was completed within 20 minutes after the completion of mixing. All specimen were casted on a vibrating table and were allowed to remain on the table for the next 30 seconds, after filling. The filling of molds was completed via scoops used to move the UHPC from the mixing pan into the mold. In prisms specimens for flexure tests the

UHPC was always placed in one end of the mold and allowed to flow to the other end in order to complete the filling.

After filling the specimens were removed from the vibrating table and were screeded. Although it was implemented here to make the later preparation of cured specimens easier. After screeding each specimen had its exposed surface covered 29 in plastic to prevent moisture loss. The specimen then sat undisturbed until final set had occurred.

Test

Slump test as per IS: 1199 – 1959 is followed. The apparatus used for doing slump test are slump cone and tamping rod.

Result

The slump measured mm as the subsidence of the specimen during the test was found 75cm. which is categorized as very workable by Indian Standard.

Conclusion & Future Research

The following conclusions focus on the overall body of the work presented in the research:

1) UHPC displays significantly enhanced material properties compared with normal and high performance concrete.
2) UHPC exhibits very high compressive strengths, regardless of the curing treatment applied. The average 28-day compressive strength of submerged and Air treated UHPC were found to be 180MPa and 126.17MPa.
3) The setting time of UHPC is significantly delayed as compared with normal concrete; final set does not occur until 12 to 24 hours after casting. This time to set could also be longer depending on the admixtures and on other constituents in the mix
4) Once setting has initiated, UHPC gains compressive strength very rapidly. If maintained at normal laboratory temperatures, UHPC compressive strength will increase to over 68.94 MPa by 2 days after setting. Subsequently, the rate of strength gain will decrease;96.57MPa will be reached by 10 days after setting.

5) Curing conditions present during and just after the setting of UHPC can significantly affect the final properties of the concrete, in the air treated case, concrete cubes that were stripped as final set was being reached exhibited 30% lower compressive strengths compared with submersion treated case. These strength differences are likely due to the relatively more permeable nature of UHPC at earlier ages combined with the very low moisture content in the UHPC. This low moisture content results in a loss pf water to the surrounding atmosphere and thus reduced hydration of the concrete.

Future Research

The findings from this research suggest a number of potential topics for future research:

1) Develop optimized bridge girders that take advantages of the material properties of UHPC. These bridge girders should use the tensile and compressive capacities of UHPC, while also enhancing the design life of the bridge as a whole by eliminating many of the less durable components of a normal bridge.
2) Fabricate full scale, optimized UHPC bridge girders to resolve problems associated with casting slender concrete members with fiber reinforced concrete.
3) Conduct full – scale flexure and shear testing to verify the design philosophies presented in this research.

References

1) Acker, P., and M. Behloul, “Ductal Technology: a large Spectrum of Properties. A wide range of applications, “Proceedings of International Symposium on UHPC, Kassel, Germany, September 13-15-2004.
2) Aldea, C., S. Shah, and A. Karr, “Permeability of cracked concrete”, “Material and structures”
3) IS 383:1970- “Specifications for course and fine aggregates from natural sources for concrete”
4) IS 650:1991- “Specification for course and fine aggregates for testing of cement”

5) Indian standard method of test for compressive strength of Cement Mortar "(using 50mm cube specimens)," in standard Specifications for Transportation Materials and Methods of Sampling and Testing.
6) IS 516:1959- "Method of test for strength of concrete"
7) IS 2(part 386(part 1):1963- "methods of test for aggregates for concrete: Part Particle size and shape"
8) IS 2386(part 3):1963- "Methods of test for aggregates for concrete: part 3 Specific Gravity, density, voids, absorption and bulking.
9) SP 23 (S&T): 1982- "Handbook on concrete mixes (based on Indian 1 Standards)
10) ASTM A820-06- "Standard Specification for Fiber reinforced Concrete"
11) American Association of State Highway and Transportation Officials, AASTHO standards.
12) ASTM C1018-97- Standard Test Method for flexural Toughness and first crack strength of Fiber-Reinforced concrete (using Beam with third - point loading)
13) ASTM C109, "Standard Test Method for compressive strength of Hydraulic Cement Mortars (using 50mm cube specimens),"American society for testing and Materials Standards Practice C109, Philadelphia, Pennsylvania,1998.
14) Concrete Technology- Theory and practice by M.S. Shetty, S. Chand Publications (ISO 9001 : 2000 company)