

Ultra High Strength Concrete

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ABSTRACT:The construction of high-rise buildings and mega projects around the world, and the increasing demands of owners and designers have led to the increasing demand on Ultra-High Strength Concrete (UHSC). Progress in concrete materials science and technology during the last 30 years has far exceeded that made during the previous 150 years. The technology development of concrete and demand for high strength construction materials give momentum to the development of Ultra-High Strength Concrete (UHSC). This new type of concrete is characterized with very high compressive strength i.e., strength higher than 100 MPa. Current UHSC preparation methods require costly materials and relatively sophisticated technology. In this project, study on Ultra-High Strength Concrete has been made. Concrete mix design and experimentation on Ultra-High Strength concrete have been carried out. The mechanical properties such as compressive strength, split tensile strength, Young's modulus of elasticity and flexural strength of ultra-high strength concrete have been researched.

KEYWORDS:High strength concrete (UHSC), M100, silica fume, super plasticizer.

I. INTRODUCTION

New types of concrete such as High Strength Concrete (HSC), High Performance Concrete (HPC), Self Compacting Concrete (SCC), Ultra High Performance Concrete (UHPC) and Ultra-High Strength Concrete (UHSC) are being constantly developed in order to meet the increasing demand for improved mechanical properties and durability. The properties of such concrete show a substantial improvement over conventional concrete of low or medium strength.

The concrete which has compressive strength greater than 100MPa is called as Ultra-High Strength Concrete (UHSC). Ultra-High Strength Concrete is a concrete which has an extremely low water to cement ratio (i.e. less than 0.26), higher binder content, optimum packing density to eliminate capillary pore and provide an extremely dense matrix. It is a high strength material formulated from a special combination of constituent materials which include Portland cement, silica fume, fine aggregate, coarse aggregate, high-range water reducer and water. The material has the capability to sustain deformation and resists flexural and tensile forces, even after initial cracking. Therefore the aim is to study the constituents and mechanical properties of Ultra-High Strength Concrete (UHSC).

II. MATERIALS USED

Ordinary Portland cement (OPC) - The cement used during the experiments is Ordinary Portland Cement of Grade 53 conforming to IS 12269:1987. According to IS 4031 the tested 28-day mortar compressive strength is 58MPa. The specific gravity is 3.15; the initial setting time is 35 minutes. The normal consistency being 30% and the particle size range lies between 31 μ m to 7.5 μ m.

Fine aggregate - In concrete technology specific gravity of aggregate is made use of in design calculations of concrete mixes. Indian standard specification in IS: 2386 (Part III) of 1963 gives various procedure to find out the specific gravity of different sizes of aggregates. The specific gravity is 2.71, Loose bulk density = 1520 kg/m³ and rodded bulk density = 1632 kg/m³.

Coarse aggregate -The ideal CA should be clean, cubical, angular, 100% crushed aggregate with a minimum of flat and elongated particles (ACI 363R, 1992).In concrete technology specific gravity of aggregate is made use of in

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design calculations of concrete mixes. Indian standard specification in IS: 2386 (Part iii) of 1963 gives various procedure to find out the specific gravity of different sizes of aggregates.

In this research, dry aggregates and saturated aggregates were used. Dry aggregates are used for control specimens of various mix proportions. For saturated aggregates, two different sizes of aggregates were soaked in water in for 1 hour and then that were used for this mix. The properties of them were given in table-1.

Table-1: properties of saturated aggregates.			
Aggregate size	Description	Obtained results	
12mm	Specific gravity	2.71	
	Bulk density	Loose	1323 kg/m ³
		Rodded	1538.4 kg/m ³
	Crushing strength	27%	
	Fineness modulus	4.72	
Water absorption	2%		
6mm	Specific gravity	2.71	
	Bulk density	Loose	1300 kg/m ³
		Rodded	1600 kg/m ³
	Crushing strength	27%	
	Fineness modulus	3.71	
Water absorption	2%		

Water- conforming to the requirements of BIS: 456-2000 is found to be suitable for making concrete. It is generally stated that water fit for drinking is fit for making concrete. For the present investigations, drinking water supply in project conducted area was used for making concrete.

Silica fume - is a very fine non-crystalline SiO₂, is a by-product of producing silicon metal or ferrosilicon alloys. It is made at a temperature of approximately 2000°C. It acts as an excellent pore-filling material. It can be used in proportions of 5-10% of cement content in a mix. Specific gravity of Silica fume is about 1.3 as compared to 3.15 for Ordinary Portland Cement (OPC). Depending on its chemical composition the specific gravity of silica fume varies from 1.3 to 1.4. The particle size range lies between 5.3µm – 1.8µm.

CONPLAST SP430 - For the present investigation, a super plasticizer by the name CONPLAST SP430 has been used for obtaining workable concrete at low w/b ratio. CONPLAST SP430 complies with BIS: 9103-1999 and BS: 5075-part3 and ASTM C494. Super plasticizer molecules and cement grains are oppositely charged and hence repel each other. This increases the mobility and hence makes the concrete flow. Super plasticizers enable savings in cement for a given strength and ideal for pumping concrete, casting heavily reinforced concrete members, and the precast elements of concrete.

III. MIX PROPORTION AND EXPERIMENTAL PROCEDURE

For ultra-high strength concrete the chosen grade of concrete was M100 and the mix design was made for suitable proportions based on the test results of the materials. The mix proportions used in this study was given in table-2. The same mix proportion was used for both dry and saturated aggregates.

Initially the specimens were casted using dry aggregates as control and then the specimens with coarse aggregates of 12 and 6mm by following the mix design. Then their mechanical properties such as compressive strength split tensile strength and flexural strength were tested for comparative study. For compressive test: The cube moulds of size 100mm x 100mm x 100mm were used for casting specimens. Nine specimens for each proportion were casted and it was kept in curing tanks. Similar to compressive strength, the splitting tensile strength of the specimens was tested. The specimens

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used were casted by using cylindrical moulds of dia.150mm and length 300mm. For flexural test prism of size 100mm x 100mm x 500mm was casted.

Table-2: mix proportions			
Materials	Mix - 1	Mix - 2	Mix - 3
	Quantity	Quantity	Quantity
Cement(kg/m ³)	450	630	810
Fine aggregate((kg/m ³)	797	715	616
Coarse Aggregate(kg/m ³)	1195	1073	923
Water(l/m ³)	90	126	162
Silica fume(kg/m ³)	50	70	90
Super plasticizer(l/m ³)	18	18	18
w/b ratio	0.18	0.18	0.18

IV. RESULTS AND DISCUSSION

During the curing periods of 3, 7 and 28days, three specimens for each curing period was tested for its compressive strength and their average compressive strength was shown in the table-3. From the table it was identified that the mix 3 has higher compressive strength than other mix proportions. The graphical representation of the test results were given in figure-1.

Table-3: compressive strength of dry coarse aggregate concrete				
S. No.	Mix	Average compressive strength (N/mm²)		
		3 days	7 days	28 days
1	1	18.966	34.008	58.86
2	2	22.236	38.586	65.4
3	3	24.198	41.856	70.632

The test results of concrete using saturated coarse aggregates of size 12mm and 6mm were given in table-4 and table-5 respectively. From the results it was known that the mix 3 was higher in compressive strength of both sizes of coarse aggregates. The graphical representation of the test results was given in the figure-2 and figure-3 for 12mm and 6mm size aggregates respectively.

Table-4: compressive strength of saturated aggregate concrete (12mm)				
S. No.	Mix	Average compressive strength (N/mm²)		
		3 days	7 days	28 days
1	1	44.472	64.092	87.636
2	2	47.088	69.324	94.176
3	3	52.320	75.864	104.64

Table-5: compressive strength of saturated aggregate concrete (6mm)				
S. No.	Mix	Average compressive strength (N/mm²)		
		3 days	7 days	28 days
1	1	48.396	71.94	98.1
2	2	53.628	77.172	104.64
3	3	57.552	83.712	116.412

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The split tensile strength test was conducted on UHSC cylinders at the age of 28 days and the results obtained are presented in Table 6. And it was found from figure-4 that the mix 3 gives best result for all dry and saturated aggregates concrete. The Young's modulus of elasticity test was also conducted on UHSC cylinders at the age of 28 days and the results obtained are presented in Table-7. Mix 3 was found to be higher modulus of elasticity value.

Table-6: split tensile strength of the concrete specimens				
Mix	Age of curing (days)	Average split tensile strength (N/mm ²)		
		Dry aggregate	12mm aggregate	6mm aggregate
Mix-1	28	3.981	5.739	6.29
Mix-2	28	4.28	6.294	6.85
Mix-3	28	4.814	6.850	7.22

Table-7: Modulus Elasticity of concrete				
Mix	Age of curing (days)	Modulus of elasticity (MPa)		
		Dry aggregate	12mm aggregate	6mm aggregate
Mix-1	28	31,321	46,256	49,516
Mix-2	28	33,230	49,115	51,143
Mix-3	28	34,429	51,550	53,945

Three standard prism specimens were casted for each mix proportions and tested under two-point loading. The experimental results of flexural strength with OPC mix case is shown in table-8 and their graphical representation by figure-6.

Table-8: Flexural strength of concrete				
Mix	Age of curing (days)	Average flexural strength (N/mm ²)		
		Dry aggregate	12mm aggregate	6mm aggregate
Mix-1	28	6.082	8.983	9.979
Mix-2	28	6.562	9.700	10.779
Mix-3	28	7.171	10.738	11.929

Finally the relationship between the split tensile against compressive strength K1, modulus of elasticity against compressive strength K2 and flexural strength against compressive strength K3 were calculated and tabulated in table-9.

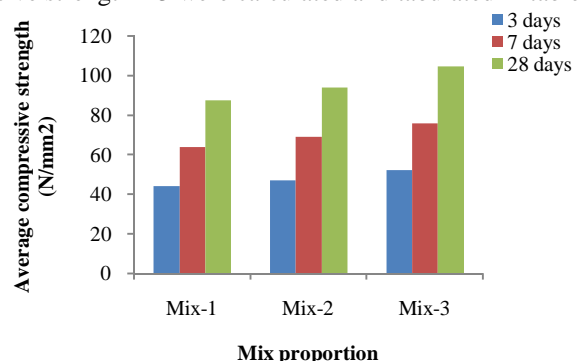
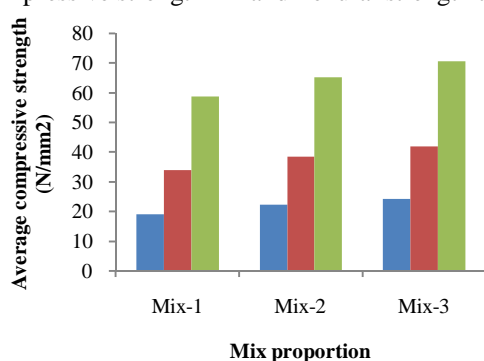


Fig-1: Compressive strength of dry coarse aggregate concrete

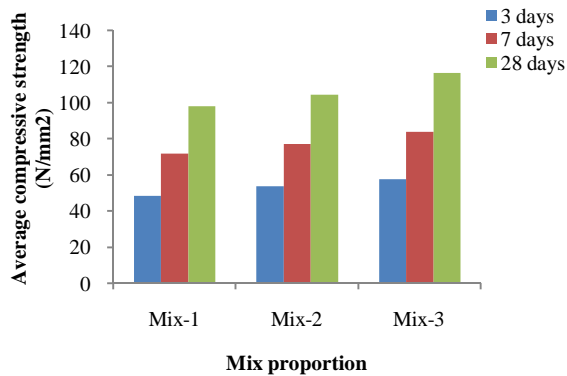


Fig-2: compressive strength of saturated aggregate concrete (12mm)

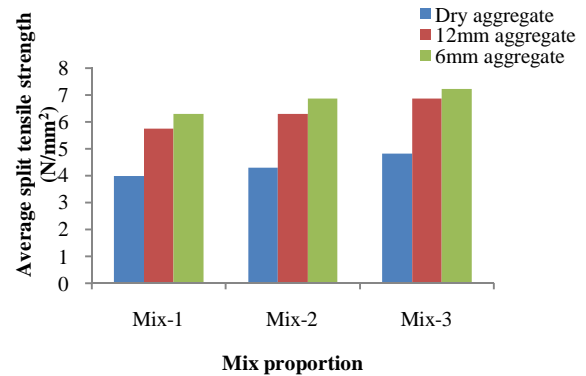


Fig-3: Compressive strength of saturated aggregate concrete (6mm)

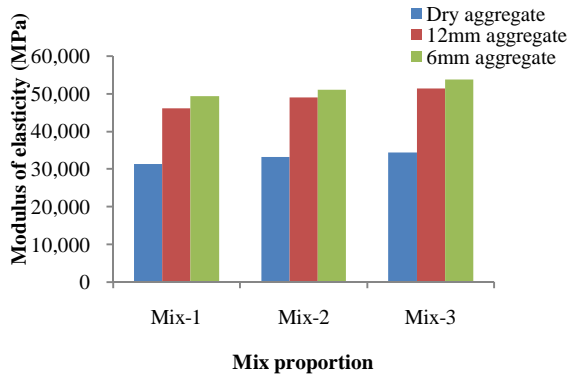


Fig-4: Split tensile strength of the concrete specimens

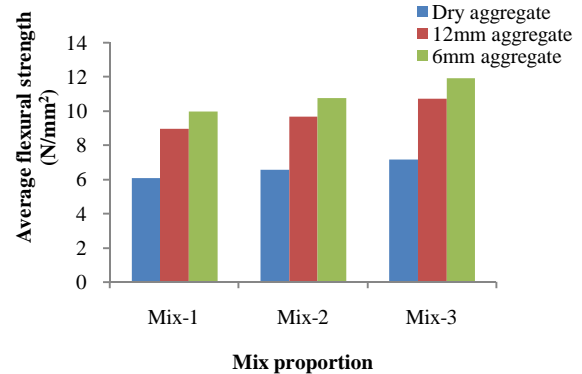


Fig-5: Modulus Elasticity of concrete

Fig-6: Flexural strength of concrete

Aggregate type	Proportion	K1	K2	K3
Dry aggregate	Mix 1	0.52	5129.9	0.1016
	Mix 2	0.53	5123.1	0.1020
	Mix 3	0.57	5118.7	0.1024
12mm size aggregate	Mix 1	0.61	4941.136	0.1025
	Mix 2	0.65	5061.09	0.1031
	Mix 3	0.67	5039.411	0.1026
6mm size aggregate	Mix 1	0.64	5063.938	0.1018
	Mix 2	0.67	5108.233	0.1031
	Mix 3	0.67	5139.841	0.1025

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(An ISO 3297: 2007 Certified Organization)

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V. CONCLUSION

In this project, an intensive study has been made on the development of Ultra-High Strength Concrete. Three different concrete mixes have been used to get Ultra-High Strength Concrete. Cubes, cylinders and prisms have been cast using this three different mixes and their properties in fresh and hardened states have been experimentally found out.

Based on the experimental investigation, the following conclusions could be drawn: Three different concrete mixes have been identified to get ultra-high strength based on cube (100mm size) compressive strength in the range 98.1 MPa to 116.4 MPa. Two grades of aggregates have been used namely, 6mm and 12mm. It is found that the concrete having 6mm aggregates gives 10.26% higher compressive strength, 2.97% higher split tensile strength, 6.94% higher modulus of elasticity and 10% higher flexural strength when compared to the concrete with 12mm aggregates. Two conditions of aggregates have been used, namely, dry and saturated aggregate. It is found that the concrete having saturated aggregates gives 38.9% higher compressive strength, 23.08% higher split tensile strength and 21.557% higher Modulus of elasticity when compared to the concrete with dry aggregates. The stress – strain curves of concrete obtained using these three types of mixes are linear up to failure. If the split tensile strength of concrete is taken in the form of $K1 \times \sqrt{\sigma_{cu}}$ for 6mm dry aggregate, then the value of K1 for concrete of compressive strength in the range 58 MPa to 70 MPa has been found to be equal to 0.52 to 0.57. If the split tensile strength of concrete is taken in the form of $K1 \times \sqrt{\sigma_{cu}}$ for 6mm saturated aggregate, then the value of K1 for concrete of compressive strength in the range 98.1 MPa to 116.4 MPa has been found to be equal 0.64 to 0.67. If the split tensile strength of concrete is taken in the form of $K1 \times \sqrt{\sigma_{cu}}$ for 12mm saturated aggregate, then the value of K1 for concrete of compressive strength in the range 87.6 MPa to 104.64 MPa has been found to be equal 0.61 to 0.67. If the modulus of elasticity of concrete is taken in the form of $K2 \times \sqrt{\sigma_{cu}}$ for 6mm dry aggregate, then the value of K2 for concrete of compressive strength in the range 58 MPa to 70 MPa has been found to be 5123.926. If the modulus of elasticity of concrete is taken in the form of $K2 \times \sqrt{\sigma_{cu}}$ for 6mm saturated aggregate, then the value of K2 for concrete of compressive strength in the range 98.1 MPa to 116.4 MPa has been found to be 5104. If the modulus of elasticity of concrete is taken in the form of $K2 \times \sqrt{\sigma_{cu}}$ for 12mm saturated aggregate, then the value of K2 for concrete of compressive strength in the range 87.6 MPa to 104.64 MPa has been found to be 5013.9. If the flexural strength of concrete is taken in the form of $K3 \times \sigma_{cu}$ for 6mm saturated aggregate, then the value of K3 for concrete of compressive strength in the range 98.1 MPa to 116.4 MPa has been found to be 0.1025. If the flexural strength of concrete is taken in the form of $K3 \times \sigma_{cu}$ for 12mm saturated aggregate, then the value of K3 for concrete of compressive strength in the range 87.6 MPa to 104.64 MPa has been found to be 0.1028. The flexural strength of the concrete is about 10% of cube compressive strength of concrete.

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