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DEVELOPMENT OF ULTRA HIGH PERFORMANCE CONCRETE

MADHUMITHA.S.K [1], SREERAMBABU.J [2]

[1] M.E Structural Engineering Student, Department of Civil Engineering,
Thanthai Periyar Government Institute of Technology, Vellore.
[2] Associate Professor ,Department of Civil Engineering,
Thanthai Periyar Government Institute of Technology, Vellore.

ABSTRACT - This work describes experimental investigation of various mechanical properties of Ultra High Performance Concrete (UHPC) which is completely free from coarse aggregate. It is a modern cementitious composite containing a large amount of cement, both non reactive and reactive ultra fine particles, chemical admixtures with micro and macro steel fibres. This type of concrete has superior flexural, durability and excellent mechanical properties. In this work UHPC containing 2% of fibres by volume with compressive strength exceeding 120 MPa is proportioned with a cement content of 850kg/m3 and water cement ratio of 0.25. In this study detailed descriptions of the measurement of compressive strength and split tensile strength are given. The results shows that, based on the optimized particle packing with hybrid macro and micro fibres, it is possible to produce UHPC with a relatively low water-binder ratio. Moreover, due to the mutual effects between the utilized fibres, the hybrid fibre reinforced UHPC shows an improved flowability and better mechanical properties.

KEYWORDS - Steel Fibres, UHPC, Mechanical Properties.

I . INTRODUCTION

Ultra High Performance Concrete is a cementitious concrete material of compressive strength of greater then 120MPa with high durability, specific toughness, high tensile strength and fibres are being added as admixture to satisfy these requirements. It is also called as Reactive Powder Concrete (RPC) formulated with combination of Portland cement and other cementitious materials, limestone powder, and quartz flour. So that the compressive strength can excess to 120Mpa. The main idea behind this concrete development was designed specifically for a particular application and not only forhigh strength but also for high tensile capacity, high durability and extreme workability. It is a new class of concrete that has been developed in recent years and it is a combination of High Performance Concrete (HPC), Self Compacting Concrete (SCC) and Fibre Reinforced Concrete (FRC) due to its exceptional properties of strength and durability. It also have low porosity and density matrix.

II HISTORICAL BACKGROUND OF DEVELOPMENT OF UHPC

During the roman empire the continuous process of development of concrete has evolved. The modern history of concrete was developed in back dates to 1824 with Portland cement. The cement was mixed eventually with water, sand, gravel and other aggregates which resulted in concrete. Reinforced concrete was evolved in 1849 with addition of metallic reinforcement for increasing strength and ductility. The advanced concrete technology was developed throughout the 19th and 20th centuries as many were interested in optimized strength, particle density an d bond strength. High performance concrete and high strength concrete were both coined in 1980's, which resulted in improved durability with high compressive strength ranging from 7000 to 17000psi. To involve brittle matrices, fibre reinforced concrete was developed laterally where the application of fibres increased durability, resistance, strength and more on. The crack control and impact performance also improved with addition of fibres in concrete. Durability and compressive strength tend to focus continuously on the concrete technology in 1980's. When the development of UHPC increased the concrete strength more then 17000psi to 30000psi.UHPC was officially invented in the year 1994 and was in applications in North America. In the year 1970's the development of Ultra strength cement pastes with low porosity was introduced by Yudenfreund's et al and Roy et al.

III MATERIALS OF UHPC

A. Cement - It is a basic component in UHPC with 30% of the concrete volume. OPC consist of finely ground gypsum and clinker. The main composition of clinker includes C3S, C2S, C3A and C4AF. C-S-H gel a hydration product of C3S and C2S, it is the main contributor to increase the strength of concrete. The combination of C2S + C3S is greater then 65% in cement used in developed UHPC. According to (Wille et al 2012) cement with d50 = 10 micro meter is used for UHPC.

TABLE I - PROPERTIES OF CEMENT

Particulars	**Percentage of chemical composition (%)**
Lime (CaO)	61.33
Silica (SiO2)	21.01
Iron oxide (Fe2O3)	3.12
Alumina oxide (Al2O3)	6.40
Magnesia (MgO)	3.02
Sulfuric anhydride (SO3)	2.30

TABLE II - TESTS ON CEMENT

Si No	**Material property**	**Tested value**
1	Specific gravity of cement	3.14
2	Fineness	89%
3	Setting time	
I	Initial setting time	45 Mins
Ii	Final setting time	650Mins

B. Silica fume- It is also called as condensed silica fume or micro silica. It is a binding material used in UHPC which should normally be multi componential containing large amount of additives of pozzolonas such as silica fume. It is a by-product of production of silica meta or ferro silica alloy. It is composed by very small , glassy silica particles. Low carbon content of silica fume is preferred to achieve good workability.

TABLE III - PROPERTIES OF SILICA FUME

Silica (SiO2)	90.26%
Iron oxide (Fe2O3)	01.11%
Alumina oxide (Al2O3)	05.84%
Loss on ignition	02.20%
Moisture	02.20%

C. Sand - It is used to add strength and replaces binders in reducing the cost of concrete. 30% of volume of cementaitious materials can be replaced by sand in compression strength. To produce concrete with high compressive strength the preferred sand is expected to have strong texture and limited chemical reactivity .Usually UHPC mix do contain sand with Maximum aggregate size (MSA) of 1mm.

TABLE IV - TESTS ON FINE AGGREGATE

Si No	Material property	Tested value
1	Specific gravity of sand	2.16
2	Water absorption test	1.1 %
3	Sieve analysis (passing- 600microns)	Uniformly graded

D. High range water reducer (HRWR)- The high requirement of special concrete especially in self compacting concrete requires the use of polymers of special type like melamine sulfonate, vinylco polymers and naphthalene sulfonate in high range. These are traditional super-plasticizers used as normal requirement in concrete. Among all these special polymers, (Polycarboxylate ether) type super-plasticizers have become most widely used in recent years.

E. Water - The water should be clean and must not contain any sugar , gur, or their derivatives, or sewage, oils, organic substances.

F. Reinforced fibres - Fibres are added to improve the characteristics in hardened state of concrete. To optimize the performance of single fibre, fibres are need to be homogeneously distributed. The mix composition of fibre reinforced concrete often is compromise between requirements on fresh and hardened concrete states. Due to long elongated shapes and higher surface area the workability of concrete is affected and still fibre change the structure of granular skeleton while synthetic fibres can fill the space between them. Steel fibres are normally incorporating UHPC, it is classified in two groups based on the type of fibres used:-

1) Micro steel fibres - High strength smooth steel fibres with diameter less then 0.5mm and length less then 13mm. The use of micro steel fibres require high amount to secure strain hardening behaviours.

2) Macro steel fibres – Small amount of deformed steel fibres (Hooked end) with less then 2% was reinforced in UHPC matrix to produce strain hardening behaviours accompanied with multiple micro cracks. Here steel fibres of length greater then 30mm and diameter greater then 3mm is used.

In blending micro and macro fibres the expected tensile strength, durability, and other mechanical properties increases. This approach is selected in this research to blend micro and macro fibres to enhance both the post working strength and strain capacity of UHPC in small amount without reducing the workability.

Fig 1 Micro Steel Fibres

Fig 2 Macro Steel Fibres

TABLE V - PROPERTIES OF STEEL FIBERS

Fibre type	Steel fibre (Micro –Straight steel fibres, Macro – Hooked end steel fibres)
Length(mm)	Micro fibre – 13mm Macro fibre – 30mm
Diameter(mm)	Micro Fibre – 0.5mm Macro fibre – 0.5mm
Shape	Micro fibre – Straight Macro fibre – Hooked end
Tensile strength	1100 N/mm2
Density	7800
Elastic modulus	212

IV MIX DESIGN

Gaussian Process-Batch Bayesian Optimization framework for Mixture Design of Ultra-High-Performance Concrete.The components of UHPC considered in the proposed GP model are cement, water, silica fume, fly ash, sand, steel fiber, Quartz Powder, and admixture – and more components can be added as well and in a total of 110 points pairing formulae with their associated compressive strength.

TABLE VI STANDARD MIX DESIGN OF UHPC

Ingredient (kg/m3)	Mean	Minimum	Maximum
Cement	879.7	383	1600
Water	197.1	0	185
Sand	980.0	0	1898
Admixture	31.9	0	185
Quartz powder	750	0	750
Steel fiber	39.0	0	470
Silica fume	192.0	0	367.95

Here the ratio of steel fibres varies in two ratios.
1. 0.5% Micro fiber + 1.5% Macro fibre.   2. 1.5% Micro fibre + 0.5% Macro fibre

The silica sand and limestone powder are first dry-mixed for about five minutes. Cement and fine aggregate are added to the mixture and dry-mixed for another five minutes. Water and HRWR are first mixed together and then added gradually to the dry material. After five minutes of adding water the steel fibres are added and mixed untill the concrete archives its workability. Clean the mould with dry cloth and apply oil to avoid friction. Fill the concrete in 3 layer by tamping each layers 25times with tamping rod and the concrete is filled up to the top of the mould by compacting each layer.The first batch of 9 test specimens are stored in moist air for 24 hours and after this period the specimen are marked and removed from the mould and kept submerged in clean fresh water until taken out prior to test.

V RESULTS

A . TEST ON FRESH AND HARDENED CONCRETE - The fresh concrete shall be provided against gaining or losing water. Provided that care is taken to ensure that no water or other material is lost, the concrete used in workability and density tests may be remixed with the reminder of the batch before making any specimen for testing hardened.

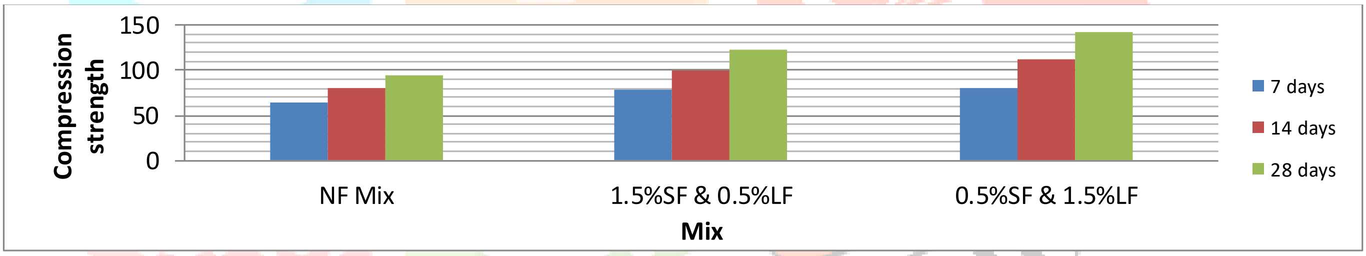
Table VII TEST ON FRESH CONCRETE

Si No	Name of the test	Value
1	Slump cone test	Collapse slump
2	Flow table test	120% (Sloppy)

TABLE VIII TEST ON HARDENED CONCRETE

Si No	Material	Compression Strength	
		7 days	28days
1	Non- Fibers mix	64.3	94.3
2	1.5% SF & 0.5% LF	77.6	122
3	0.5% SF & 1.5% LF	81	142

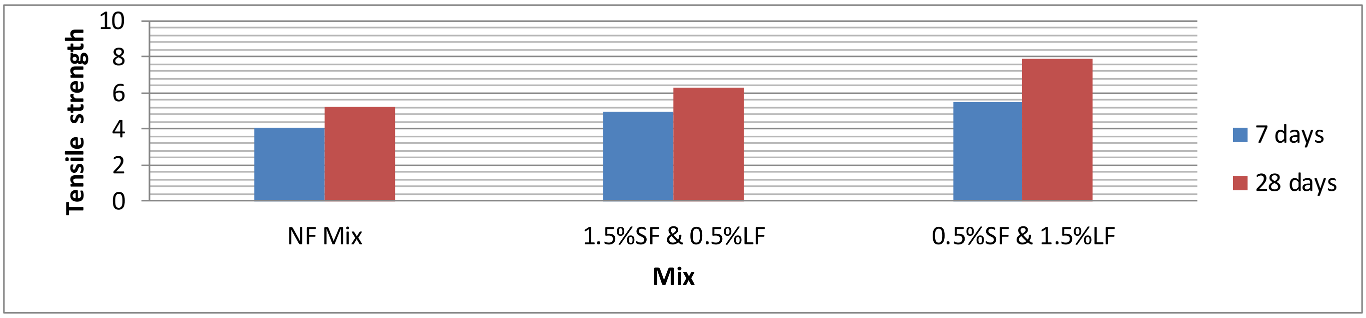
TABLE IX : COMPRESSIVE STRENGTH OF CONCRETE



The cylindrical specimens of diameter 150mm and height 300mm were used to determine the split tensile strength. The specimens were tested in computerized universal testing machine of capacity 1000 kN. Three cylindrical specimens were tested for each percentage of replacement. The cylinders were placed in the machine horizontally. Load was applied gradually at a uniform rate until the specimens failed. Split tensile strength was taken as the average strength of three specimens.

TABLE X TEST FOR SPLIT TENSILE STRENGTH OF CONCRETE CYLINDERS

Si NO	Material	Tensile Strength	
		7 days	28 days
1	Non Fiber Mix	4.10	5.20
2	1.5%SF & 0.5%LF	4.95	6.35
3	0.5% LF & 1.5% LF	5.51	7.89



VI CONCLUSION

The incorporation of higher fiber contents in the mixture of UHPC has results in higher tensile and compressive strength.

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