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Preparation and Engineering properties of Slurry Infiltrated Fibrous Concrete (SIFCON) :A Review

LUMA A. ZGHAIR[1,*] , SALWA R. AL-TAA[1] , SUHA RASHEED ABBAS[1]

[1]Civil Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

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ABSTRACT

This paper discusses the preparation of Slurry Infiltrated Fibrous Concrete (SIFCON) and its important characteristics. Previous studies have shown that SIFCON has improved ductility, strength, and durability. The paper also highlights different materials that can replace cement, such as silica fume and fly ash, and different percentages of steel fibers of over 4% can be used. Many previous investigations have shown that there is a significant relationship between the strength of concrete and the mortar and fiber mixture used in terms of size and type. It has also been found that when using an amount exceeding 5% of fibers, certain steps should be followed in casting concrete specimens. These steps include using fine sand less than 1 mm in size to create suitable cement slurry and replacing up to 30% of the cement with pozzolana material to create cement slurry that can penetrate and interlock with fibers of all forms and volumes. Finally, The research offers a concise overview of Slurry Infiltrated Fibrous Concrete properties and their significance, in addition analyzed the impact of fiber quantity increase on the density and various properties of concrete, including its compressive and tensile strength, as well as energy absorption. Additionally, [illegible] esponds to external elements like exposure to sulfate attack, acids, and fire.

1. Introduction

Concrete is a strong material in compression but weak in tension. Therefore, its use as a structural member is limited when it comes to tension loads and strain. Reinforcing bars and other connected reinforced concrete (RC) parts control concrete drying shrinkage in (RC) constructions. This causes a tensile stress in the concrete that causes cracking and lessens the RC members structural rigidity [1] However, studies have proven that the use of fibers can significantly enhance concrete's tensile strength and reduce the occurrence of cracks in concrete. Steel fiber is now the primary material used to strengthen concrete and solve the brittleness issue. [2][3][4][5].

Regardless of the different types of fibers used, their use improves the strength of concrete in terms of shear capacity. [6] In general, the tensile strength is improved, the crack width and spacing are reduced, and the fatigue life is also improved [7]the toughness of the concrete is also improved [8] However, if a higher percentage of fibers is added, it can cause separation and balling in the concrete and mortar [9] When the fiber content exceeds 2 percent, the process of

[*] Corresponding author E-mail address: drlumacivileng@uomustansiryah iq.edq
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mixing and pouring concrete becomes difficult or maybe impossible. [10]SIFCON concrete can be considered high-performance concrete and a special type of concrete reinforced with steel fibers reinforced concrete. (SFRC)[11]. Several researchers have proven that using SIFCON concrete with a high volume fraction of more than 4% can improve its mechanical properties [12][13][14][15]

2. Significance of research

The primary aim of this study is to assess and analyse recent experimental findings in the field of slurry-infiltrated fibrous concrete (SIFCON). The study concentrates on the materials utilized in SIFCON, the recipe design, and the methods of preparation. Furthermore, it highlights the key characteristics of SIFCON, which significantly impact the structural behaviour and durability of concrete when exposed to harsh environmental conditions.

3. Preparation of the Mould

The process of manufacturing SICON (or concrete containing high percentages of fibers greater than 4) differs from concrete with lower fiber percentages. The production process involves three steps. First, the fibers are pre-placed in the mold. Second, a cement mortar is made using fine sand, cement, and pozzolanic materials, with the addition of water and superplasticizer. Finally, the mortar is poured into the mold. [16][17]

4. Constituent materials and mix proportions

4.1. Matrix

The primary components of SIFCON are steel fibers and either cement mortar or pure cement. Admixtures such as silica fume or fly ash can be used with cement, and bottom ash is also an option [18]. To create SIFCON, it is recommended to use a sand-to-cement ratio of 1:1, 1:1.5, or 1:2. You may also add fly ash and silica fume, but not exceeding 10% to 15% of the cement weight. The sand used should be fine enough to pass through a sieve size 1 or smaller to ensure complete infiltration into the steel fiber matrix. [19] . The water to cement ratio in SIFCON concrete should be maintained between 0.3 and 0.4, whereas the superplasticizer ratio should range from 2 to 5% of the weight of cement. The percentage of fiber in the concrete can vary from 4 to 20% [20].It is worth noting that some researchers have experimented with using waste fibers recovered from scrap tires to produce SIFCON concrete. [21] Some researchers have utilized discarded tire rubber as a substitute for fine aggregate in order to create SIFCON concrete [22] . Table 1 shows some mixture ratios from previous research

Table 1. Some special mixtures for SIFCON mortar from previous studies

.

Researchers	Cement Kg/m3	Find sand Kg/m3	w/c ratio or w/b	Slica fume	Slag	Metakaolin	*SP% Kg/m^3
Abbas and Mosheer 2023[14]	850	850	0.29				12.5
Naser and Abeer [2020][23]	886	886	0.31				1.76%
Hameed DH et al. 2020[24]	900	900	0.3				1.6
Alrubaie, M. F. et al. 2019[25]	900	900	0.4	470			1
B. Abdollahi et al 2014[26]	900	700	0.3	270			3.5%
Gilani, A. M. 2007[27]	885.1	885.1	0.4				10.6
Alrubaie et al 2020[28]	799.5	885	0.32			85.5	1.2
Salih, S. A. 2018[29]	796.5	885	0.3	88.5			2.4
Shelorkar and Jadhao (2019)[30]	678.57	714.28	0.4	35.71			-
Elavarasi D., 2017[31]	70	100			30		0.4

*Not: superplasticizer percentage or in Kg/m^3

5. Engineering characteristics of SIFCON

In the next subsection, we will be discussing the characteristics of infiltrated fibrous concrete (SIFCON).

5.1. Density

Due to its high fiber content, SIFCON concrete typically has a higher unit weight than conventional concrete and regular fibre reinforced concrete FRC. [32]

A study was conducted on the production of modified-weight SIFCON concrete. [33] Different mixtures of fibers were used, including micro and macro steel fibers as well as polypropylene fiber. Various percentages (3%, 4% and 7%) for micro steel fibres, macro hooked end steel fibres and polypropylene fibres respectively were also tested. The results indicated that using twisted steel fibers with propylene and hook-end steel fibers achieved good density (18.66 KN/m3) while maintaining acceptable flexural strength (8.09MPa).

5.2. Flexural , splitting and Compressive strength of SIFCON

Various factors can impact the strength of SIFCON, such as the strength of the slurry, the type of fibers used, and their alignment and volume. [34] Studies have shown that increasing the percentage of fibers added to concrete mixtures results in increased compressive strength.[15][35] .Other researchers have found that there is an increase in strength up to a certain percentage of steel fibers.as shown in figure 1

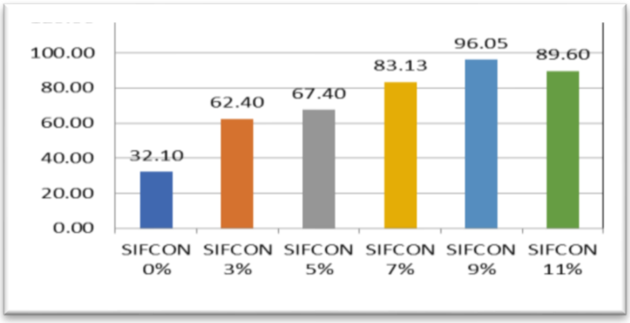

Figure 1 effect of different percentage of fiber on 28 days compressive strength [36]

Vijayakumar and Kumar[37] used different ratios of straight stainless steel fibers, ranging from 5% to 12%. The use of these fibers enhances the ductility and strength of the concrete.

Aravind[38] conducted a study on the behavior of Slurry Infiltrated Fibrous Concrete reinforced concrete - reinforced cement concrete (SIFCON-RCC) composite beams in a flexural test. The results showed that the mixtures containing SIFCON performed better in terms of strength when compared to models containing reinforced cement concrete (RCC). Additionally, Aravind mentioned that using a composite package with 40% SIFCON can reduce costs without compromising strength.

Ipek and Aksu [39] conducted a study to investigate the impact of using a combination of propylene and filament fibers in varying proportions on the bending strength. The study revealed that incorporating steel fibers with lengths of 60 mm and 35 mm, as well as mixing 60 mm steel fibers with 50 mm propylene fibers, led to a significant improvement in the flexural strength.

Jain, and Kumar [40] conducted a study to investigate the impact of different percentages of iron fibers (ranging from 3% to 9%) on the production of SIFON. They also partially replaced cement with slag at rates ranging from 0% to 30% of the weight of cement. To make the concrete mixture, they used a combination of 60% river sand and 40% stone dust as fine aggregate. The results of the study showed that the optimal percentage of fiber was 6% and that cement could be replaced with up to 20% of slag without significantly reducing the flexural strength of the concrete.

5.3 Toughness and impact load of SIFCON

SIFCON is a new type of building material that has a high absorption energy capacity due to its fiber content exceeding 4%. Rao et al., [41] conducted a study comparing the performance of SIFCON concrete slabs to concrete containing fibers, reinforced concrete, and concrete without fibers. The findings revealed that SIFCON concrete slabs that contained 12% fiber content had the most outstanding performance in energy absorption compared to the other slabs.

Farnam et al. [42] conducted an experiment where they used varying percentages of steel fibers (0%, 2%, 5%, and 10%) to create three different types of concrete: high strength concrete (HSC), High performance reinforced concrete (HPFRC), and SIFCON. The goal was to analyze the failure modes and criteria for each type of concrete. The study found that there was an increase in the peak stress, energy absorption, Poisson's ratio, and toughness for all three concrete

In their study, Yazıcı et al. (43) utilized grade C fly ash to produce SFCON. The study incorporated a high percentage of fly ash, which constituted 60% of the weight of cement, and three different percentages of fibers (2%, 6%, and 10%). The results of the study revealed a significant improvement in flexural strength and toughness, especially at the 10% fiber percentage, which mainly consisted of steel fibers.

5.4 Durability of SIFCON

Civil engineering plays a crucial role in safeguarding buildings from environmental factors and enhancing their durability characteristics. It should be able to cope with sudden abnormal loads and resist acid and sulfate attacks. [44]

A research study was conducted to investigate the impact of temperature on the flexural test of SIFCON. The models were subjected to increasing temperatures ranging from 300 to 900 degrees. The findings indicated an enhancement in mechanical performance at a temperature of 300 degrees. However, when the temperature was increased beyond 300 degrees, high temperature caused the steel fibers to lose their cross-section and the calcium silicate hydrates (C-S-H) structure to be destroyed. The results of the mechanical tests were consistent with the microstructural analysis. [45]

In a study conducted by Ali et al. [46], the impact of temperatures ranging from 200 to 600 degrees Celsius on the properties of SIFCON and ordinary concrete was investigated. Three different percentages of fibers (5%, 7.5%, and 10%) were used, and the samples underwent standard and rapid processing. The results indicated that increasing the temperature above 200 degrees Celsius led to a significant reduction in the compressive strength for both ordinary and SIFCON mixtures that contained 5% fiber. However, the compressive strength of the mixtures containing 7.5% and 10% fiber increased. It was also observed that higher percentages of steel fibers helped to prevent spalling of concrete, making SIFCON a unique material for resisting explosive loads.

Y. Aygormez et al. [47] conducted a study on the impact of using fly ash and metakaolin with white cement to produce SIFCON concrete. The addition ratio of fly ash and metakaolin was 50% and 25%, respectively as a partial replacement of the cement , and the fiber addition ratio was 5%. The researchers exposed the concrete to temperatures ranging from 200 to 600, and examined the effect of increasing temperatures on mechanical properties such as bending, compressive strength, weight loss, and UVP. The results showed that the concrete gained resistance at a temperature of 300 degrees Celsius. However, with continued exposure to heat, the resistance decreased as it approached 600 degrees Celsius. The researchers also found that replacing 25 percent of cement with metakaolin improved the mechanical properties and durability of the concrete.

Patil and Jayant [48] conducted a study to investigate the impact of magnesium sulphate on SIFCON concrete. They used hooked-ended steel fibers in their study and added three different percentages of fly ash: 5%, 10%, and 15%. After 28 days, the results showed a decrease in compressive strength of the concrete.

Hashim and Al-Shathr [49] conducted a study on the bending behavior of modified fiber concrete (SIFCON) panels after being exposed to high temperatures. The research used eight modified SIFCON panels, which contained rubber powder waste as a partial replacement for the used sand (0%, 5%, 10%, 15%). Four samples were exposed to fire for two hours at a constant temperature of 600°C, and then quickly cooled by spraying them with water. The study revealed that an increase in the ductility factor was observed, as well as an increase in both service and ultimate deflection, after increasing rubber powder content in fired and unburned modified samples.

Mays et al. [50] conducted a study on the impact of acid rain exposure on the mechanical properties of static concrete. They used metakaolin, anti-corrosion additives, and epoxy coating to enhance the concrete mixtures' performance when exposed to acid rain. The study also included using different percentages of fibers (1.5%, 6%, 8%, and 10%) to create SIFCON concrete. The research findings indicate that the concrete mixtures continued to develop strength even after being exposed to acid rain for 180 days. Furthermore, the treated mixtures demonstrated greater durability compared to untreated mixtures. Overall, the study showed that steel fibers reduce electrical resistance even before being exposed to acid.

6. Conclusion

1. SIFCON concrete is a special type of concrete that is reinforced with steel fibers, and is considered to be a high-performance concrete. In comparison to other concretes that contain fibers, the process of manufacturing SIFCON concrete is different
2. Due to the use of higher percentages of fibers. These percentages are typically higher than 4, which is a significant difference from concrete mixtures containing lower percentages of fibers.
3. To produce SIFCON, it is preferable to use a sand to cement ratio of 1:1, 1:1.5, or 1:2, with the possibility of adding fly ash and silica fume
4. Waste fibers that are recovered from scrap tires can be utilized to produce a type of concrete known as SIFCON.
5. Due to its high fiber content, SIFCON concrete usually has a higher unit weight compared to conventional and regular FRC.
6. Several factors can affect the strength of SIFCON, including the slurry strength, fiber volume, alignment, and types. These factors significantly affect the strength of SIFCON samples.
7. Researchers have demonstrated that the incorporation of steel fibers in concrete enhances its strength up to a certain percentage.
8. There was a significant decrease in compressive strength for ordinary and SIFCO mixtures containing 5% fiber when temperatures increased above 200. However, mixtures containing 7.5% and 10% fiber showed an improvement in compressive strength.
9. SIFCON concrete, which contains 12% fibers, has superior energy absorption performance compared to other types of concrete.

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