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An experimental study on micro-structure and hardened properties of ultra-high strength self-compacting concrete by incorporating Graphene Oxide

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Abstract

The modern material in the rapidly expanding building sector is ultra high strength self-compacting concrete (UHSSC). There are several ways to make UHSSC, but one of the best ways is by employing graphene oxide to improve the microstructure of cement (GO). GO is a cutting-edge nanomaterial that excelled in a number of disciplines. This study examines the microstructure and toughened characteristics of UHSSC with GO incorporation. Improved GO dispersion in the concrete is achieved by using silica fume (10% cement weight), while better pore structure and resistance to chloride penetration are achieved by using GGBS (30% cement weight). To achieve UHSSC, GO is added to cement at concentrations of 0.25, 0.5, 0.75, 1.0, and 1.25% by weight of cement. EDS (Energy dispersive x-ray spectroscopy) technique is used to determine the crystalline properties of GO nanomaterial and SEM (Scanning electron microscope) is used to determine the microstructure of the GO incorporated UHSSC.

Keywords: Ultra-high strength, Micro-structure,Graphene oxide,Hardened Properties.

1. Introduction

A group of particles known as a nanomaterial is one whose minimum diameter is 100 nm. At this scale, special qualities predominate and have significant effects in the fields of construction, medicine, and other industries. Nano materials including In the construction sector, materials such as nanosilica, fullerene, carbon nanotubes, and graphene oxide are used. In this study, graphene oxide is used to make HSSCC by changing the microstructure of cement. When GO is added to cement, flower-like crystals consisting of cement hydrate and calcium silica hydrate gel start to form, which refines the pore structure. With an increase in GO concentration, cement's crystalline structure improves and its pore structure becomes more compact. Additionally, GO's filling impact in the transition zone, calcium silica hydrate nucleation, and cement and GO adhesion all contribute to cement's improved mechanical properties.

Concrete that self-compacts without any vibration under its own weight is known as self-compacting concrete. Its invention is genuinely astounding and represents a breakthrough in concrete technology. SCC is especially advantageous in densely reinforced structures that are constrained, in areas that vibrators cannot access, and complicated networks of form work that could otherwise make casting impractical. It also provides a surface that is significantly more exceptional than control mix concrete.

Due to attributes like durability and low maintenance costs, concrete is highly valued in the current construction sector. Although it has great tensile and compressive strength, its poor tensile strength makes it fragile in the absence of steel support. Experiments have been carried out to strengthen the tensile zone of the concrete. There have been attempts, such as adding silica fume, fly ash, glass fibres, steel fibres, etc. The strength qualities of all of these materials were enhanced, but they also had some disadvantages, such as drying shrinkage, temperature cracks, and a longer setting time, for instance. We can avoid these issues by changing the nanoscale or microstructure of cement. The correct nanoscale manipulation of the elements using nanomaterials affects the macro features and produces materialtheories lies in the handling of the number of unknowns. With the increase in the number of layers, the unknown increases which are difficult to evaluate. Thus, these theories are computationally inefficient for multi-layered structures." Another class of LWTs called as refined layerwise theory or zigzag theory.

In zigzag theories, the unknowns at each layer are defined with respect to unknowns at reference layer. This class of theory satisfies inter-laminar transverse shear stress continuity condition at interface along with zero value at top and bottom of plate. works available in

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literature pertaining used of higher-order zigzag theory (HOZT) for analysis of laminated composite plates under thermal conditions are [16-20].Noor and Burton [21,22] presented 3D solutions for studying buckling behavior of laminated composite plates under thermal conditions. Recently, Garg and Chalak [23] presented a detailed review on the analysis of laminated composite and sandwich plates under hygrothermal conditions.

In present work, buckling analysis of laminated composite plates is carried out by using recently proposed HOZT which includes transverse displacement field [24,25].

2. Materials used

The Different concrete materials to take the experimental programme to create UHSSCC are 53 Grade OPC Cement, GGBS, Silica Fume, Graphene Oxide, River sand, coarse aggregate and super plasticizers. Cement, Silica Fume and GGBS are used as micro fillers and Graphene Oxide is used to improve the microstructure of concrete.

3. Preparation of Graphene Oxide Nano material

The steps for preparing GO according to the modified Hummer's approach are as follows:

1. Following the first injection of 5g of graphite, 2g of sodium nitrate, and 30 ml of strong sulfuric acid, the conical flask containing the ice bath was placed on a magnetic stirrer for two hours.
2. The reaction mixture was stirred constantly for two hours, and then 5g of potassium permanganate was progressively added while maintaining a steady temperature in the ice bath. For another half hour, stirring was done. Since rising temperatures could lead to explosions, maintaining the temperature is crucial.
3. The mixture is removed from the ice bath and cooked on a magnetic stirrer with a hot plate for one and a half hours at 350 C.
4. After adding 100 cc of distilled water, the mixture was heated at 900C for an hour.
5. After that, the mixture was chilled to room temperature. 300 cc of distilled water was added after cooling, and the mixture was agitated using a magnetic device for 30 minutes.
6. After placing the flask on a magnetic stirrer for half an hour, 30 ml of hydrogen peroxide (30 percent H2O2) was added, forming graphene oxide with a pH of 1.
7. This solution was filtered, and 200 ml of 30% HCL was added to wash the metal ions into chloride ions in order to adjust the PH. This is cleaned several times with distilled water to get rid of the chloride contamination.
8. Add a few drops of filtrate to a solution of silver nitrate to see if all of the chloride ions have been eliminated; if no white colour appears, the chlorides have been completely removed.
9. To achieve dry GO powder in a brown colour, it was cleaned with 200 ml of ethanol in the final step.

4. EDS Testing of GO

Chemical composition of GO was identified by EDS testing of three batches of lab made GO Powder and the values are shown in Table.1 and analysis of GO is shown in Figure1

5. Dispersion

To prevent agglomeration and strengthen the bond between the nanomaterials and the binding phase of concrete, it is crucial to achieve good dispersion of these nanomaterials. No dispersing agents are used, which results in large aggloromates and bundles. Increased dispersion of nanomaterials inside the matrix phase and improved bonding have been demonstrated by using an efficient superplasticizer, ultrasonification, high speed mixing, and chemically functionalizing the surfaces of the nanomaterials.In our experiment, to prevent agglomeration GO was first sonicated with water and then the water was added while mixing concrete.

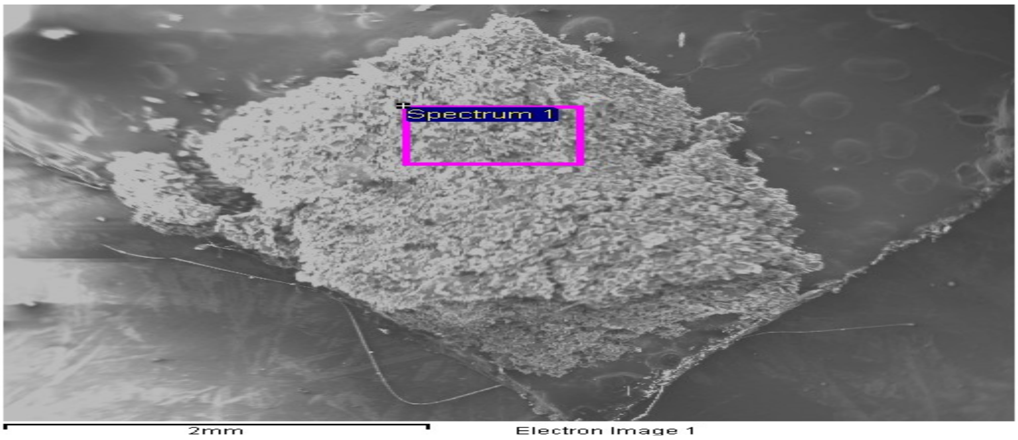

Figure. 1 EDS Testing image of Graphene Oxide

Table 1: Composition of Graphene Oxide

Chemical	C	O	Si	Al	S	Mg
G	95.57	5.65	0	0	0	0
GO	74.78	26.45	4.85	0.51	1.45	0.48

6. Experimental Investigation of UHSSCC with GO

The mix proportions for UHSSCC with GO are shown in Table 2. The mix designation Ultra High Strength Self Compacting Concrete (UHSSCC1) indicates specimenswithout GO. whereas UHSSCC2-HSHFSCC6 indicates the addition of GO to improve the strength properties of concrete

7. Micro structural Properties

The nucleation of cement hydrate and calcium silica hydrate (C-S-H) gel forms flower like crystals.

These Flower-like crystals refine the pore structure of cement. Initially concrete without GO has pores and has needle like structure. Whereas concrete with GO has dense matrix due to its flower like structure. The C-S-H gel shown in Figure.2 spreads and adheres to GO to form strong and impermeable concrete.

FE-SEM images of UHSSCC-5 and UHSSCC-1 are shown in figure.2

8. Fresh Properties

The different proportions of mixes of UHSSCC described as shown in Table 1 and verified the flow properties on the basis of EFNARC guidelines.

Fig 3, 4 and 5 represents the variation of spread, L-box ratio and V-flow with variation in GO dosage.

Table 2: Mix proportion of Ultra high strength self-compacting concrete

Mix Designation	Cement (kg/m^3)	Silica Fume (kg/m^3)	GGBS (kg/m^3)	GO % of powder content	FA (kg/m^3)	CA (kg/m^3)	Super Plasticizer% of Powder content	W/P ratio
UHSSCC 1	640	64	192	0	910	800	0.63	0.34
UHSSCC 2	640	64	192	0.25	910	800	0.63	0.34
UHSSCC 3	640	64	192	0.5	910	800	0.63	0.34
UHSSCC 4	640	64	192	0.75	910	800	0.63	0.34
UHSSCC 5	640	64	192	1.0	910	800	0.63	0.34
UHSSCC 6	640	64	192	1.25	910	800	0.63	0.34

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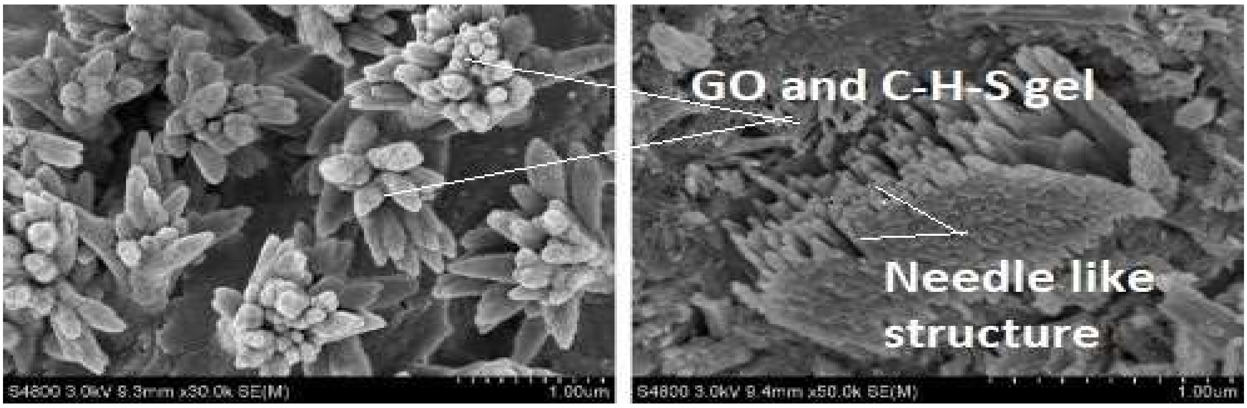

Figure. 2 Showing the FE-SEM of concrete with and without Graphene Oxide.

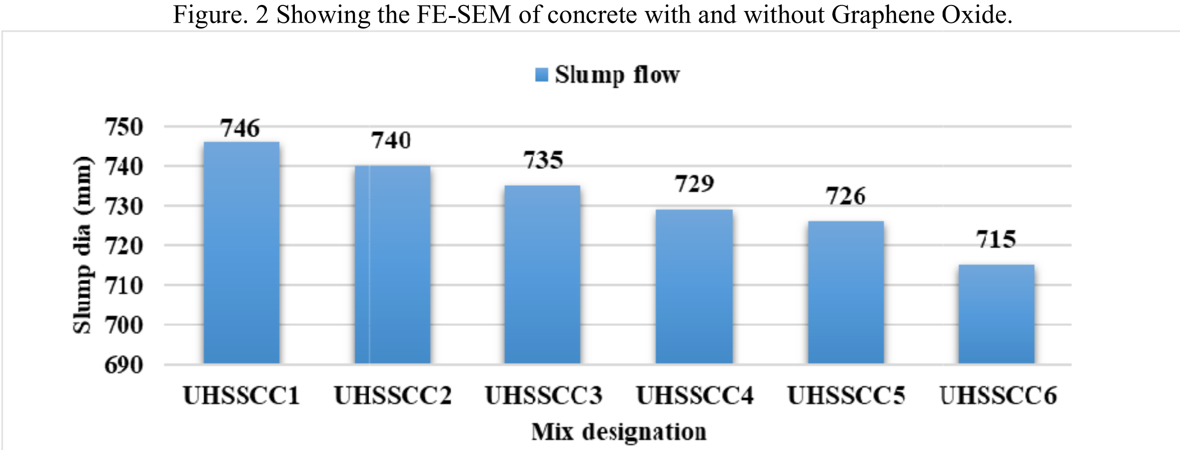

Figure. 3 Flow Values of Slump of UHSSCC1-UHSSCC6

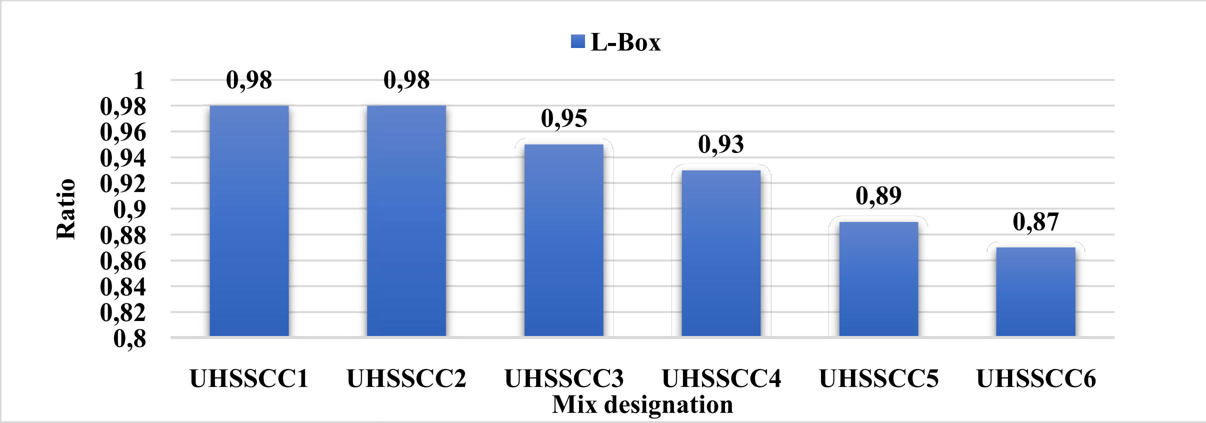

Figure. 4 Ratios of L-box of UHSSCC1-UHSSCC6

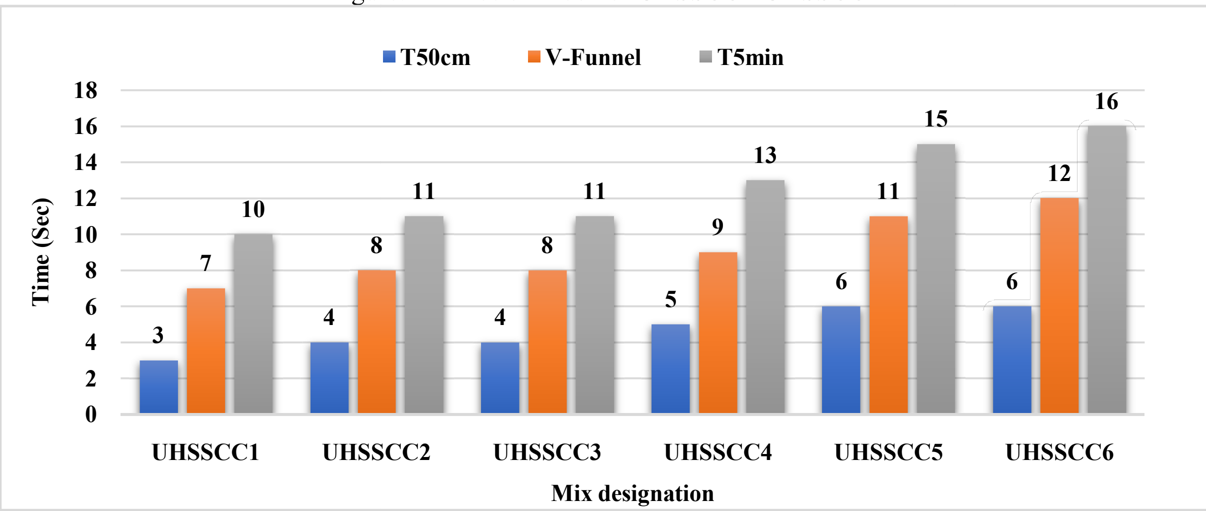

Figure. 5 Reading of time in T50cm, V-Funnel, V-Funnel T5min of UHSSCC1-UHSSCC6

9. Mechanical Properties

9.1. compressive strength

Compressive, split tensile, and flexural strength characteristics are determined, as stated in the previous articles.

Age and compressive strength details for various UHSSCC mix trails are shown in Fig. 6. A curing age of 7, 28, 56, and 90 days was determined. Fig. 7 displays the relationship between compressive strength at various ages and 7-day compressive strength for various GO dosages

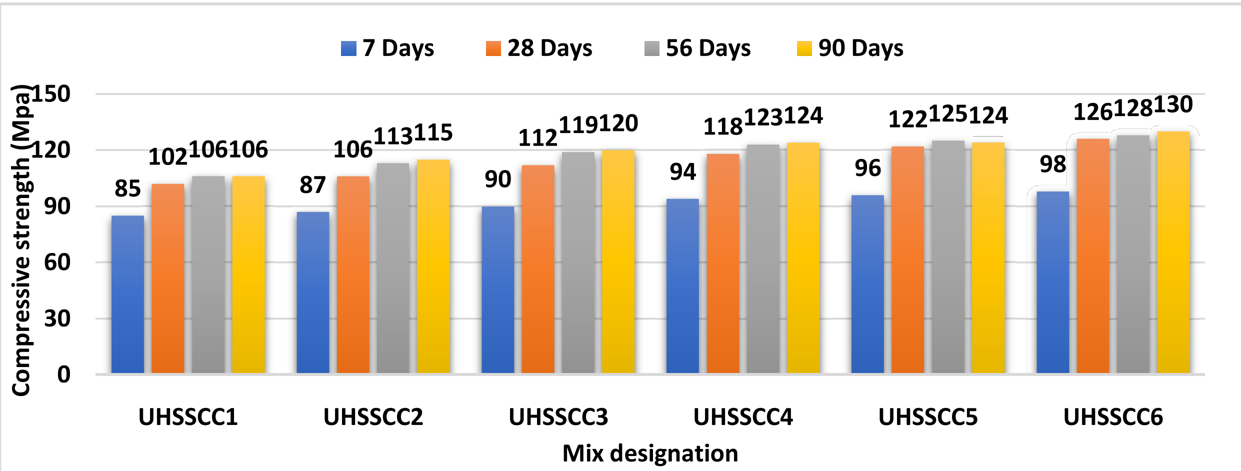

Figure. 6 Compressive Strength values of UHSSCC1-UHSSCC6

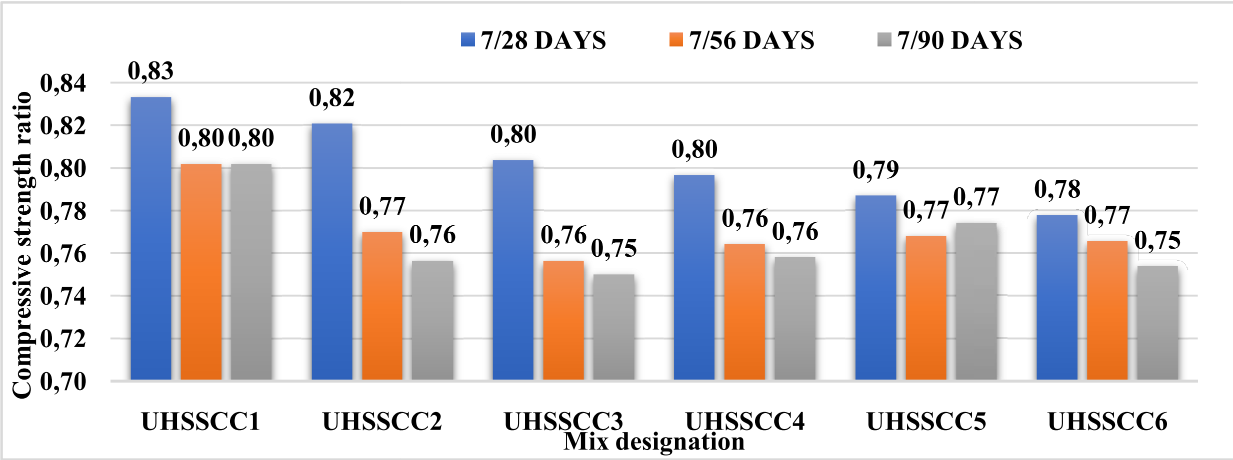

Figure. 7 Ratios of Compressive Strength of UHSSCC1-UHSSCC6

9.2. Split tensile strength

For various mixtures of UHSSCC and GO, Fig. 8 displays the relationship between age and split tensile strength. A curing age of 7, 28, 56, and 90 days was determined. Figure 9 explains the relationship between split tensile strength at various ages and 7-day compressive strength for various GO dosages.

9.3. Flexural strength

For various mixtures of UHSSCC with GO, the details of age vs. flexural strength are shown in Fig. 10. A curing age of 7, 28, 56, and 90 days was determined. Figure 11 demonstrates the relationship between 7-day compressive strength and flexural strength at various ages for various GO dosages

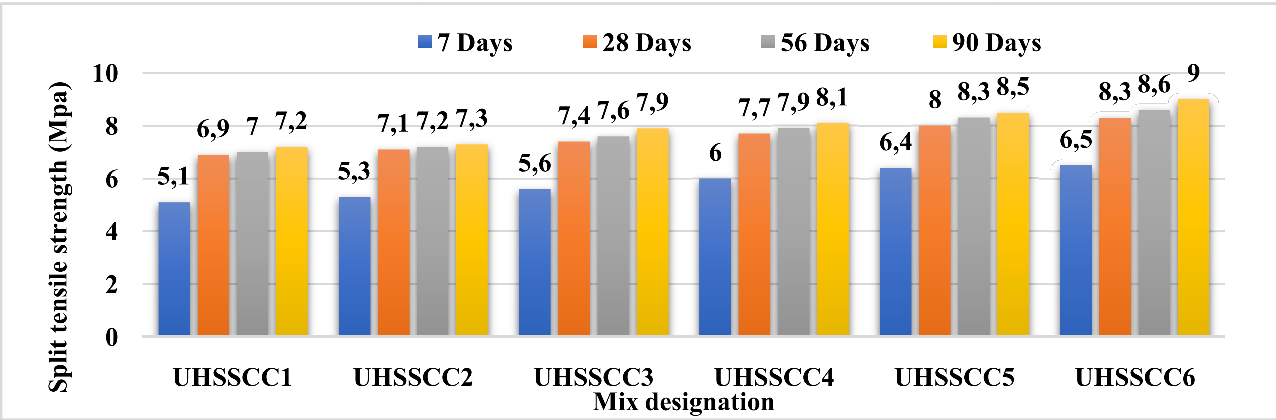

Figure. 8 Split tensile Strength of UHSSCC1-UHSSCC6

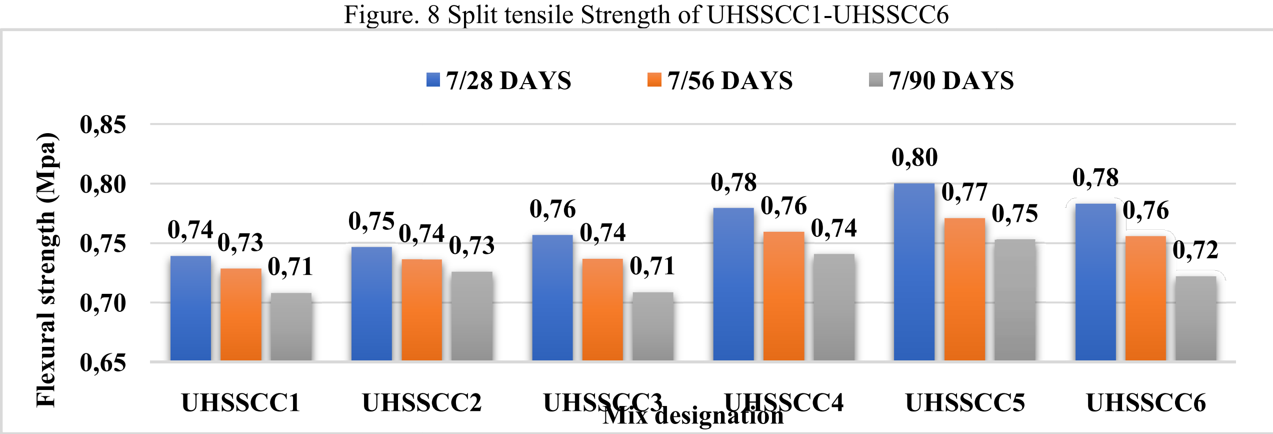

Figure. 9 Ratios Split Tensile Strength of UHSSCC1-UHSSCC6

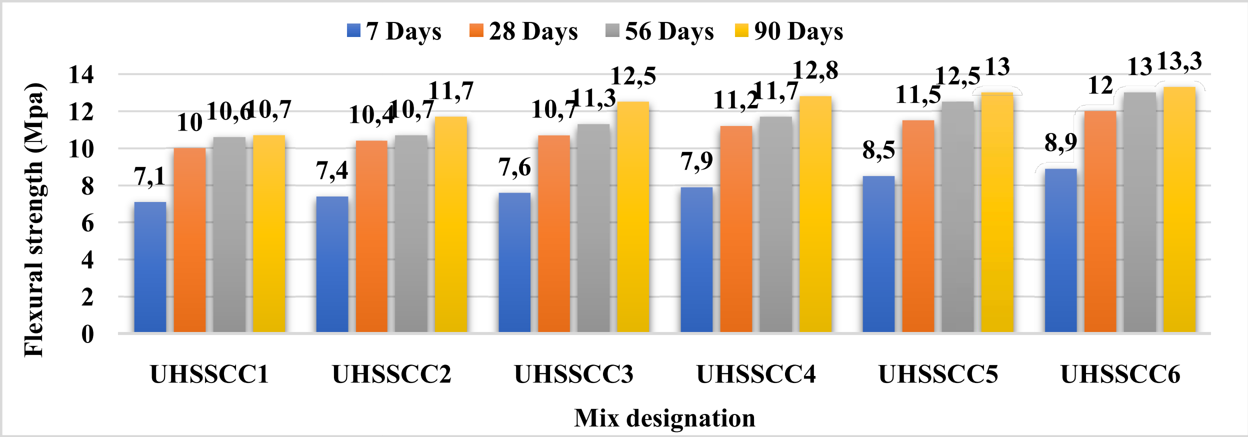

Figure. 10 Flexural Strength of UHSSCC1-UHSSCC6

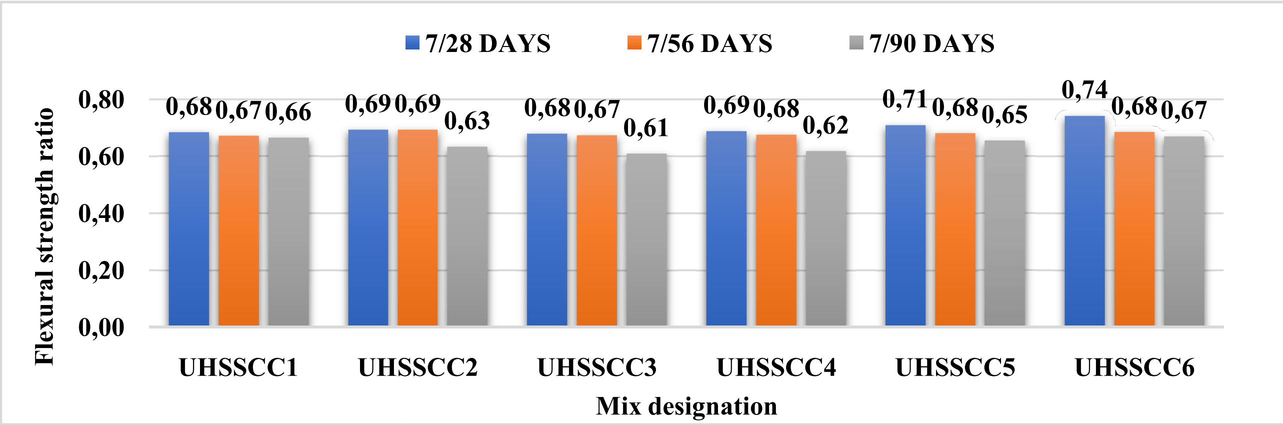

Fig. 11 Plot of Flexural Strength ratios of UHSSCC1-UHSSCC6

Figure.12 Compression Testing Machine

Figure.13 Split Tensile Test

Figure.14 Compression Testing Machine

10. Conclusion

1. Addition of GO decreased the workability, but there is an improvement in all the mechanical properties.
2. From a strength perspective, the ideal dosage of GO between 1.25 and 1.255 percent by weight of the total powder content. The fresh properties met the EFNARC Specifications at this percentage and were thus satisfied.
3. There is an increase in compressive strength of about 12.8%, 13.3%, 14.7% and 15.54% respectively at the end of 7, 28, 56 and 90 days in optimised GO mix (UHSSCC- 6) compared to no GO concrete (UHSSCC 1).
4. At the conclusion of 7 days, 28 days, 56 days, and 90 days, respectively, the Split Tensile strength is 21.18 percent, 19.42 percent, 22.86 percent, and 23.12 percent higher than the High Strength SCC.
5. When comparing the flexural strength of UHSSCC 6 and UHSSCC 1, it can be seen that UHSSCC 6 has increased by 17.6%, 18.46%, 23.41%, and 24.31% at the end of 7, 28, 56, and 90 days, respectively.
6.

Disclosures

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