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Design and durability aspect of hybrid fiber reinforced self-compacting concrete: A Review

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Abstract: Fiber Reinforced Self Compacting Concrete (FRSCC) is a type of concrete that combines the benefits of Self Compacting Concrete (SCC) with the added strength and durability of Fiber Reinforcement. FRSCC is designed as highly workable, having easy flow and able to fill all voids in the mould or formwork without applying external compaction. Durability is defined as the ability of a material to withstand the effects of weathering, chemical attack, and other environmental factors without significant deterioration over time. FRSCC has been shown to exhibit excellent durability due to its high density, low porosity, and resistance to cracking. The fiber reinforcement provides additional toughness and ductility, which helps to prevent cracking and improve durability. In this study, M35 grade of FRSCC is designed by adding hybrid steel fibers. The effect on mechanical properties and durability of FRSCC is checked with different hybrid steel fibers and with different proportion of fibers. It is found that, steel hybrid Fiber Reinforced Self Compacting Concrete is a promising material with excellent mechanical properties and durability. Its use in construction can lead to improved structural performance, increased safety and reduction in maintenance costs.

Keywords: Self compacting concrete, Hybrid fiber reinforced self compacting concrete, Hybrid fibers, Steel fibers

I. INTRODUCTION

In recent years, there has been growing interest in developing advanced concrete materials with enhanced properties to address the increasing demand for durable and sustainable infrastructure. One such innovative material is hybrid fiber reinforced Self Compacting Concrete (HFRSCC), which combines the benefits of both fiber reinforcement and self-compacting properties. HFRSCC is a type of concrete that contains a combination of different types of fibers, such as steel fibers, polymeric fibers, or a combination of both, along with self-compacting properties, making it a promising material for various structural applications.

The use of fibers in concrete has been proven to improve its mechanical properties, such as tensile strength, toughness, and durability. Fibers act as reinforcement by bridging cracks and preventing their propagation, resulting in improved resistance to cracking and improved post-cracking behavior. On the other hand, self-compacting concrete (SCC) is a highly flowable and non-segregating concrete that can easily fill intricate and congested reinforcement without the need for vibration, resulting in improved consolidation and reduced labor requirements during casting.

The combination of fibers and self-compacting properties in HFRSCC can result in a concrete material that exhibits superior mechanical performance, improved durability, and ease of placement compared to conventional concrete. This makes HFRSCC a potential solution for addressing challenges in structural applications, such as reducing crack formation, improving load-carrying capacity, enhancing durability, and minimizing maintenance costs.

This thesis aims to investigate the properties and behavior of HFRSCC, including its mechanical properties, fresh state properties, and durability performance. The research will involve experimental testing of HFRSCC specimens with varying fiber types, fiber dosages, and mix proportions to evaluate their mechanical properties, such as compressive strength, flexural strength, and toughness. The fresh state properties, including workability, passing ability, and filling ability, will also be assessed through various tests. Furthermore, the durability performance of HFRSCC, including resistance to cracking and freeze-thaw cycles, will be evaluated to understand its long-term performance and sustainability.

The findings of this research are expected to contribute to the knowledge and understanding of HFRSCC as an innovative material for structural applications. The results may provide insights into the optimal fiber types, fiber dosages, and mix proportions for HFRSCC to achieve desired mechanical properties and durability performance. The research outcomes

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may also have practical implications for the construction industry in adopting HFRSCC as a viable solution for improving the performance and durability of concrete structures, leading to more sustainable and resilient infrastructure.

II. LITERATURE REVIEW

Haddadou N et.al[6], [2014] had compare the properties of self-compacting concrete (SCC) and fiber-reinforced self-compacting concrete (FRSCC) with a high volume of mineral addition. Six different mixtures were prepared, with constant cementitious material content and water/cementitious material ratio. The SCC mixtures contained 30% cement replacement with marble powder, while two types of steel fibers with different lengths were used in the FRSCC mixtures, with a constant total fiber content of 60 kg/m3. The fresh properties of the mixtures were assessed using various tests, while the hardened properties were evaluated for compressive, splitting tensile, and flexural strengths, as well as ultrasonic pulse velocity. Although a marginal improvement in ultimate strength was observed, the addition of steel fibers significantly enhanced the ductility of the FRSCC. The study found that high-volume marble powder can be used to produce FRSCC, despite a decrease in compressive strength due to the fiber geometry affecting both the fresh and hardened state properties of SCC mixtures.

Mahakavi P. et.al[9], [2019] had analyzed an investigation into the properties of self-compacting concrete reinforced with a combination of hooked end and crimped steel fiber in varying fiber volumes. The study analyzed the fresh and hardened states of the concrete, using tests such as the slump flow diameter, T50cm, V-funnel, compressive strength, flexural strength, and impact resistance. Regression analysis was used to establish a correlation between the fresh and hardened properties of the concrete. The results indicated that the addition of hybrid hooked end and crimped steel fiber had a positive impact on compressive strength, flexural strength, and impact resistance. Hooked end steel fiber had a greater effect on compressive strength than crimped end fiber, while increasing the crimped fiber content reduced the impact of hooked end steel fiber on flexural strength.

Iqbal S. et.al[7], [2015] had investigate how to adding micro steel fibers to high strength lightweight self-compacting concrete (SHLSCC) affects its properties. By adding steel fibers to the concrete, it becomes more ductile, which can reduce additional loads, and the self-compacting nature of the concrete eliminates the need for vibrators during compaction. The study prepared five different concrete mixes with varying fiber contents (0%, 0.5%, 0.75%, 1%, and 1.25%) to examine changes in fresh and hardened properties. Workability was assessed through a slump flow test, while compressive strength, splitting tensile strength, modulus of elasticity, and flexural strength were tested for hardened concrete. The results showed that increasing the steel fiber content to 1% or more significantly affected the workability of SHLSCC. Additionally, increasing the steel fiber content from 0% to 1.25% resulted in a 12% reduction in compressive strength, a 37% increase in splitting tensile strength, a 110% increase in flexural strength, while the modulus of elasticity remained unchanged.

Cristina Frazao et.al[4], [2015] presents that the research on the durability of steel fiber reinforced self-compacting concrete (SFRSCC) is still limited, particularly in terms of corrosion resistance and its potential to cause cracking and spalling. Commonly used durability indicators for conventional concrete may not be applicable to SFRSCC, and their values are unknown. To address this, an experimental study was conducted on SFRSCC and self-compacting concrete (SCC) specimens to evaluate their mechanical properties and durability indicators. The results showed that adding steel fibers to SCC increased post-cracking flexural resistance and energy absorption without significantly affecting self-compacting requirements or durability indicators.

Maagorzata Pająka et.al[12], [2017] had conclude that adding steel fibers to SCC can improve its tensile properties by delaying the propagation of cracks. The use of fibers with different geometrical parameters can help prevent various types of cracks. This study examined the effects of combining straight and corrugated steel fibers with different lengths (6 mm and 35 mm) and cross-sectional shapes on the compressive strength and flexural behavior of SCC with fiber volume ratios ranging from 1.0% to 3.0%. The addition of hybrid fibers did not affect the workability of SCC but reduced its passing ability. Mixes with high fiber volume ratios did not meet the requirements for SCC. There was no significant difference in compressive strength between the fiber-reinforced and unreinforced SCC mixes. However, the flexural properties were significantly improved in the SCC mixes with hybrid fibers, and the proportion of the two types of fibers affected the results. Using high volumes of fibers did not result in further improvements in flexural properties.

Yehia Sherif et.al[16], [2016] explored the mechanical properties and durability of self-compacting concrete reinforced with steel, synthetic, and hybrid fibers, under early wet/dry cycles. The experimental program consisted of two phases, where Phase I involved tests on workability, mechanical properties, RCPT and SEM. The evaluation of mechanical properties included compressive, flexural and splitting tensile strengths, and modulus of elasticity. In Phase II, specimens

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were exposed to wet/dry cycles to investigate the effect of moisture on mechanical properties. All mixes achieved a cube compressive strength of 70 ± 5 MPa in Phase I. The exposure of Fiber-Reinforced Self-Compacting Concrete (FRSCC) to early wet/dry cycles resulted in an improvement in mechanical properties of all mixes, with a 10 MPa increase in compressive strength compared to non-exposed specimens. The microstructure of Synthetic Fiber-Reinforced Self-Compacting Concrete (SFRSCC) and Steel Fiber-Reinforced Self-Compacting Concrete (SFRSCC) differed, which explains the variation in their respective crack-resistance mechanisms.

Sahmaran Mustafa et.al[14], [2007] had present a study on the fresh and mechanical properties of a fiber reinforced self-compacting concrete incorporating high-volume fly ash that does not meet the fineness requirements of ASTM C 618. A polycarboxylic-based superplasticizer was used in combination with a viscosity modifying admixture. In mixtures containing fly ash, 50% of cement by weight was replaced with fly ash. Two different types of steel fibers were used in combination, keeping the total fiber content constant at 60 kg/m3. Slump flow time and diameter, V-funnel, and air content were performed to assess the fresh properties of the concrete. Compressive strength, splitting tensile strength, and ultrasonic pulse velocity of the concrete were determined for the hardened properties. The results indicated that high-volume coarse fly ash can be used to produce fiber reinforced self-compacting concrete, even though there is some reduction in the concrete strength because of the use of high-volume coarse fly ash.

Rafat Siddique et.al[15], [2016] had examine the properties of self-compacting concrete (SCC) produced using class F fly ash and hooked steel fibers, at varying volumes (0.5%, 1.0%, and 1.5%). The impact of these fibers on rheological (slump flow, V-funnel, L-box, U-box), strength (compressive, splitting tensile, and flexural), and permeation (porosity, rapid chloride permeability, and ultra-sonic pulse velocity) properties of the SCC specimens were investigated. The results indicate that the workability of SCC with 0.5% and 1.0% hooked steel fibers falls within the range prescribed by EFNARC, but decreases to some extent with increasing fiber volume fractions up to 1.5%. Other rheological characteristics, as prescribed by EFNARC and ACI 237 R, also decreased as fiber volume increased. The enhancement in properties of SCC was attributed to increased interfacial or bond strength of steel fibers and pore refinement by fly ash. Conversely, the properties of the concrete, such as compressive strength (from 34.6 to 38.5 N/mm2), splitting tensile strength (from 3.8 to 6.2 N/mm2), and flexural strength (from 5.5 to 8.2 N/mm2) at 28 days, were observed to improve with increasing fiber content. SCC mixes with steel fibers exhibited very low range charge passing (100–1000 Coulomb) in rapid chloride ion penetrability, an increase in porosity from 9.3% to 9.9%, and a decrease in ultra-sonic pulse velocity of about 17% at 28 days with increasing steel fiber volume in SCC mixes.

Clifford A.O. Okeh et.al[11], [2019] had conclude that the addition of steel fibers with different aspect ratios, including innovative macro hooked ends steel fibers with multiple hooks and longer length, has been found to improve the response of concrete to cracking. A recent study has shown that these new macro hooked ends steel fibers outperform traditional single hooked ends steel fibers when used in self-compacting concrete. To investigate the stress-strain curve relationship of this composite material, a laboratory experiment was conducted to compare two different conditions of steel fiber hybridization using straight micro steel fiber and two types of hooked ends macro steel fibers with single and double hooks. The results indicate that steel fiber hybridization reduced workability, but the use of single hook macro steel fiber improved material properties compared to using only macro hooked end steel fiber, including compressive strength, tensile strength, and fracture energy. However, the use of double hook macro hooked end steel fiber resulted in a decrease in fracture energy, despite positive results for other properties.

III. MAJOR INFERENCES

It was observed that no testing or analysis has been carried out on the use of steel fibers with Hooked ends and round crimped shapes, having an aspect ratio (length/diameter) of 50, in reinforced concrete structures using self-compacting concrete (SCC). Recent developments in structural health monitoring, such as smart sensors, have enormous potential.

CONCLUSION

The addition of hybrid steel fibers, can significantly improve the mechanical properties of self-compacting concrete, such as Compressive strength, flexural strength, and impact resistance. It is observed that, the addition of fibers improves the compressive strength of the concrete, but it still experiences a significant reduction in strength when subjected to high temperatures.

Durability aspects, such as residual strength, can also be improved with the addition of hybrid fibers. However, the effect of fibers on durability may depend on the fiber type, dosage, and the sustained elevated temperature of the oven. The use of hybrid fiber reinforced self-compacting concrete can lead to more sustainable and durable concrete structures, which may have a longer service life and lower maintenance costs.

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