Experimental Investigation on the Mechanical Properties of Ultra High Performance Fibre Reinforced Concrete with Fly Ash

Reju R
Executive Engineer, KSEBL
Trivandrum, India

Jiji Jacob G
Department of Civil Engineering
College of Engineering Trivandrum
India

Abstract—**Ultra High Performance Fibre Reinforced Concrete (UHPFRC) is a special concrete which exhibits very high compressive strength and flexural strength. In this study, polypropylene fibres are used as fibres. These fibres reduces the greater risk of corrosion while using the conventional steel fibres. The high cement content in conventional UHPFRC often leads to higher shrinkage and greater heat of hydration besides increased cost. This is solved by the use of supplementary cementitious materials like fly ash. Here the mechanical properties of UHPFRC with fly ash is experimentally investigated. The effect of varying the percentage of fibres on the properties of UHPFRC is studied. The effect of varying the percentage of fly ash when it is just added and when it is added as replacement for cement are also investigated. The fibres were found to increase the ductility of concrete. The cement replacement by fly ash was found to increase the strength of UHPFRC.**

Keywords—UHPFRC; fly ash; polypropylene fibres; mechanical properties.

I. INTRODUCTION

Ultra High Performance Fibre Reinforced Concrete (UHPFRC) or Reactive Powder Concrete (RPC) is a high strength ductile material. The constituent materials are ordinary portland cement, silica fume, fine river sand, super plasticizer, water, and fibres. UHPFRC has compressive strengths ranging from 80 to 200 MPa and flexural strengths 10 to 30 MPa.

The material has the ability to deform and support flexural and tensile loads, even after initial cracking. The enhanced performance is mainly due to the denser mix and better micro-structural properties of the mineral matrix and the control of the bond between the matrix and the fibre.

The use of chemical admixtures (superpasticizers) increases the workability and reduces the water content thereby reducing the porosity within the hydrated cement paste. Mineral admixtures act as pozzolanic materials as well as fine fillers thereby the micro structure of hardened cement matrix becomes denser and stronger.

Reference [1] studied Steel Fibre Reinforced Self Compacting Concrete(SFRSCC) in detail. In this paper, a mix design method is proposed to develop cost effective and high performance SFRSCC. The behaviour of SFRSCC was found to have improved by addition of steel fibre reinforcement. A comparative study on impact strength of a few natural fibre reinforced cement mortar slabs was done by [2]. It was found that the addition of natural fibres increased the impact resistance by 3 to 18 times that of the reference plain mortar slab.

The mechanical and durable behaviour of alkaline cement mortars reinforced with polypropylene fibres was studied by [3]. The results obtained showed that the strength development depends mainly on the nature of the matrix. Fibre presence and content also had influence on strength development.

The response of ultra high performance steel fibre reinforced concrete to impact and static loading was studied by [4]. Three-point and four-point bending response was studied on plates which were subjected to quasi-static loading. Dynamic three-point bending loads were applied to UHPFRC plates by drop weights. The results of this study showed that there was significant increase in strength and fracture energy in dynamically loaded plates when compared to quasi-static loading.

The tensile behaviour of Polypropylene Fibre Reinforced Mortar (PFRM) was studied by [5]. In this study, the behaviour of PFRM was studied by conducting direct tensile test on dog-bone shaped specimens. It was found that the tensile properties depended mainly on the type and content of fibre. PFRM was found to exhibit a double peak response with the occurrence of a second peak at higher deformation. The effect of mineral admixture (silica fume and fly ash) on High Performance Concrete (HPC) was studied by [6]. The compressive strength, porosity, oxygen permeability, oxygen diffusion and chloride migration of HPC with silica fume and fly ash was studied. The results showed that the presence of silica fume and fly ash improved the properties of HPC, but at different rates depending on the binder type.

From the detailed literature review it is seen that fibres have a positive influence in absorbing energy during formation of cracks in concrete. Admixtures like fly ash was found to improve the mechanical and durability property of

HPC. In the above works polypropylene fibres were not used to develop an UHPFRC mix. Moreover the effect of fly ash has not been studied in a UHPFRC mix with polypropylene fibres. The objective of the present study is to evaluate the fresh and hardened properties of polypropylene fibre based UHPFRC with and without fly ash.

II. MATERIALS

The materials used for the UHPFRC are cement, fine aggregate, silica fume, superplasticizer, water and polypropylene fibres. The cement used in this study is 53 grade Ordinary Portland Cement. Tests were conducted to determine standard consistency, initial and final setting time and compressive strength. Locally available river sand sieved through 600 micron sieve was used as fine aggregate. Sieve analysis was done to plot the gradation curves and to find the fineness modulus of sand. All the tests were carried out as per relevant IS codes. The results of the gradation analysis of fine aggregate is shown in Fig. 1. The super plasticizer used in this study is based on a unique carboxylic ether polymer with long chains. It combines the properties of water reduction and workability retention. The normal dosage as specified by the manufacturer is 0.5 to 3.0 litre per 100 kg of cementitious material. Potable water is used for mixing the constituents. The recommended dosage of fibre is 0.9 kg/m^3 of concrete. The length of fibre is 20mm and diameter is 0.1mm.

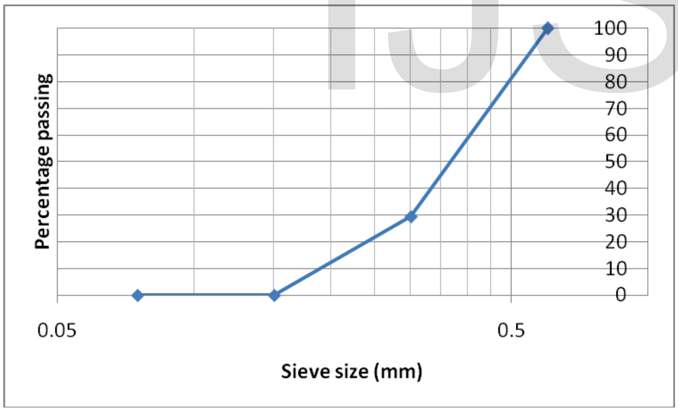

Fig. 1 Gradation Analysis of Fine Aggregate

TABLE 1. MIX PROPORTION OF UHPFRC

Particulars	Quantity (Kg/m^3)
Cement	750
Silica Fume	187.5
Fine aggregate	1355
Water	240
Superplasticizer	27.5
Fibre	0.9

TABLE 2. PROPERTIES OF CONTROL MIX

Property	Strength (MPa)
Cube Compressive Strength (7th day)	55
Cube Compressive Strength (14th day)	75
Cube Compressive Strength (28th day)	99
Cylinder Compressive Strength (28th day)	74.7
Modulus of Elasticity	48963
Split Tensile Strength	16.34
Flexural Strength	10.88

III. EXPERIMENTAL PROGRAMME

The experimental investigation has been done to develop a UHPFRC mix of target compressive strength of 80 MPa. The effect of varying the percentage of polypropylene fibre on the properties of fresh and hardened UHPFRC was studied. The effect of varying the percentage of fly ash was also studied. The mix proportion of the control mix is detailed in Table 1. Extended mixing time is necessary both to fully disperse the silica fume, breaking up any agglomerated particles and to allow superplasticizer to develop its full potential.

The workability of the freshly prepared mix was tested using the flow test and found to be 400mm. The 7th day, 14th day and 28th day compressive strengths of cubes were found. The tests were done on cubes of size 50cm^2 face area (3 cubes each). After curing the cube specimens were tested in 1000kN compression testing machine and loaded to failure. To determine the modulus of elasticity, compressometer was fixed to cylindrical specimens and were subjected to repeated loadings. Value of modulus of elasticity was computed from the stress strain plot. The results are shown in Table 2.

IV. TEST RESULTS AND DISCUSSION

The effect of water cement ratio on properties of UHPFRC was studied by conducting tests on mixes with varying water content. The results of the experiment are given in Fig. 2 and Fig. 3. From Fig. 2 it is observed that the flow of fresh UHPFRC initially increases gradually with increase in water content. There is a sharp increase in flow for water cement ratios higher than 0.32. Correspondingly the 28th day compressive strength (Fig. 3) shows a gradual increase upto about 100N/mm^2. With further increase in water cement ratio a fall in compressive strength is observed. Hence an optimum water cement ratio of 0.32 is used for further tests.

The effect of fibre content on the properties of UHPFRC was studied by conducting tests on mixes with varying percentage of fibre content. The results are shown in Fig. 4 and Fig. 5. From Fig. 4 it is observed that with increase in fibre content there is a gradual decrease in flow of fresh UHPFRC. However the compressive strength (Fig. 5) shows an initial increasing trend with a peak followed by a fall. The peak value of 99MPa is observed for a fibre content of 0.9 kg/m^3 of concrete. Hence a fibre content of 0.9 kg/m^3 is used for further tests.

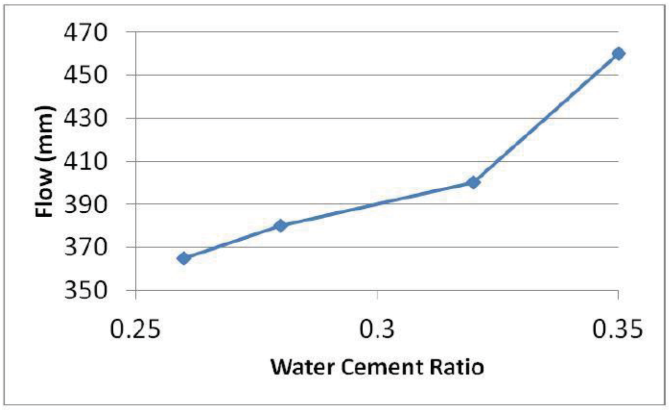

Fig. 2 Effect of Water Cement Ratio on Flow of Fresh UHPFRC

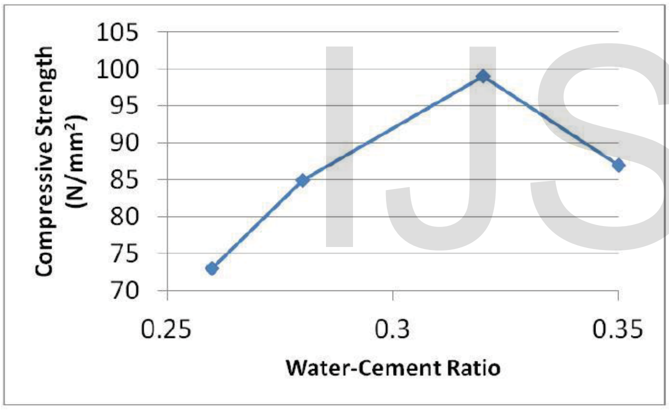

Fig. 3 Effect of Water Cement Ratio on 28th day Compressive Strength of UHPFRC

The effect of fly ash addition on the properties of UHPFRC was studied by conducting tests on mixes with varying percentage of fly ash addition. The results are shown in Fig. 6 and Fig.7. From Fig. 6 it is seen that with increase in fly ash content, there is decrease in flow of fresh UHPFRC. The values for compressive strength (Fig. 7) shows a gradual increase initially followed by a fall after attaining a peak value of 102MPa at a fly ash content of 15%.

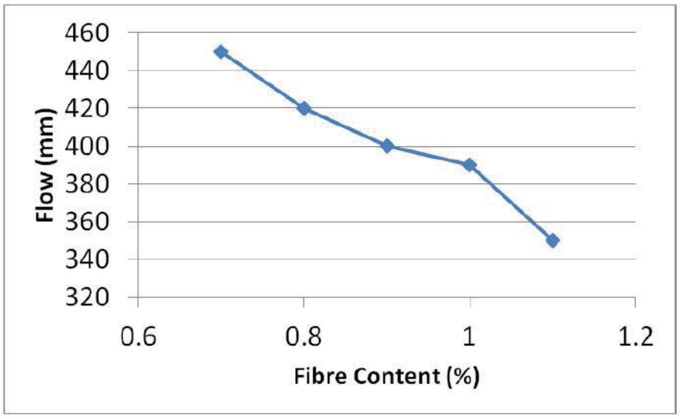

Fig. 4 Effect of Fibre Dosage on Flow of Fresh UHPFRC

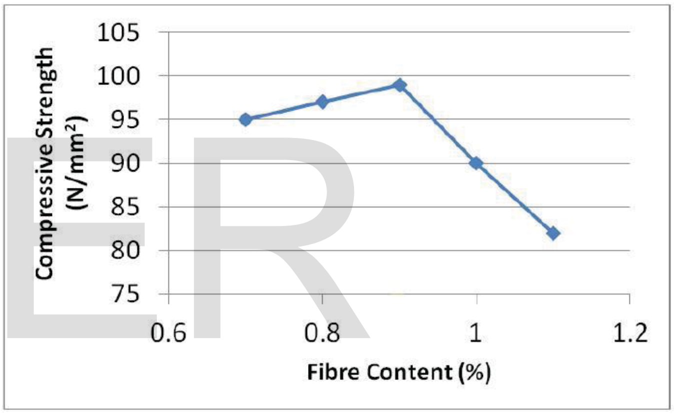

Fig. 5 Effect of Fibre Dosage on 28th Day Compressive Strength of UHPFRC

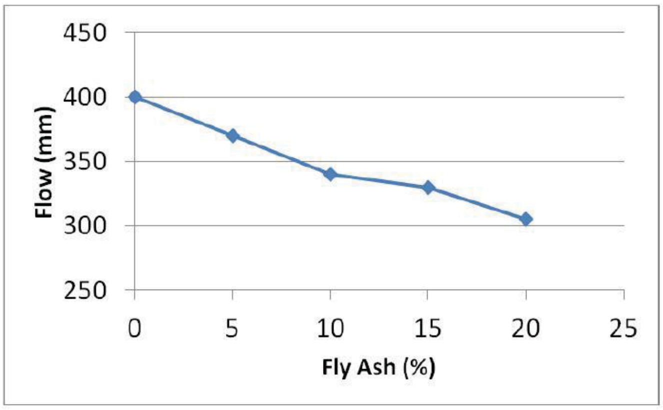

Fig. 6 Effect of Fly Ash on Flow of Fresh UHPFRC

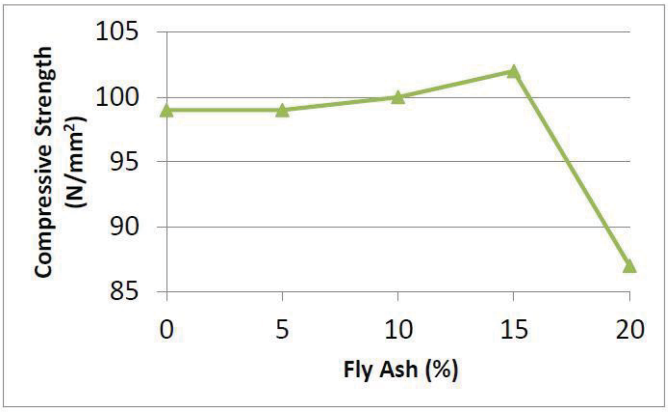

Fig. 7 Effect of Fly Ash on 28th Day Compressive Strength of UHPFRC

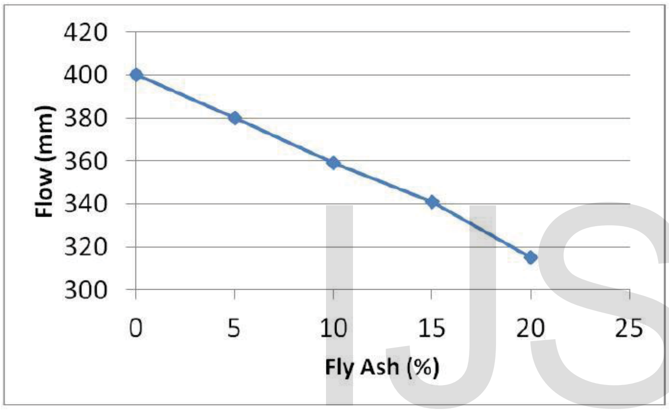

Fig. 8 Effect of Cement Replacement with Fly Ash on Flow of Fresh UHPFRC

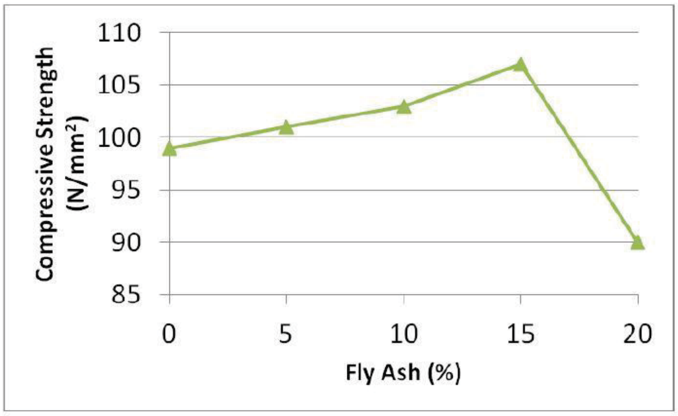

Fig. 9 Effect of Cement Replacement with Fly Ash on 28th Day Compressive Strength of UHPFRC

The effect of replacement of cement with fly ash on the properties of UHPFRC was studied by conducting tests on mixes with varying percentages of replacement of cement with fly ash. The results are shown in Fig. 8 and Fig. 9. From Fig. 8 it is seen that there is a gradual fall in flow with increasing replacement of cement with fly ash. The values for compressive strength (Fig. 9) shows a gradual increase in the initial stages followed by a fall. A peak value of 107 MPa is observed for cement replacement with 15% fly ash.

V. CONCLUSIONS

1. A compressive strength of 99 MPa can be attained for UHPFRC by using a water cement ratio of 0.32 and a polypropylene fibre content of 0.9 kg/m^3.

2. Addition of supplementary cementitious material (fly ash) results in slight increase in the strength of UHPFRC. Fly ash addition of 15% by weight of cement results in a maximum compressive strength of 102 MPa.

3. Replacement of cement with fly ash also improves the strength of fly ash. Replacement of cement by fly ash to the extent of 15% results in a maximum compressive strength of 107MPa.

References

[1] E. N. B Pereira, J.A.O. Barros and A. Camões, "Steel Fibre Reinforced Self Compacting Concrete: Experimental Research and Numerical Simulation", Journal of Structural Engineering, ASCE, Vol. 134, No. 8, p.1310, 2008.

[2] G. Ramakrishna and T. Sundararajan, "Impact Strength of a Few Natural Fibre Reinforced Cement Mortar Slabs: a Comparative Study", Cement and concrete composites, Vol 27, No. 5, p. 517, 2005.

[3] T. Puertas, T. Amat, A. Ferna´ndez-Jime´nez and T. Va´zquez, "Mechanical and Durable Behaviour of Alkaline Cement Mortars Reinforced with Polypropylene Fibres", Cement and Concrete Research, Vol. 33, No. 12, p 2031, 2003.

[4] K. Habel, and P. Gauvreau, "Response of Ultra High Performance Fibre Reinforced Concrete (UHPFRC) to Impact and Static Loading", Cement and concrete composites, Vol. 30, No. 10, p. 938, 2008.

[5] P. Sukontasukkul, "Tensile Behaviour of High Content Steel and Polypropylene Fibre Reinforced Mortar", Thammasat Int. J. Sc. Tech., Vol. 8, No. 3, p. 50, 2003.

[6] K.E. Hassan, J.G. Cabrera and R.S. Maliehe, "The Effect of Mineral Admixtures on the Properties of Concrete", Cement and Concrete Composites, Vol 22, p. 267, 2000.

[7] IS 2386 Part-I, 1963, "Methods of Tests for Aggregates for Concrete".