Jurnal Kejuruteraan 36(1) 2024: 155-167
https://doi.org/10.17576/jkukm-2024-36(1)-15

# Slurry Infiltrated Fiber Concrete Properties: A Review

Esraa Kh. Abuzaid[a,b*], S.A. Osman[b] , Azrul Bin Amutalib[b] & Salah R. Al Zaidee[b]

[a]*Department of Highway and Transportation Engineering, Mustansiriyah University, Baghdad, Iraq*
[b]*Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia*

[*]*Corresponding author: p114746@siswa.ukm.edu.my*

*Received 8 January 2023, Received in revised form 18 June 2023*
*Accepted 18 July 2023, Available online 30 January 2024*

ABSTRACT

*"Slurry infiltrated fibrous concrete" refers to a contemporary, high performing fiber-reinforced concrete and infiltrated with a specially designed fiber bed, cement-based slurry. The material has excellent mechanical properties along with high durability and ductility. The SIFCON Laboratory's research revealed SIFCON to be a unique building material with improved abilities to absorb energy and resist impact, as well as greater ductility and strength. With all these qualities, SIFCON can repair and fortify both reinforced and unreinforced concrete structures. Ductility is currently one of concrete's most critical characteristics. The issue of brittleness with concrete has been solved by utilizing a high volume of fibers instead of coarse aggregate, which provides stress-resistant properties and increases the ductility of the structural component. However, due to the placement and mixing challenges because of the high volume of fibers' interlocking action, there is a necessity to design unique production techniques. Since SIFCON compounds are a novel trend in the fields of areas of civil engineering that have a catalytic effect, it is necessary to highlight the few studies that included it so this review paper discusses and presents the behavior of SIFCON under various external loads. The focus is on the effects of the SIFCON mortar type—which substitutes silica fume and/or fly ash for cement—and fiber type—which uses hooked end fiber and micro steel fiber—are the main topic of discussion. The mechanical characteristics and optimal percentages are also reviewed. All previous studies are noted and summaries are made in comprehensive tables, which display the studied parameters and SIFCON mortar mix ratios. In addition to indicating research gaps, for example, future work in this field needs to focus on developing a detailed analytical model that requires the ability to calculate these factors. A better understanding of the SIFCON's features can serve as a theoretical foundation for future research projects and engineering applications for creating concrete materials for the construction industry.*

*Keywords: SIFCON; hybrid concrete; splitting tensile strength; compressive strength; strengthening of concrete*

## INTRODUCTION

Concrete is a substance that is frequently utilized in the world of building. Essentially, it is a mixture of aggregates, water, and a binder, such as lime, cement, etc. (Arain et al. 2022). However, RC upkeep necessitates a number of financial expenses. Due to heavy mechanical loads and environmental changes, they age and experience function degradation, which reduces their durability, sustainability, and serviceability. Thus, it is necessary to strengthen many degraded RCs in order to reduce maintenance costs and lengthen service life (Dawood and Taher 2021).

Various methods and materials have been proposed in recent decades to repair existing RCs. The most popular retrofitting methods include wrapping in "fiber-reinforced polymer" (FRP), steel or concrete jacketing, reinforcing composite materials with fiber, near-surface mounting, and external pre-stressing. According to literature findings, these techniques have several drawbacks despite being proven to effectively strengthen the targets and increase strength and durability. These drawbacks include the interface ageing of the adhesion materials during FRP reinforcing, being fire resistant during steel plating, as well as causing corrosion and increasing weight during concrete jacketing (Y. Zhu, Y. Zhang, H.H. Hussein 2019).

The world's most popular building material is concrete, with usage double that of wood, steel, aluminum, and plastics put together. Millions of employment are created worldwide by activities related to concrete, from the manufacturing of the raw materials to the final products, and these activities significantly increase GDP, or Gross Domestic Product of the majority of the world's countries(Nkem Ede and Oluwabambi Ige 2014); concrete has a high compressive strength but is fragile and easily brittle when exerted with tension. Fibers have been used to reinforce concrete in an effort to reduce the latter's frailty. Concrete with fiber reinforcement is often used in many different applications and has a variety of stiffness and tensile properties. SIFCON is currently thought of as a new and distinct category of concrete created to increase the strength of a unique type of concrete reinforced with fibers (FRC). It is made up of a specific steel fiber matrix that gives the composite matrix powerful tensile capabilities. SIFCON features parallel kinds of increased qualities in the ductility sector and energy absorption due to this high steel fiber content. The primary changes between the SIFCON and FRC were incorporated into the steel fiber variances in the volume fraction (VF). The uneven mortar aggregates of SIFCON not involved in the synthesis process. The utilization of coarse aggregates prevents mortar penetration through the steel fiber network. Additionally, compared to FRC and regular concrete, SIFCON contains more cement. The different SIFCON production methods are because of the larger percentage of steel fibers. Steel fibers are first poured into the mold to completely fill it before the current form of concrete is casted. Next, Cement based mortar penetrates and assists steel fiber network SIFCON. Meanwhile, in the FRC, The steel fibers are mixed with the wet concrete mix before being sprayed into the form. The amount of the steel fiber (Vf) depends on a number of factors, including the degree of vibration, the placement method, mold size, as well as the orientation, ratio, diameter, and form of the fibers, and external vibration (Al-Abdalay, Zeini, and Kubba 2020).

There are certain structural and durability requirements for modern civil engineering constructions, hence it is now necessary to modify conventional concrete(S. Ali et al. 2020).A specific class of steel fiber-reinforced cement composition is known as SIFCON. These ingredients range in volume fraction of fiber content, i.e., between 5 to 30%. In this method, the forms will be filled with fibers. The papers are then pumped or poured with a flow able slurry that contains cement and fine aggregate. SIFCON's rich mechanical properties include flexural strength, sheerness, tenseness, and compressive with extremely high values. In SIFCON specimens, compressive strains of above 10% are documented without a dramatic loss in strength. Four important design factors need be taken into account for the SIFCON manufacturing process: type, alignment, and volume of fiber, as well as slurry strength. The behaviors of the SIFCON composite are affected by the elastic modulus of the hardened slurry, tensile strength, and compressive strength (H. Yazıcı, S. Aydın, H. Yiğiter, M.Y. Yardımcı 2010). Various kinds of steel fiber are utilized to make SIFCON. The most widely used types are crimped fibers and hooked ends. Additionally, both straight and bent fibers are used. These two kinds are not typically employed, nonetheless. By packing shorter or smaller fibers more densely than the longer ones, it is possible to produce a larger volume of fiber with acceptable vibration. The SIFCON fibers must be loose (discreet or single) to allow for fiber bed infiltration without it being clogged or honeycombed. As a result, before being added to the mold, agglutinant fibers must be separated, whereby crimped fibers are the most popular type. Similar to bent fibers, straight and deformed fibers are also used, though less frequently. Therefore, Before being put into the molds, the agglutinant fibers need to be separated and spread out. (S.S. Khamees, M.M. Kadhum 2020). However, there aren't enough guidelines and restrictions, on using SIFCON constructions according to usual standards for achieving the set goals. Therefore, there is a need to understand the chemical, physical and mechanical properties of SIFCON to select the appropriate mixture and effective position for a particular structural applications. Moreover, with further field testing, researchers and experts can ultimately play an important role; in shaping future reliable codes and standards for the design of SIFCON structures.

## SIFCON PREPARATION

It is actually impossible to mix concrete as usual due to the fiber congestion; the fibers must first be placed before the appropriate network can be built. for large sections, the fibers can be manually placed or placed using fiber distribution machines, but the cement-based slurry (mortar) needs to be placed manually via gravity (Thomas 2014)(Y. Farnam a,∗ 2010). Fiber placement in the mold, slurry formation, and finishing are the standard steps for producing SIFCON (Vijayakumar and Kumar 2017).

If the SIFCON is to be used in any project, a variety of criteria should be considered; including the slurry's mechanical strength capability, the amount of fibers, how the fibers are aligned, and the type of fibers chosen, should be considered. This is because short fibers aid in-attaining the maximum density possible for the entire matrix, and the volume and alignment of the fibers have an impact on the workability.

Three distinct methods can be used to incorporate the steel fibers into the matrix.; The first involves preplacing the steel strand in the mold and allowing slurry to flow through the fiber (single-layer technique), as shown in Figure (1). The second method entails carrying out the same process while dividing the section's overall height into three equal portions (three-layer technique). The third step is putting in the fiber until the section can reaches-its full height after prefilling the slurry with one-thirds of its height (immersion technique). The vibration needs to be used in conjunction with all three methods(Parameswaran, V., Krishnamoorthy, T., Balasubramanian, K., & Gangadar 1993).

FIGURE 1. Casting procedure of SIFCON (Yazıcı, H., Yiğiter, H., Aydın, S., & Baradan 2006).

## MATERIALS AND MIX PROPORTIONS

The primary components that should be employed in the creation of SIFCON are cement-based mortar slurry and steel fibers .

### SLURRY OF SIFCON

To create SIFCON, the ratios of sand and cement are typically 1:1, 1:1.5, or 1:2. Additionally, fly ash or silica fume of 10% to 15% maximum of the cement weight can be added to the mixture. Normally, in order to accomplish complete infiltration into the steel fiber matrix, only fine sand that can pass through a sieve with a mesh size of 1.18 mm or less is required.

Additionally, the w/c ratio might range between (0.3 and 0.4), but "super plasticizer" proportions require (2%–5%) times the cement weight. Additionally, although the current experience only covers a range of (4%-12%) (A. S. Ali and Riyadh 2018), fiber amounts are typically taken in the range of (4%-20%). The typical mix proportions mentioned in the literature are shown in Table 1.

TABLE 1. Shows recent contributions' slurry mix proportions for SIFCON.

| Papers | Sand | Cement | Water /binder | Silica fume % | Fly ash | HRWR (by wt. of cement) %. |
|---|---|---|---|---|---|---|
| (Elavarasi and Mohan, 2016) (Elavarasi & Mohan 2016). | 1 | 1 | 0.4 | 5,10,15, 20,25** | - | 2 |
| (Parthiban et al. 2013)(Parthiban, K., Saravanara, K. & Kavimukila 2014). | 1 | 1 | 0.5f | - | - | - |
| (Rao and Amana, 2005) (Sudarsana Rao and Ramana 2005). | 1 | 1 | 0.45 | - | - | 1.5 |
| (Yan et al. 1999)(Yan, L., Zhao, G., & Qu 1999) | 1 | 1 | 0.28 | 15* | - | 1.5 |

*continue ...*

*... cont.*

| | | | | | | |
|---|---|---|---|---|---|---|
| (Wang and Maji, 1994(Wang, M., & Maji 1994). | 1 | - | 0.3 | - | 0.3 | 1.9 |
| (Parameswaran et al. 1993) (Parameswaran, V., Krishnamoorthy, T., Balasubramanian, K., & Gangadar 1993). | 1 | 1 | 0.38<br>0.38<br>0.35<br>0.32 | - | - | 2<br>1<br>2<br>1 |

*=Silica fume was used as additives.
** =Silica fume used as replacement by weight of cement.

## INFLUENCE OF SIFCON (THE EFFECT OF SIFCON ON THE PROPERTIES OF CONCRETE)

Numerous studies have examined the behaviors of SIFCON in terms of compression, tension, channel, power effect, and flexion. By adjusting the fiber size components and other characteristics, several types of fiber can be produced. Since SIFCON is a relatively new technology, there is a limited amount of information available describing its behavior at the application level. Textual research on these areas are presented below and based on the experimental results reviewed in the current paper, which also covered the reinforcing properties of several SIFCON blend formulations. In general, When compared to a reference mix that does not contain SIFCON, SIFCON mixes often have greater mechanical characteristics, (SIFCON) specimens have higher compressive strength, tensile, flexural strength, toughness, and dynamic modulus of elasticity). Moreover, the mechanical properties of SIFCON mixes increase with increasing the steel fiber volume percentage, The mechanical characteristics of SIFCON alloys also increase with the increase in the size of the steel fibers, but the researchers did not mention how difficult it is to work when the proportion of steel fibers is increased and how to address this issue.

## COMPRESSIVE STRENGTH

Compressive strength is considered one of the most important properties of hardened concrete, and the Common practice in standard specifications relies heavily on the compressive strength of concrete to estimate the other mechanical parameters. (Abdul Kareem 2015). The impact of SIFCON on compression strength has been assessed, and with the addition of steel fiber, a noticeable improvement has been seen as demonstrated in the following sections.(M. A. A.-W. Ali 2018) investigated the effect of steel fiber volume percentage on compressive strength; when the fiber volume percentage is increased from 6% to 11%, whereby the compressive strength increases by (4.9 % and 8.3%) at 28 days. [19] SIFCON was investigated utilizing five specific quantities of PMSF (Plain Mild Steel Fiber). at 0%, 5%, 15%, 25%, and 35%. Following 28 days of SIFCON cube specimens' curing, the compressive strength variation are 22.85, 31.02, 36.42, 40.31, and42.08 (N/mm2) (Sampath and Asha 2019).

## SPLITTING TENSILE STRENGTH

The investigation of split tensile is required in order to judge and evaluate the SIFCON material's quality. (M. A. A.-W. Ali 2018)showed that the SIFCON samples had superior tensile properties over the reference mix, with tensile strength values for SIFCON reaching approximately (204)% for (SIFCON slurry of 8.5% Vf compared to the strength of the reference mix) at. 28 days. The study also tested the effect of steel fiber types on split tensile strength using straight micro fibers, Hooked fibers, and Hybrid). It was observed that the SIFCON micro fiber samples exhibited higher tensile strength compared to the hooked end fiber samples. The increase in resistance of the micro steel fiber samples compared to the hooked end samples amounted to 42.2%, 48%, and 40.3% a respectively 7, 28, and 90 days. This is because the aspect ratio of the microfibers as opposed to the hooked end fibers, which increases the specimens' tensile strength. This means that the tensile strength of SIFCON increased with aspect ratio of the utilized fibers has increased. (Praful N K 2015) also investigated the effect of SIFCON on the Split tensile strength variation at 28 days of curing of the SIFCON cube specimens; the results are 0%, 5%, 15%, 25% and 35% for 1.42, 3.57, 4.16, .39, 5.66 (N/mm2) with the percentage of strength increments in terms of control mix being 151%, 193%, 276% and 299% (Sampath and Asha 2019). The findings of (A. Hamed and W. Abass 2022) demonstrated that the 8% steel fibers of SIFCON increases the consequent splitting tensile strength by 23.3% at 28 days and the 10% steel fibers of SIFCON increases the consequent splitting tensile strength by 25.65% at 28 days, while the 12% steel fibers of SIFCON increases the consequent splitting tensile strength by 39.81% at the same age.

## ABSORPTION

Since water absorption is one of the mechanisms that is directly related to the surface quality of concrete and provides useful information about the pore structure in the concrete surface area, it helps simulate the corrosion of steel fibers (A. Hamed and W. Abass 2022). According to the pervious papers, all SIFCON mixes have lower water absorption compared to the reference mix. The fact that steel fibers operate as physical barriers that cross channels and capillary pores is the main factor decreasing the absorption of steel fibers, forming obstructions that, to a large extent, restrict the flow's ability to freely traverse the matrix. Hence, the increased steel fiber content in the mixture makes it difficult for water to flow through. (M. A. A.-W. Ali 2018)showed that all SIFCON mixtures not only had lower water absorption compared to the reference mixture, but also had lower shrinkage strains up to (64.6%) less than the shrinkage of the reference mixture at 180 days. As shown in Figure1 below, incorporating steel fibers into concrete mix has a metallurgical influence on total absorption despite a decrease in the results of the SIFCON blends. This is explained by the deficiency of coarse aggregate in SIFCON. (Azoom and Pannem 2017).


FIGURE 2: Total absorption at 28 days

## IMPACT ENERGY OF SIFCON

SIFCON has excellent and distinctive properties in both energy absorption and impact resistance, which are also recognized as among the most important characteristics of SIFCON (Balaji and Thirugnanam 2018). This is because the SIFCON's steel fibers with hooked ends have a larger carrying capacity samples to absorb larger amounts of energy before experiencing failure. Therefore, the energy input required to initiate the first crack and cause failure of the SIFCON mixtures is much higher than that of the control mixture. It is discovered that RC beams with SIFCON have an energy absorption capacity in the tension zone that is 90% more than that of regular RC beams and 55% greater than that of FRC beams. The energy absorption capacity for SIFCON beams is discovered to be 140% more than that of standard RC beams and 95% greater than that of FRC beams. (Mohammed, Sarsam, and Korkess 2020). When compared to the reinforced slab, they discovered that SIFCON specimens had impact resistance that was up to 10 times greater with steel fibers and 7 times higher with polypropylene fibers. They also found that the reinforced slab samples are scattered with impact while the SIFCON sample was intact (Naaman 2003). According to the test results, all SIFCON mixes have significantly improved impact resistance at first crack and failure when compared to the reference mix, Additionally, the SIFCON mix (M3-F11) has the highest impact resistance, and the energy needed to completely fail was (109471.8 N. m), up 11.87 times from the reference mix. (Balaji and Thirugnanam 2018). SIFCON has significant impact resistance, contains about 11.87 times more energy than the reference mix at 90 days. SIFCON mixes have better impact resistance than reference mixes, with an energy for full failure that is 11.87 times greater after 90 days. (M. A. A.-W. Ali 2018).

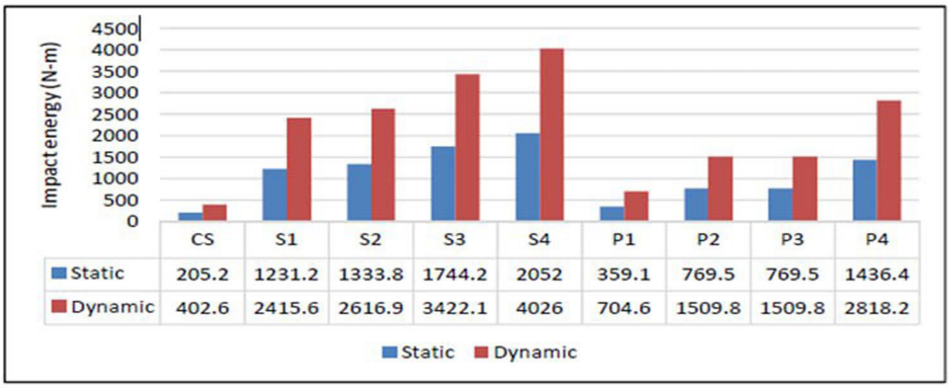


FIGURE 3. Impact energy of SIFCON with different fibers (Azoom and Pannem 2017)

## DUCTILITY CHARACTERISTICS

The ratio of the mid-span deflection at the ultimate load (Δu) to the mid-span deflection at steel yielding (Δy) can be used to define the ductility of reinforced concrete. (Manolia Abed AL-Wahab Ali 2018). The greatest deflection at any load level divided by the deflection at the initial yield break is known as the ductility factor. This is a very important parameter and is an indication of the robustness that SIFCON provides as a result of the ductility of the beam. (Hashim and Kadhum 2020) investigated the effect of SIFCON on the ductility of the beam of which result is shown in Table 1. (Mohammed, Sarsam, and Korkess 2020) RC beams with SIFCON were found to have a ductility factor in the tension zone that was 185% higher than that of normal RC beams and 140% higher than that of FRC beams. The ductility factor for SIFCON packages was discovered to be 270% greater than that of traditional RC packages and 200% higher than that of FRC packages. In other words, SIFCON's existence raises the beam tolerance, which in turn raises the peak load and the beam equivalent deviation. This shows that the deformability (also known as ductility) of standard RC beams is increased by using SIFCON at selected locations. (Hashim and Kadhum 2020). This investigation has demonstrated that the ductility of the matrix normally used in reinforced concrete can result in a significant increase in energy absorption and the ductility of the components of the reinforced concrete structure. The use of the SIFCON matrix in reinforced concrete beams results in varying indicators of ductility from 2.9 to 5.45, and strength ratios from 3.7 to 9.2 (Khamees, Kadhum, and Alwash 2020) (S.S. Khamees, M.M. Kadhum 2020). Meanwhile, the control beam without fibers produced findings for the ductility and energy ratios that varied from 2.47 to 3.60 and 3.28 to 5.69, respectively. This represents a several hundred per cent improvement (Al-Wahab Ali, Ahmed Salih, and Jawad Frayyeh 2020).

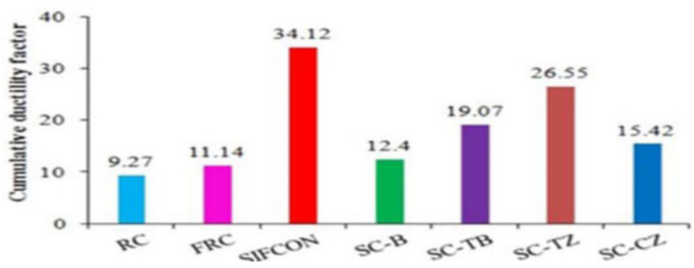


FIGURE 4. Comparison of Cumulative Ductility Factor (Balaji and Thirugnanam 2018)

TABLE 2. Ductility results(Mohammed, Sarsam, and Korkess 2020)

| Beams | Δy (mm) | Δu (mm) | μΔ | % μΔ |
|---|---|---|---|---|
| Ref No:1 | 6.85 | 12 | 1.751 | - |
| Ref No:2 | 7.63 | 23.35 | 3.060 | +74.757 |
| S-B-25%T | 6.1 | 8.1 | 1.327 | -24.214 |
| S-B-50%T | ## | 6 | - | - |
| S-B-25%C | 7.52 | 22.78 | 3.029 | +72.986 |
| S-B-50%C | 8.2 | 26.01 | 3.171 | +81.096 |
| ## not yield. | | | | |

## EFFECT OF STEEL FIBER TYPE

Concrete and other cementing networks show brittle failure and low- tension strength, respectively. By incorporating fibers into the network, the structural elements' mechanical properties are improved, especially their energy absorption ability, ductility, toughness, and damage resistance in structural elements under cyclic loading.

In addition, the fiber's cross section can also be flat, diamond-shaped, round, rectangular, square, polygonal, and triangular. The fiber may adjusted along its length by roughening up the surface and/or increasing the permitted deformation capacity to suggest good attachment between the matrix and fiber. As a result, the fibers can be scarred with "usual lengths" ranging from 6 mm to 150 mm and thicknesses between 0.005 mm and 0.75 mm. They can also be indented, smoothen, twisted, crimped, coiled, by paddles, end hooks, or buttons. Some fibers have a surface that has been inscribed or treated with plasma to improve glue when viewed at the microscopic level.

\Additionally, the matrix strength and the relevant physical properties of the fibers are the fundamental elements that control how the composite material behaves (Alrubaie et al. 2019) & (Beglarigale et al. 2016). Straight and deformed fibers are also utilized, however they are less commonly than hooked and crimped fibers (Gilani 2007) (Mondragon 1987). It is also possible to mix two types of steel fibers to obtain a hybrid model that has all their properties, where the addition of the hybrid fibers leads to a good progress in the final load(Abuzaid 2019).

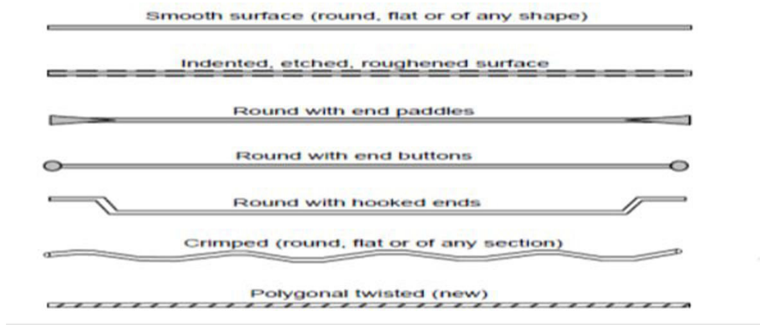


FIGURE 5. Steel fibers profiles of that are usually utilized in SIFCON (Naaman 2003).

(M. A. A.-W. Ali 2018) noticed that:

1. SIFCON microfiber-reinforced samples have higher tensile and compressive strengths of increased to 32 and 40.3%, respectively at 90 days compared to the bound samples. While microfibers demonstrated reduced bending strength and toughness (up to 7.2% and 11.5%) compared to the bonded samples.
2. SIFCON samples reinforced with hybrid fibers have higher compressive, tensile, flexural strength and toughness up to (5%, 24.7%, 5%, and 8.4%) at 90 days, respectively, compared to the tied ones.
3. The use of fine steel fibers and hybrid fibers in the SIFCON sample leads to a significant increase in the impact energy when the final load reaches (100.2% and 33.9%) respectively compared to the bound sample.
4. SIFCON blends with microfibers or hybrid fibers have an increased modulus of elasticity of up to (10.4% and 9.4%) respectively at 90 days compared to the hooked fiber samples.
5. Specimens made of crimped fibers show lower absorbency compared to those made of fine steel fibers, while specimens with hybrid fibers show higher water absorption compared to those made of blended fibers.
6. SIFCON microfiber samples show slightly more shrinkage compared to crimped fiber samples. While the SIFCON hybrid fiber samples show lower shrinkage compared to the suspended fiber samples.
7. SIFCON microfiber panels have a slightly lower final load compared to the suspended fiber sample, while the mixed fibers show a higher final load.


FIGURE 6. The steel fibers used: a) hooked end and, b) micro fiber (Manolia Abed AL-Wahab Ali 2018)

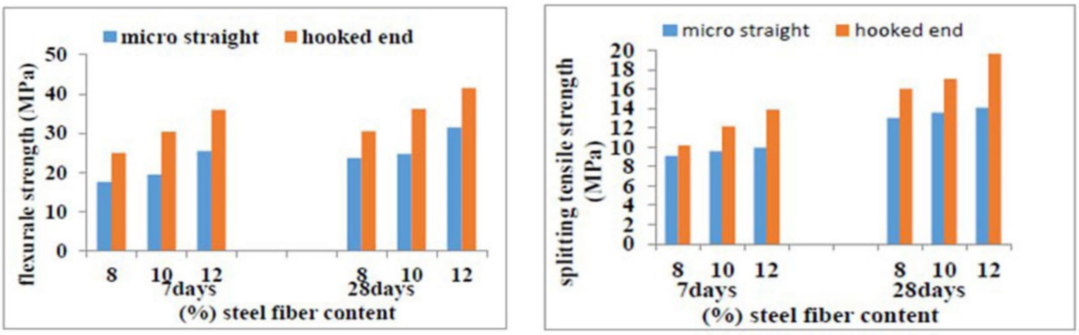


FIGURE 7. Levels of flexural strength after 7 and 28 days & Levels of splitting tensile strength at days at 7 days and 28 days (A. Hamed and W. Abass 2022)

TABLE 2. Classification of research

| Papers | Parameters | | | | | | Tests | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ductility | Modulus of Elasticity | Type of steel fiber: Hooked | Type of steel fiber: Micro | absorption | $V_f$% | Spiting test | Compressive Strength | Flexural Strength |
| H. A. Hamed and Z. W. Abass (A. Hamed and W. Abass 2022) | | | X | X | | 8%,10% 12% | X | X | X |
| G. K. Mohammed, K. F. Sarsam, and I. N. Korkess (Mohammed, Sarsam, and Korkess 2020) | | X | X | | | 9% | X | X | X |
| A. M. Hashim and M. M. Kadhum (Hashim and Kadhum 2020) | | X | X | X | | | X | X | |
| S. S. Khamees, M. M. Kadhum, and N. A. Alwash (Khamees, Kadhum, and Alwash 2020) | | | X | X | | | X | X | X |
| S. S. Khamees, M. M. Kadhum, and N. A. Alwash (Al-Wahab Ali, Ahmed Salih, and Jawad Frayyeh 2020) | | | | | | 6%,8.5% 11% | | | X |

*continue ...*

... *cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M. Alrubaie, D. Hameed, S. Salih, G. Habeeb, and W. Abbas (Alrubaie et al. 2019) | | | X | | X | 1.5%,6% | | X | X |
| P. Sampath and P. Asha (Sampath and Asha 2019) | | | X | | | 5%, 15% 25%, 35% | X | X | |
| P. Sampath and P. Asha (Balaji and Thirugnanam 2018) | X | | X | | X | 9% | | | X |
| M. A. A.-W. Ali (M. A. A.-W. Ali 2018) | X | | X | X | X | 6%,8.5% 11% | X | X | X |
| Manolia Abed AL-Wahab Ali | | | | | | | | | |
| P. Sampath and P. Asha (Azoom and Pannem 2017) | | | | | | | | | |
| P. Sampath and P. Asha (Beglarigale et al. 2016) | | | | | | | | | |
| R. T. Abdul Kareem (Abdul Kareem 2015) | | | X | X | | 1.5%,2% | X | X | |
| Praful N K (Praful N K 2015) | | | X | | | 1%, 1.5% 2% | | | X |
| (Ipek et al. 2014) M. Ipek, M. Aksu, K. Yilmaz | | | X | | | 4%,6% 8%,10% | | | X |
| (Chun et al. 2013) P. J. Chun, S. H. Lee, S. H. Cho | | | X | | | 9% | | X | X |

## CHALLENGES AND SCOPE OF FUTURE WORK

Based on an in-depth analysis review of the papers published on the performance of SIFCON, many useful conclusions were derived that could help in it improving its tangible and environmentally sustainable behavior. However, there is a lack of guidelines and regulations on using SIFCON constructions according to familiar standards for achieving the set goals. Therefore, there is a need to understand the physical, chemical and mechanical properties of SIFCON to select the appropriate mixture and effective position for a particular structural applications. Moreover, with further field-testing, researchers and experts can ultimately play an important role; in shaping future reliable codes and standards for the design of SIFCON structures. Some structures are subjected to severe dynamic loads on a regular basis, and as a result, concrete surfaces may develop huge fractures that eventually cause the structure to collapse. The design of these rigid columns causes highly dynamic stresses, which can be calculated by following concrete material standard specifications. Choosing the appropriate proportions enables them to be used in appropriate and specified parts in the structural

applications. To consider SIFCON, It is essential to conduct more practical investigations to examine its dynamic behavior. Moreover, calculating the construction's overall cost modified structures using SIFCON requires a huge amount of steel fibers to create, its use is another difficulty that should not be ignored. Very few studies on the matter had been published in the past five years, most of which were research tests conducted on cubes and cylinders. Hence, more research on the structural nature is needed. Findings have that there are differences between them which may be due to the use of various steel fibers in different proportions and strength properties. This can be considered a research question to determine the optimal behavior of SIFCON. Further studies are hence needed to determine the optimal design limitations. This paper can be the basis for future studies in finding solutions to the weaknesses that were not covered before.
Research in the future can include:

1. Investigate the optimal locations of SIFCON in a conventional RC structure that maximizes load bearing capacity, ductility and energy absorption.
2. Gain further information about the strength of SIFCON's impact. Currently, the only information available is from PARAM Eswaran et al. Further investigation is needed on the behavior of SIFCON samples because of impact loads.
3. Study the possibility of producing reinforced SIFCON elements with different fiber contents, replacing part or all of the main reinforcement and stirrups, and comparing their behavior with that of these elements using only the complete SIFCON.
4. Examine the construction of cyclic loading to determine the responses of the SIFCON mechanism against the composite structures' flexural ability. This is because most of the past studies reviewed had only focused on the stationary flexural workload on beams.
5. Study the joint procedure that occurs between the RC and SIFCON laminates, for the purpose of productivity improvement so as to attain the necessary bond strength between the SIFCON layer and cement surface.
6. Examine weaker RC systems that have been SIFCON-reinforced, as most of the previous lab experiments had only focused on reinforcing unpatched and inexperienced RC beams.
7. Examine the effect of leakages between SIFCON and RC surfaces on slipping and total intensity measurements in numerical and statistical instruments, as the relationship has not been completely determined.
8. Independently test the ductility reinforcement mixed with SIFCON and other structural components such as FRP in view of the costliness of SIFCON. There is also a need to determine the response of such membranes and the configuration of the reinforcement combinations.
9. Study the possibility of using hybrid fibers instead of suspended fibers in SIFCON mixtures, for the possibility of adding further improvement to their properties.
10. Study the effect of using another type of steel fiber such as crimped fibers, and comparing the behavior of its mixtures with those reinforced with hook fibers, in addition to the effect of using shorter and longer knotted fibers using another aspect ratio on the SIFCON attributes.
11. Determine and validate how the performance of SIFCON is affected by the addition of supplemental cementing materials (silica fume and/or fly ash in place of cement).
12. Use another mineral mixture as an alternative to cement such as methacholine and blast furnace slag in different proportions and study their effect on the properties of SIFCON mixtures.
13. •Examine the effects of employing various cements and mineral additives on the structural durability of SIFCON. Research the durability characteristics of SIFCON mixes, such as permeability and resistance to chloride penetration.

## CONCLUSIONS

This paper reviews the effects of using a highly elastic matrix such as SIFCON. This is accomplished effectively by reviewing the advantages and disadvantages identified by several researchers. Furthermore, this paper discusses the viability of employing SIFCON in sustainable structures containing different types of steel fibers in different proportions. This work mainly investigates the effects of SIFCON on mechanical properties and derives the following conclusions. The maximum volume friction (Vf) of steel fiber is limited to 2% volume. When it is higher, mixing concrete becomes difficult. To create new concrete with good mechanical qualities, steel fiber quantities have increased in recent years. The new concrete named slurry infiltrated fiber concrete composite (SIFCON) has greater ductility, crack resistance property and strength.

1. Since SIFCON contains a high fiber content (5% to 20%), the cost of the fibers can have a considerable impact on the final cost of the structural SIFCON elements. Therefore, the entire section of (RC)elements with SIFCON is seen as uneconomical. SIFCON utilized in selected spots of traditional RC beam can result in both greater strength and being more economical.
2. One of the latter moves materials is (SIFCON). It is fascinating high-performance fiber reinforced concrete (HPFRC) with a greater fiber content.

3. When the same fraction size (either 8%, 10%, or 12%) of hooked-end steel fibers are used in place of micro straight steel, the splitting tensile strength and flexural strength values rise by 20% to 45 %.
4. There is a possibility of using SIFCON to strengthen faulty construction as a sustainable solution. As mentioned earlier, SIFCON possesses a special mechanical behavior which is evidenced by its high strength, super ductility and crack-stopping property.
5. The test sample's composition, which contains SIFCON, requires specific handling in order to stop SF allocation from inappropriate SF orientation.
6. SIFCON is used in applications that require a high degree of plasticity and energy absorption, mostly for earthquake-resistant reinforced concrete structures
7. and structures subjected to abnormal or explosive loads. In addition, pavement overlays, pre-stressing beam reform, and structural reinforced concrete element all restores were effective.
8. From the previous experimental work, it is recommended to use steel fibers by the volume of (8.5%) in the production of SIFCON mixtures. This value is found to be the most practical limit for steel fibers that can fill molds, and that any type of SIFCON slurry can easily penetrate even though it produces SIFCON mixtures.
9. It is recommended to use SIFCON slurry containing (10%) silica fume and 20% fly ash in the production of SIFCON, which has a high working capacity, as well as the effect of giving an additional increase in the mechanical properties of SIFCON mixtures.
10. To improve the mechanical properties of SIFCON, it is recommended to use hybrid fibers (micro fibers and hooked -end steel fibers) instead of hooked -end steel fibers in SIFCON blends which give an additional increase in their properties.

## ACKNOWLEDGEMENT

The authors would like to thank Mustansiriyah University, Baghdad, Iraq for the support to conduct this research.

## DECLARATION OF COMPETING INTEREST

None.

## REFERENCES

A. Hamed, Haneen, and Zinah W. Abass. 2022. Effect of steel fiber proportion on sifcon mechanical properties. *Journal of Engineering and Sustainable Development* 26 (1): 55–63. https://doi.org/10.31272/jeasd.26.1.6.

Abdul Kareem, Rana T. 2015. Behavior of Hybrid Fiber Reinforced Self Consolidating Concrete Incorporating Nanoparticles. no. June 2015: 346–51.

Abuzaid, Esraa Khudhair Mohsin. 2019. Behavior and strength of steel-carbon-plastic hybrid fiber reinforced concrete beams. *IOP Conference Series: Materials Science and Engineering* 518 (2). https://doi.org/10.1088/1757-899X/518/2/022061.

Al-Abdalay, Nadia Moneem, Husein Ali Zeini, and Huda Zuhair Kubba. 2020. Investigation of the behavior of slurry infiltrated fibrous concrete. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 65 (1): 109–20.

Al-Wahab Ali, Manolia Abed, Shakir Ahmed Salih, and Qais Jawad Frayyeh. 2020. Study the behavior of Slurry Infiltrated Fibrous Concrete (SIFCON) under impact loading. *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/737/1/012069.

Ali, Ahmed S, and Zolfikar Riyadh. 2018. Experimental and numerical study on the effects of size and type of steel fibers on the (SIFCON) concrete specimens. *International Journal of Applied Engineering Research* 13 (2): 1344–53. http://www.ripublication.com.

Ali, Manolia Abed AL-Wahab. 2018. *Properties of Slurry Infiltrated Fiber Concrete (SIFCON)No Title*.

Ali, Saqib, Haresh Kumar, Samar Hussain Rizvi, Muhammad Saleem Raza, and Jawaid Kamal Ansari. 2020. Effects of steel fibres on fresh and hardened properties of cement concrete. *Civil and Environmental Engineering Reports* 30 (3): 186–99. https://doi.org/10.2478/ceer-2020-0039.

Alrubaie, Mays, Dalya Hameed, Shakir Salih, Galib Habeeb, and Waleed Abbas. 2019. Slurry infiltrated fiber concrete as sustainable solution for defected buildings. *Engineering and Technology Journal* 37(1C): 132–38. https://doi.org/10.30684/etj.37.1c.21.

Arain, Fahad Ahmed, Masroor Ali Jatoi, Muhammad Saleem Raza, Fahad Ali Shaikh, Farhan Khowaja, and Kunal Rai. 2022. Preliminary investigation on properties of novel sustainable composite: Fish scales reinforced cement concrete. *Jurnal Kejuruteraan* 34(2): 309–15. https://doi.org/10.17576/jkukm-2022-34(2)-14.

Azoom, K. T., and Rama Mohan Rao Pannem. 2017. Punching strength and impact resistance study of SIFCON with different fibres. *International Journal of Civil Engineering and Technology* 8(4): 1123–31.

Balaji, S., and G. S. Thirugnanam. 2018. Behaviour of reinforced concrete beams with SIFCON at various locations in the beam. *KSCE Journal of Civil Engineering* 22(1): 161–66. https://doi.org/10.1007/s12205-017-0498-9.

Beglarigale, Ahsanollah, Cąłlar Yalçinkaya, Hüseyin Yiłiter, and Halit YazIcI. 2016. Flexural performance of SIFCON composites subjected to high temperature. *Construction and Building Materials* 104: 99–108. https://doi.org/10.1016/j.conbuildmat.2015.12.034.

Chun, Pang Jo, Sang Ho Lee, Sang Ho Cho, and Yun Mook Lim. 2013. Experimental study on blast resistance of SIFCON. *Journal of Advanced Concrete Technology* 11 (4): 144–50. https://doi.org/10.3151/jact.11.144.

Dawood, Mustafa B., and Hawra Mohamed Ali M. Taher. 2021. Various methods for retrofitting prestressed concrete members: A critical review. *Periodicals of Engineering and Natural Sciences* 9 (2): 657–66. https://doi.org/10.21533/pen.v9i2.1849.

Elavarasi, & Mohan, K. S. R. 2016. Performance of Slurry Infiltrated Fibrous Concrete (SIFCON) with silica fume. *International Journal of Chemical Sciences*.

Gilani, A.M. 2007. Various durability aspects of slurry infiltrated fiber concrete. Ph.D. thesis, the Graduate School Of Natural and Applied Sciences of Middle East Technical University , Turkey.

H. Yazıcı, S. Aydın, H. Yiğiter, M.Y. Yardımcı, and G. Alptuna. 2010. Improvement on SIFCON performance by fibre orientation and high-volume mineral admixtures. *J. Mater. Civ. Eng.* 22(11): 1943–5533.

Hashim, Ali Mudhafar, and Mohammed Mansour Kadhum. 2020. Compressive strength and elastic modulus of Slurry Infiltrated Fiber Concrete (SIFCON) at high temperature. *Civil Engineering Journal (Iran)* 6(2): 265–75. https://doi.org/10.28991/cej-2020-03091469.

Ipek, Metin, Mecbure Aksu, Kemalettin Yilmaz, and Mucteba Uysal. 2014. The Effect of pre-setting pressure on the flexural strength and fracture toughness of SIFCON during the setting phase. *Construction and Building Materials* 66: 515–21. https://doi.org/10.1016/j.conbuildmat.2014.04.107.

Khamees, Shahad S., Mohammed M. Kadhum, and Nameer A. Alwash. 2020. Experimental and numerical investigation on the axial behavior of solid and hollow SIFCON columns. *SN Applied Sciences* 2 (6). https://doi.org/10.1007/s42452-020-2907-9.

Manolia Abed AL-Wahab Ali. 2018. Properties of Slurry Infiltrated Fiber Concrete (SIFCON). Thesis Submitted to the Department of Building and Construction Engineering of the University Technology.

Mohammed, Ghazwan K., Kaiss F. Sarsam, and Iqbal N. Korkess. 2020. Modeling the flexural performance of reinforced concrete built-up beams. *IOP Conference Series: Materials Science and Engineering* 745 (1): 669–80. https://doi.org/10.1088/1757-899X/745/1/012108.

Mondragon, R. 1987. SIFCON in compression. *Fiber Reinforced Concrete Properties and Applications* SP-105: 269–82.

Naaman, A. E. 2003. Engineered steel fibers with optimal properties for reinforcement of cement composites. *Journal of Advanced Concrete Technology* 1: 241–52.

Nkem Ede, Anthony, and Abimbola Oluwabambi Ige. 2014. Optimal polypropylene fiber content for improved compressive and flexural strength of concrete. *IOSR Journal of Mechanical and Civil Engineering* 11 (3): 129–35. https://doi.org/10.9790/1684-1134129135.

Parameswaran, V., Krishnamoorthy, T., Balasubramanian, K., & Gangadar, S. 1993. Studies on Slurry-Infiltrated Fibrous Concrete (SIFCON). *The National Academies of Sciences, Engineering, and Medicine* (1382): 57–63.

Parthiban, K., Saravanara, K., & Kavimukila, G. 2014. Flexural behaviour of Slurry Infiltrated Fibrous Concrete (SIFCON) composite beams. *Asian Journal of Applied Sciences* 7 (4): 232–239.

Praful N K. 2015. A study on behaviour of flexural strength of fibre reinforced concrete members subjected to alternate wetting and drying. *International Journal of Technology Enhancements and Emerging Engineering Research* 3 (04): 129–34.

S.S. Khamees, M.M. Kadhum, and N.A. Alwash. 2020. Effects of steel fibres geometry on the mechanical properties of SIFCON concrete. *Civ. Eng. J.* 6 (1): 21–33.

Sampath, P, and P Asha. 2019. Strength and durability properties of SIFCON with silica fume and waste binding wire 3: 917–23.

Sudarsana Rao, H., and N. V. Ramana. 2005. Behaviour of Slurry Infiltrated Fibrous Concrete (SIFCON) simply supported two-way slabs in flexure. *Indian Journal of Engineering and Materials Sciences* 12 (5): 427–33.

Thomas, Arun Aniyan. 2014. Strength and behaviour of SIFCON with different types of fibers. *International Journal of Civil Engineer and Technology (IJCIET)* 5 (12): 25–30.

Vijayakumar, M, and P Dinesh Kumar. 2017. Study on Strength properties of SIFCON. *International Research Journal of Engineering and Technology(IRJET)* 4 (1): 235–38. https://irjet.net/archives/V4/i1/IRJET-V4I144.pdf.

Wang, M., & Maji, A. 1994. Shear properties of Slurry-Infiltrated Fibre Concrete (SIFCON). *Construction and Building Materials* 8 (3): 161–68.

Y. Farnam & M. Moosavi. 2010. Behaviour of Slurry Infiltrated Fibre Concrete (SIFCON) under triaxial compression. *Cement and Concrete Research* 40 (11): 1571–1581.

Y. Zhu, Y. Zhang, H.H. Hussein, and G. Chen. 2019. Flexural strengthening of reinforced concrete beams or slabs using Ultra-High-Performance Concrete (UHPC): A state of the art review. *Eng. Struct.* 205: 110035, 2020.

Yan, L., Zhao, G., & Qu, F. 1999. Compressive properties of slurry infiltrated fiber concrete under monotonic and cyclic loading. *HKIE Transactions* 6 (1): 67–69.

Yazıcı, H., Yiğiter, H., Aydın, S., & Baradan, B. 2006. Autoclaved SIFCON with high volume class C fly ash binder phase. *Cement and Concrete Research* 36: 481–86.