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"EXPERIMENTAL STUDY ON UHPC USING NANO SILICA, WASTE GLASS POWDER AND STEEL FIBERS"

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Abstract - *Ultra High-Performance Concrete (UHPC) is new type of technology in Concrete. UHPC process improved properties such as High strength, durability and stability for long term. UHPC is generally made using fine aggregates, coarse aggregates, very low amount of water and a high amount of cement. Low water content reduces workability of the fresh concrete; hence superplasticizers are used to maintain sufficient workability. The mechanical properties, ductility behavior and durability of UHPC is different from high strength & normal concrete due to the high packing density & materials used.*

This study provides the experimental analysis to extend the properties of Ultra high-performance Concrete by reducing the cement utilization. Thus, showing the effect of nano silica, Fine glass powder, GGBS, Silica fumes and Steel fibers on mechanical properties of UHPC. In this study cement replaced from0-40% by admixtures, the fraction of binder added within the range of 0-2% Nano silica, cement is replaced with 0-8% of fine glass powder with max particle size of 63 micron. A small amount of steel fibers added ranging from 0-1% by wt. of concrete result in increase in tensile strength and durability of concrete including other mechanical properties of UHPC. The Mechanical properties obtained from testing for 7day and 28days Compressive strength and split tensile strength. The study provides that addition of Nano silica improves packing density and high durability of UHPC with better mechanical properties.

Key Words: UHPC (Ultra-High-Performance Concrete), GGBS (Ground Granulated Blast Furnace), nS (Nano-Silica), W/C (Water-Cement). W/B (Water-Binder), OPC (Ordinary Portland Cement).

1. INTRODUCTION

The development of UHPC requires utilization of OPC in optimum quality by considering both workability and as well as strength. Change in cement content will cause fluctuation of compressive strength more. Following physical properties of cement required be used in UHPC.

1.1 Ultra-High-Performance Concrete

Ultra High-Performance Concrete is considered as new type in concrete technology. UHPC tends to have improved properties like High strength, long-term stability and durability. UHPC is usually made using fine aggregates, coarse aggregates, very low amount of water and high amount of cement. low water content reduces workability of the fresh concrete; hence superplasticizers are utilized to maintain sufficient workability. The mechanical properties, durability & ductility behavior of UHPC different from normal and high strength concretes because of the high packing density.

1.2 Aggregates

Coarse aggregate makes the most of concrete mixture. Natural gravel and crushed stones are mainly used for this purpose. Careful consideration must be given at the time of selection of coarse aggregates. High strength aggregates are not suitable for concrete because of their high modulus of elasticity as compared with the modulus of a cement paste, due to which contrary stress concentrations occur, which damages the concrete structure in mechanical behaviour. The aggregates presence in concrete increases the strength of concrete above that of cement, otherwise concrete is a brittle material and makes concrete a composite material.

1.3 Water

The acceptancy of water for UHPC isn't a serious problem if potable water is considered. The evolution of UHPC requires low w/b ratio within the range of 0.15 - 0.30, the workability of concrete is improved by the use of superplasticizer in it, for production of UHPC within the laboratory. Within the present study the w/c ratio of 0.26 has been considered. The strength of concrete increases with decrease in w/b ratio, there is adverse effect of w/b ratio on strength properties of concrete.

1.4 Admixtures

Concrete admixtures are natural or manufactured chemicals or additives added during concrete mixing to enhance specific properties of the fresh or hardened concrete, such as workability, durability, or early and final, strength. Accelerators, Retarders, Water-reducing agents, Super plasticizers, Air entraining agents etc. are the commonly used chemical admixtures. Fly-ash Blast-furnace slag, Silica fume and Rice husk Ash are the examples of mineral admixtures.

2. Literature Review

1) Yang Zhang et al. (2020) studied in order to further improve flexural and tensile strength as well as ductility of ultra-high-performance concrete (UHPC), this research developed an improved device for casting layered UHPC with better alignment of the fiber. The effect of fiber content (2% or 3%) and fiber type (straight fiber, end hooked fiber and combining the two fibers) on the flexural strength was first discussed. The optimal fiber content and fiber type were used to study the effect of fiber alignment on the mechanical performance of UHPC under flexural and direct tension loading. Through image analysis, the specific influence of fiber aligning on fiber orientation and dispersion in UHPC was analyzed in detail.

2) Mahsa Farzad et al. (2019) Ultra High-Performance Concrete (UHPC) has made progress in the bridge and building industry owing to its high strength, ductility, and durability. UHPC is a relatively expensive material and is mostly used in conjunction with conventional concrete. Such composite structures should be designed considering the interaction of different concrete layers. Generally, the simplest interaction model to simulate the complex behavior at the interface is 'tie' model, but simulation results may lead to an overestimation of load capacity.

3) Yuliarti Kusumawardaningsih et al. (2015) Ultra High-Performance Concrete (UHPC) is a new cement-based material developed in the era of modern concrete technology. The present of fiber in UHPC composition is necessary to increase strengths and durability, which then lead to name the material as Ultra High-Performance Fiber Reinforced Concrete (UHPFRC). However, the exact determination of UHPC and UHPFRC have challenges due to its very high compression strength. Some issues are the limited capability to purchase high load capacity testing machines, and the surface preparation requirement for cylinder specimens. In this study, three series of experimental programs were conducted to investigate the compressive strength of UHPC and UHPFRC using cylinder and cube specimens, and to determine its converting factors (ratio). The results show that the compressive strength relationships between specimens differ from those of conventional concrete.

4) Shamsad Ahmad et al. (2019) In the present study, ultra-high-performance concrete (UHPC) mixtures reinforced with varying dosage of steel fibers were considered for studying the effects of exposure duration and fiber content on mechanical properties of the mixtures subjected to a sustained pre-spalling elevated temperature of 300 °C for different durations. Test results showed an increase in compressive strength and modulus of toughness even after exposing to elevated temperature for 5 h. However, modulus of elasticity and flexural strength decreased significantly with increase in exposure duration.

3. METERIALS USED AND SPECIFICATION

Different Materials used in the study and their specification as follows:

3.1 Ordinary Portland Cement-53 Grade

Cement is the main component of the concrete that decides the strength characteristics. Hence, always based on the strength, the cement type and the quantity are decided. The various oxide composition in raw materials used in cement manufacture are Silica (Sio2), Alumina (Al2O3), Calcium oxide (CaO), Ferrous oxide (Fe2O3), Alkalis (K2O, Na2O), Magnesium oxide (MgO) etc., The properties of cement generally influence the properties of concrete. The cement adopted was OPC 53 grade cement.

3.2 Fine Aggregate

The acceptance of water for UHPC isn't a serious until potable water is considered. The evolution of UHPC requires low w/b ratio within the range of 0.15 - 0.30, the workability of concrete is improved by use of superplasticizer. For production of UHPC within the laboratory. In this study the w/c ratio of 0.26 has been considered. Due to the restrictions of govt. laws to mine river sand now a days M-sand is commonly used in construction, M-sand used in the study.

3.3 Coarse Aggregate

The aggregate having the size greater than 4.75 mm are known as Coarse aggregates, Following are the different types of coarse segregates crushed gravel or stones from crushing gravel or crushing hard stone & also the gravels obtained from natural disintegration of rocks. In general use of crushed stones or gravel results in greater strength of concrete due to interlocking property of angular aggregates while round aggregates improve workability due to less internal friction.

3.4 GGBS

GGBS or ground coarse furnace scoria may be a by-product of iron production. The furnace in iron production is incessantly charged with iron compound, fluxing stone and fuel, The two-product obtained from the chamber area unit liquid iron that collects within the bottom of the chamber and liquid iron blast-furnace scoria floating on the pool of liquid iron.

3.5 Waste Glass Powder

Waste glass is cursed and milled to get powder of small micro size particles, this is used for industrial use and can be used in concrete because of its pozzolanic reaction with cement by making secondary calcium silicate hydrate (CSH).

3.6 Silica Fumes

Silica fume is utilized in concrete as a substitution to cement, to check its effectiveness in development of UHPC, physical properties of silica fume are important in developing UHPC. The micro size of silica fume particles improves performance of concrete.

3.7 Nano-Silica

The colloidal silica is nano particles identical to silicon dioxide as quartz sand which is suspended in water or other medium. It's an amorphous substance unlike crystalline structure of quartz. these amorphous spherical particles of silicon dioxide suspended in water which are far smaller than size of Silica fume and alccofine particles. these particles possess greeter specific surface area which result in high packing density.

it's a white liquid or nano-particles it can be completely suspended in water which has no odour. The density of Nano-silica vary form 1.38 and has particle size of 1nm to 100nm.

3.8 Steel Fibers

Steel fibre concrete is the special type of concrete that formed by normal concrete mix with discontinuous discrete steel fibre. There are many small-scale fibres are distributing randomly during the concrete mix. the utilization of steel fibres within the concrete for interchange and reduce of normal reinforcement bar within the concrete members. Thus, steel fibre tends to extend the durability of the concrete thanks to deflection of micro cracks which develop within the concrete under external force and loading effects.

The dimensions of the steel fibres are kept small and short, this can be result in improvement in workability of concrete mix and to supply proper bonding with concrete. The steel fibres usually of 0 to 1% of the concrete is used.

4. Mix Design

Test Data of Materials

Grade of cement	OPC 53 grade
Specific gravity of cement	3.01
Specific gravity of Fine aggregate	2.64
Specific gravity of Coarse aggregate	2.73
Free surface moisture of coarse aggregate	nil

Selection of water content

As per IS:10262-2009 for nominal size of aggregates of 12.5 mm max water content is 186 l/m3 for 25-50mm slump for current study at 80-100mm slump water content is 160l/m3.

Calculation of cement content

The total cementaceous material calculated by dividing of Water content by the w/c ratio with water.

Mix proportions:

The w/c ratio of 0.26 was considered in the development of UHPC to have the desired results. For given w/c ratio, nine trial mixes of different proportion were made (i.e., T1, T2, T3, T4, T5) and actual mix with max strength (M1, M2, M3 & M4) and then for each of the mixes six cubes and six cylinders were cast to determine compressive strength and split tensile strength after 7 days and 28 days, respectively. The percentage variation of ingredients used in developing the UHPC is shown in Table below

Table -1: Mix Design without Steel Fibers

Trail Mix	GGBS %	Silica Fumes %	Nano Silica %	Glass Powder %	Total %
T1	10	10	0	0	20
T2	5	2.5	0.5	2	10
T3	10	5	1	4	20
T4	15	7.5	1.5	6	30
T5	20	10	2	8	40

Table -1: Mix Design with Steel Fibers

Mix	GGBS %	Silica Fumes %	Nano Silica %	Glass Powder %	Steel Fibers %
M1	15	7.5	1.5	6	0.25
M2	15	7.5	1.5	6	0.5
M3	15	7.5	1.5	6	0.75
M4	15	7.5	1.5	6	1

4. RESULTS

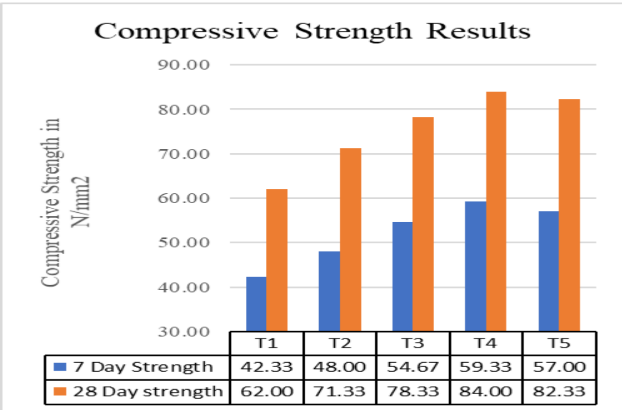

Chart -1: Compressive Strength Results

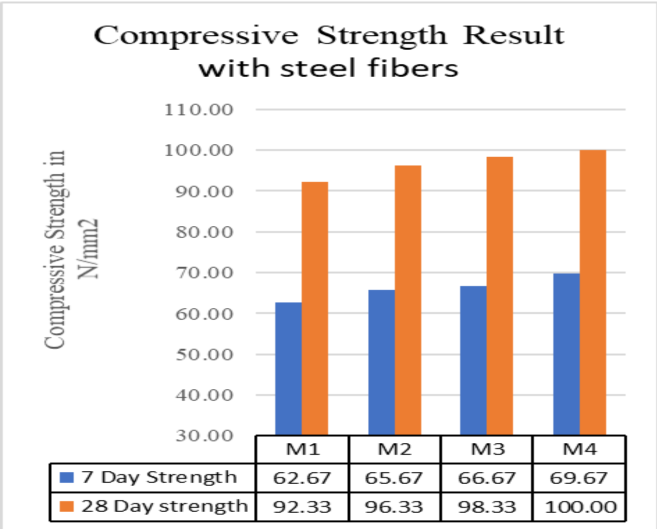

Chart -2: Compressive Strength Results with Steel fibers

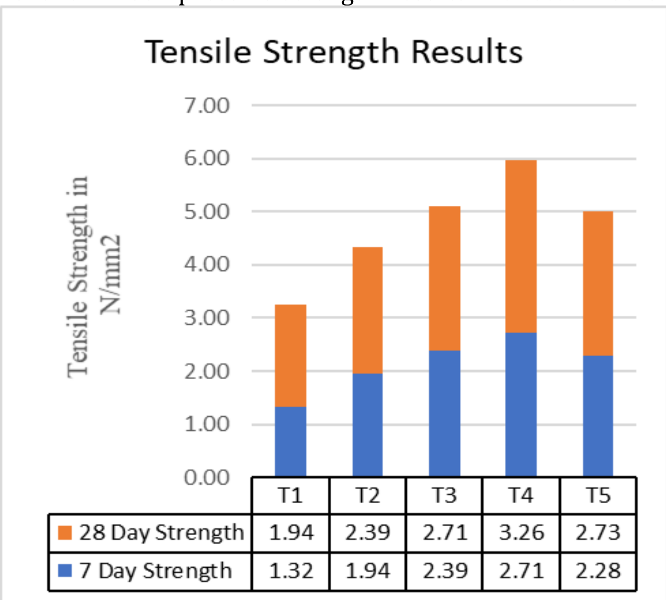

Chart -3: Tensile Strength Results

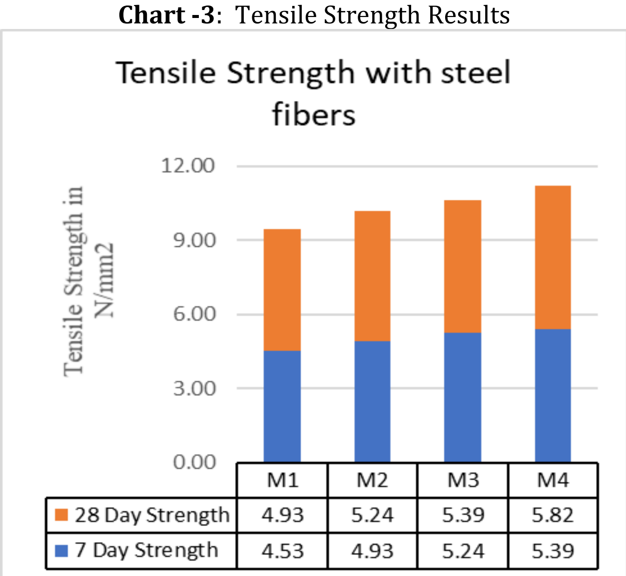

Chart -4: Tensile Strength Results with Steel fibers

4. CONCLUSIONS

- This study is to find the optimum dosage of admixtures in UHPC to obtain maximum strength with considerable w/c ratio of 0.26, The mix T4 gives the optimum strength and workability.
- The study shows that the optimum strength for UHPC obtained with Mix T4 and further Steel fibers are added to mix T4 from 0-1%.
- By adding Steel fibers in various proportion to mix T4 there is a sudden increase in strength properties for first two trails with 0.25% and 0.5%, further increase in steel fibers reduce the avg strength and workability of concrete.
- The addition of excess superplasticizer due to low w/c ratio, it slows down the hardening process and the use of Nano silica in UHPC result in early strength gain.
- Due to low w/c ratio concrete possess low workability hence excess amount of plasticizer is used.
- The study conducted without any special equipment's thus high strength achieve with conventional equipment's present at site.

5. Future Scope

- By using different admixtures in different proportions Development of even greater strength of 120MPa could be achieved in UHPC.
- The work can be extended by using other type of steel fibers or synthetic fibers and check their effect on strength properties of UHPC
- The work can be extended by analyzing the durability aspects of UHPC developed using the current mixes.
- To study can be extended on durability aspects of UHPC mixes.

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