Development of Ultra High Performance Concrete

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Abstract- *The construction industry is a major consumer of material and energy sources in the world. Among all the construction materials concrete is the most widely used. The demand for the concrete is increasing day by day due to increased consumer requirements and changing site conditions. The addition of fibers to the concrete will further enhance the properties of concrete like tensile strength, High energy absorption and prevent ductile failure. It is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the concrete. These fibers have many benefits. Many developments have been made in the fiber reinforced concrete. This Study is an attempt to use nano materialS and fibers to produce ultra high performance concrete (UHP-FRC).*

Keywords- UHP-FRC (Ultra high Performance Concrete).

I. INTRODUCTION

Initially the Concrete was primarily composed of Water, Fine Aggregate, Coarse Aggregate and binder material Cement. Once these ingredients are mixed along, they form a fluid mass. Over time, the cement forms a tough matrix that binds the remainder of the ingredients along into a sturdy stone-like material called concrete with several uses. The concrete strength imparts a chemical reaction between cement and water and is called as Hydration.

There are many factors, which makes the concrete versatile for construction industry like Mouldability, strength, workability, setting time, Coefficient of thermal expansion, modulus of elasticity, creep, shrinkage, durability, etc. One of the most import5ant and useful properties of the concrete is the compressive strength. In most structural applications, concrete is mostly active to repel compressive stresses. The concrete is one of the most natural resource consuming material like sand, Coarse aggregates which is leading to highest exploitation and causing natural imbalance as mentioned earlier. Then comes the thought of using industrial waste materials like Fly Ash, GGBS, Rice Husk Ash, Silica fume etc. This leads to the production of greener (Sustainable) concrete and it is the first advancement in concrete technology.

Increased requirements for durability, strength, security and safety of concrete structures push its expansion still further. Mega structure and High rise buildings have become the source of development cities worldwide. New hi-tech materials such as ultra-high performance concrete (UHPC) are unique for applications where tensile strength and high compressive, high energy absorption capacity and a small thickness are required. UHPC is characterized by very high strength and high durability attributable to a very low water-cementations material ratio, low permeability, high resistance to cycles of freezing and thawing, and very tight cracks under load, all of which should provide for a much longer service life compared to the use of conventional concrete. UHPC concrete consists fine materials like quartz sand, quartz powder, silica fume and now a days Nano particles are used in the concrete to enhance its mechanical properties.

Plain concrete or UHPC possesses a very low tensile strength, limited ductility, less energy absorption and little resistance to cracking .internal micro cracks are inherently present in the concrete and propagation of such micro cracks leads to poor tensile strength, eventually leading to brittle failure of the concrete. It has been observed that addition of small, closely spaced and uniformly dispersed fibers to concrete will lead decrease brittleness and increase energy absorption capacity. This type of concrete is called as Fiber Reinforce Concrete.In this way concrete has been volved from Normal strength concrete to Ultra high performance fiber reinforced concrete.The present study Involves Development of Ultra High Performance Fiber Reinforced Concrete (UHP-FRC) using Nano materials (Nano Silica, MWCNT‟s) and fibers (Basalt Fibers).

1.1 Multi-wall Carbon-Nanotube (MWCNT)

The excellent mechanical properties of CNT make it the candidate for the improvement of the volume stability of cement-based materials. An uniform dispersion of CNT in cementitious materials can be achieved with the aid of sonication and surfactant (as shown in Fig. 1). With the addition of a small amount of CNT, various researchers reported a significant improvement of the mechanical properties. For example, Li et al reported that the addition of 0.5 wt% MWCNTs into cement matrix resulted in a 25 % increase in flexural strength and a 19 % increase in compressive strength. Some other work demonstrated cement hydration acceleration of CNT. Konsta-Gdoutos et al. conducted nano-indentation on CNT- added cement pastes and revealed that the use of highly dispersed small amount (0.05 %) of MWCNTs can increase the amount of high stiffness C–S–H and decrease the porosity (see Fig. 2). The alteration of the nano-structure results in an improvement of the volume stability of cement-based materials at very early age: it can be seen in Fig. 3 that the autogenous shrinkage of cement paste was reduced by about 25 %, and this could be described to the reduction of the capillary stresses induced by the reduction of the porosity.

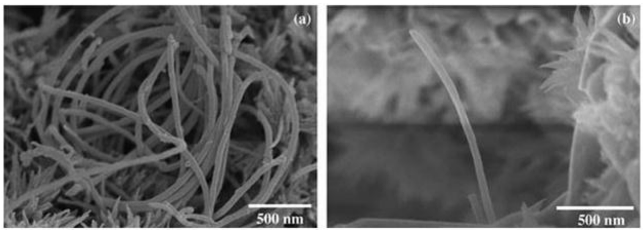

Fig.1 SEM images of cement paste fracture surfaces reinforced with undispersed (a) and dispersed (b) MWCNTs, respectively.

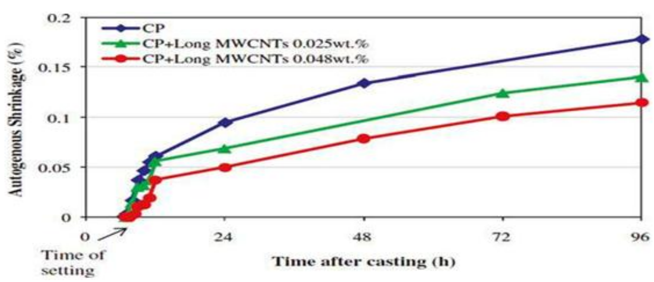

Fig.2 Probability plots of the Young's modulus of 28 days cement paste (w/c = 0.3) and cement paste reinforced with 0.025 wt% long, 0.048 wt% long and 0.08 wt% short MWCNTs.

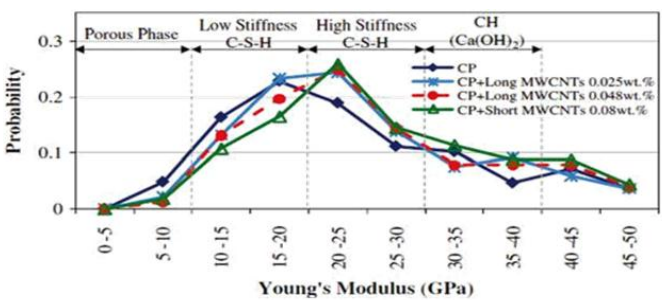

Fig.3 Probability plots of the Young's modulus of 28 days cement paste (w/c = 0.3) and cement paste reinforced with 0.025 wt% long, 0.048 wt% long and 0.08 wt% short MWCNTs.

II. RELATED WORK

Petr Máca[1] described Formulation process of Ultra High Performance Fiber Reinforced Concrete (UHPFRC) Materials locally available in the European Union were used throughout the optimization process. The mixture was also developed without any special curing, such as elevated temperature, pressure or vapour. The optimization process consisted of two steps. In the first step a cementitious matrix was optimized with respect to its maximal compressive strength, flexural strength and workability. The key element in the optimization process was to achieve maximal particles packing density, to choose efficient enough high-range water reducer (HRWR) and to decrease water binder ratio as much as possible. In the second step of the optimization process short, high tensile strength steel fibers were added into the matrix that showed highest workability and strength. The resulting compressive strength of UHPFRC mixtures exceeded 150 MPa after 28 days, average secant modulus of elasticity was in the range of 55 GPa and direct tensile strength in range of 10 MPa. During the optimization process mixtures with 1, 2 and 3% of fibers by volume were tested. It was found that with respect to acceptable workability and superior mechanical performance the optimal fiber content is between 2 and 3% by volume.

Tehmina Ayub [2],In this paper the mechanical properties and the high performance fibre reinforce concrete (HPFRC) 's microstructure containing up to 3% volume fraction of chopped Basalt fibers. Three dfifferent types of the concrete were prepared, among which, the first type was prepared by utilizing 100% cement content. The remaining two types of the concrete were prepared by replacing 10% cement content with the locally produced metakaolin and silica fume. Using each of these concrete type, four mixes were prepared in which Basalt fibers were added in the range of 0–3%; which means, total twelve mixes of the HPFRC concrete were prepared. Among twelve concrete mixes, twelve specimens were cast to estimate the mechanical properties of the HPFRC including splitting tensile strength, compressive strength (cube and cylinder), and the flexural strength. In this way, about 108 specimens were cast and tested in this study. The results of test showed that the addition of the Basalt fibers significantly increased the flexural strength and the tensile splitting strength of the HPFRC while there was slight improvement in the compressive strength with the addition of Basalt fibers.

S. Venkateswara Rao[3] The study on basalt fiber reinforced concretes workability and strength properties of concrete with basalt fibers in proportions of 0, 1, 3 & 5 kg/m3 for M20 and M40 grades at 7,28, 56 and 91 days age of curing can be presented in this thesis.

- For M20 Mix, It was observed that 27.39% of compressive strength, 69.28% of split tensile strength and 21.83% of flexural strength has increased with3 kg/m^3quantity of basalt fiber over conventional concrete at 28 days age.

- For M40 Mix, It was observed that 12.43% of compressive strength, 57.38% of split tensile strength and 25.24 % of flexural strength has increased with3 kg/m^{3}quantity of basalt fiber over conventional concrete at 28 days age.

Kay Wille[4] This study focuses on the development of UHP-FRCs without any special treatment and utilizing materials that are commercially available in the US market.

- Special treatment, such as heat curing, pressure and/or extensive vibration, is often required in order to achieve compressive strengths in excess of 150 Mpa. Enhanced performance was accomplished by optimizing the packing density of the cementitious matrix, using very high strength steel fibers, tailoring the geometry of the fibers and optimizing the matrix fiber interface properties. It is shown that addition of1.5% deformed fibers by volume results in a direct tensile strength of 13 MPa, which is 60% higher than comparable UHP-FRC with smooth steel fibers, and a tensile strain at peak stress of 0.6%, which is about three times that for UHP-FRC with smooth fibers. Compressive strength up to 292 MPa (42 ksi), tensile strength up to 37 MPa (5.4 ksi) and strain at peakstress up to 1.1% were also attained 28 days after casting by using up to 8% volume fraction of high strength steel fibers and infiltrating them with the UHPC matrix.

Hamdy K. Shehab El-Din[5] . Ultra-high performance fiber-reinforced concrete (UHPC) is a new class of concrete that has been developed in recent years. UHPC results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. When UHPC compared with high performance concrete (HPC), UHPC exhibits superior properties in terms of compressive behaviour, tensile behaviour, workability, toughness, ductility and durability. UHPC has exceptional mechanical and transport properties including a very high tensile strength, strain hardening, and a density leading to a very low permeability. In this research, tests were carried out on a total 42 cubes, 84 cylinders and 21 prisms of UHPC samples to study the effect of adding steel fibers on the mechanical properties of UHPC such as, compressive strength, modulus of elasticity, poisson's ratio,flexural strength and tensile strength. The major parameters included in this research were the volume fraction of steel fibers and aspect ratio. The test results showed that he increase of volume fraction of steel fiber from 0% to 3% for UHPC causes maximum increase in compressive strength by 18.2 flexural strength by 40% and tensile strength by 66.1% for higher side of aspect fiber ratio.

III. IMPLEMENTATION

Casting of cubes of size 150×150×150mm, cylinders of size 300mm height and 150mm diameter and beams of size 700×150×150mm are done.

This chapter consists of basic testing of all the above mentioned materials.

3.1 Cement

Main binder material in the concrete mix, an Ordinary Portland Cement (OPC) of 53 grade cement (RAMCO) is used in the experiment. As per IS-12263:1987 basic properties for cement are given below.

Sl. No	Properties	Values
1	Specific gravity	3.15
2	Initial setting time	60 min
3	Final setting time	160 min
4	Normal consistency	32%

3.2 Aggregates:

Most of the volume in the concrete mix is mainly occupied by aggregates. Aggregates are the main structural part which gives strength to the concrete mix. As per IS-383:1970 basic properties of coarse aggregates and fine aggregates are given below.

3.3 Tests on Coarse Aggregates:

Specific gravity of Coarse aggregates and water absorption:

Sl.no	Details	Weight of Sample (kg)
a	Weight of basket + coarse aggregates (w_1)	2.74
b	Weight of basket in water (w_2)	1.450
c	Weight of surface dry aggregates (w_3)	1.954
d	Weight of oven dry aggregates (w_4)	1.941
e	Weight of saturated aggregates ($w_5 = w_1 - w_2$)	1.250

Specific gravity of coarse aggregates = $\frac{(w4)}{(w3)-(w5)}$ = $\frac{1.941}{1.954-(1.073)}$ = 2.757

Water absorption of coarse aggregates = $\frac{w3-w4}{w4} \times 100$ = $\frac{1954-1941}{1941} \times 100$ = 0.67%

Sieve analysis of coarse aggregates

IS Sieve	Cumulative percentages		Specification as per IS code with respect to 20 mm nominal size of aggregates	
	Retained	Passing	Graded	Single sized
40mm	0	100	100	100
20mm	7.6	92.4	95-100	85-100
12.5mm	80.6	19.4	-	-
10mm	88.25	11.75	25-55	0-20
4.75mm	95.75	4.25	0-10	0-5

Impact value of aggregates

Sl.no	Details	Weight (gms)
1	Weight of aggregates retaining on 10mm sieve	385
2	Weight of aggregates passing through 2.36mm sieve	54

Impact value of coarse aggregates = $\frac{W_2}{W_1} \times 100 = \frac{54}{385} \times 100 =$ 14.025%

3.4 Tests on Fine aggregates:

Specific gravity of Fine aggregates

Sl.no	Details	Weight of Sample(gms)
1	Weight of bottle (w_1)	686
2	Weight of bottle + 1/3 of aggregates (w_2)	1266
3	Weight of bottle + 1/3 of aggregates + water (w_3)	1874
4	Weight of bottle + water (w_4)	1490
5	Specific gravity of fine aggregate	2.54

Specific gravity of Fine aggregates = $\frac{(w2-w1)}{(w4-w1)-(w3-w2)}$

$= \frac{(1262-686)}{(1490-686)-(1874-1262)} = 2.54$

Sieve analysis

Sl no	Sieve Size	Weight Retained (gms)	Percentage of weight retained	Cumulative percentage retained	Percentage of fine aggregate passing
1	4.75 mm	0	0	0	100
2	2.36 mm	30	3	3	97
3	1.18 mm	52	5.2	8.2	91.8
4	600 µ	102	10.2	18.4	81.6
5	300 µ	430	43.0	61.4	38.6
6	150 µ	350	35.0	96.4	3.6
7	75 µ	16	1.6	98	2
8	Pan	20	2.0	100	0

Fineness modulus of Fine aggregates = $\frac{385.4}{100}$ = 3.854

3.5 Fly ash

Specific gravity of fly ash

Sl.no	Details	Weight of Sample(gms)
1	Weight of empty bottle (w_1)	57.5
2	Weight of bottle + fly ash (w_2)	71.21
3	Weight of bottle + fly ash + kerosene (w_3)	144.8
4	Weight of bottle + kerosene (w_4)	138.08
5	Weight of bottle + water (w_5)	158.01

$$\text{Specific gravity of fly ash} = \frac{(w2-w1)}{(w4-w1)-(w3-w2)} \times \frac{w4-w1}{w5-w1}$$

$$= \frac{(71.21-57.5)}{(138.08-57.5)-(144.8-71.21)} \times \frac{138.08-57.5}{158.01-57.5} = 2.1$$

IV. TESTING OF PREPARED SPECIMEN

4.1 Compressive Strength Test

Compressive strength test is themost significant common test conducted on hardened concrete.This test is done because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.The compressive strength test is conducted on compression testing machine according to IS 516 : 1959[c]. The test specimens are cubical in shape and their dimensions being 150mm×150mm×150 mm in size are used for testing. The rate of loading is to be maintained at 140 kg/cm^2/min. This test was carried out for the different percentages of Meta-kaolin replacements, also for 28 Days strength test.

The equation used to find the compressive strength is as follows:

$$\text{Compressive strength} = \frac{\text{Load at failure}}{\text{cross sectional area}} \text{ MPa}$$

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