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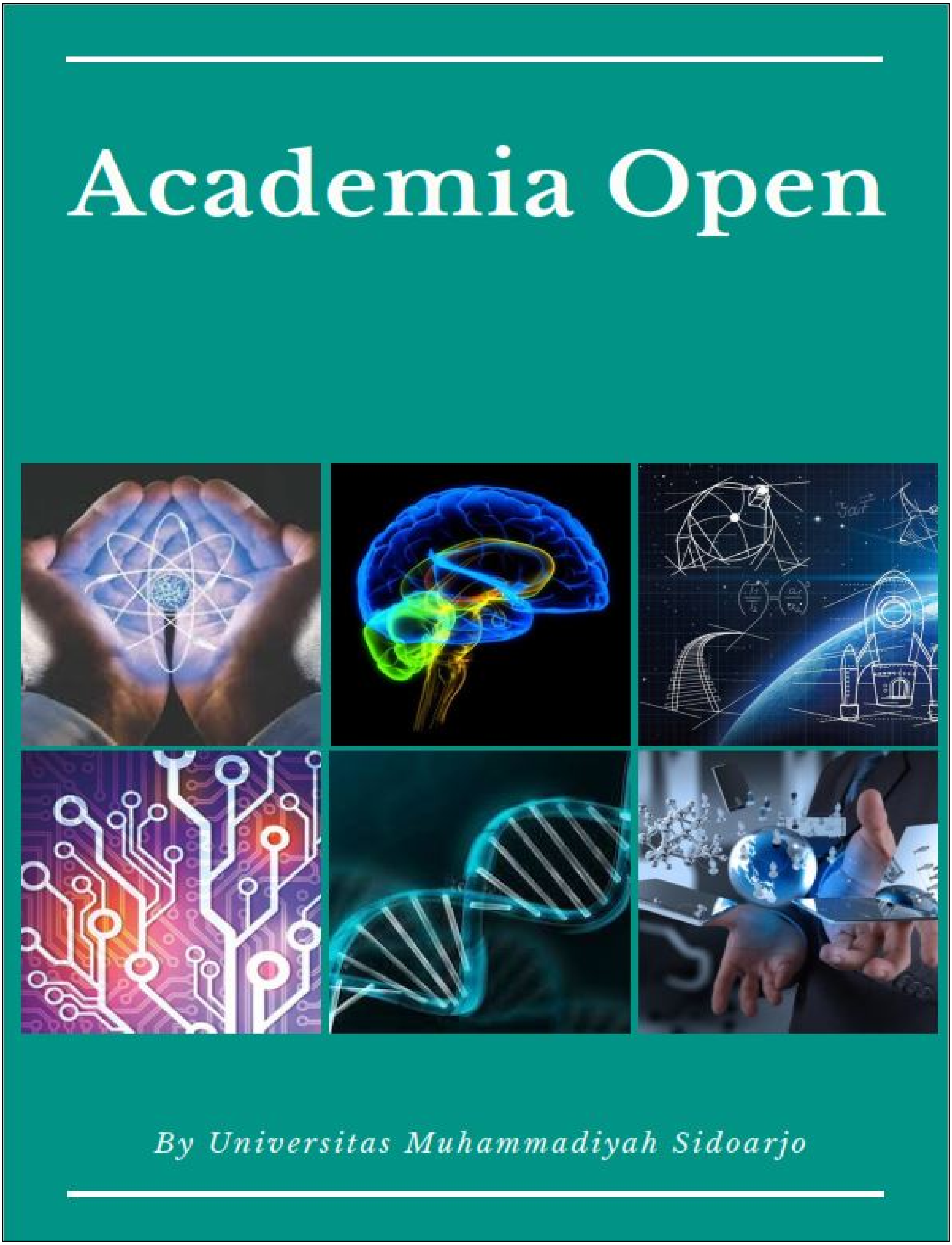
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Experimental Behavior of SIFCON Corbels

Perilaku Eksperimental SIFCON Corbels

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Abstract

This study explores the performance of six Slurry Infiltrated Fiber Concrete (SIFCON) corbels with a constant steel fiber volume of 6%, under varying vertical loads. By altering the shear span-to-depth ratio (a/d) from 0.4 to 0.6 and utilizing different fiber types (hooked end and micro) and reinforcement configurations (2Ø12mm and 3Ø12mm), the research examines the impact on maximum and cracking load capacities of the corbels. Results indicate that the a/d ratio, along with fiber type and reinforcement choice, significantly influences the structural behavior, offering insights for enhancing SFRC corbels' design and efficiency in construction applications.

Highlights:

- Shear Span Impact: Changing the shear span-to-depth ratio critically affects load capacity.
- Material Influence: Fiber types and reinforcement configurations alter load behavior.
- Design Implications: Results highlight the importance of design choices in enhancing SIFCON corbels' structural performance.

Keywords: SIFCON, Corbels, Shear Span, Steel Fiber, Load Capacity

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Introduction

SIFCON, also known as Slurry Infiltrated Fiber Reinforced Concrete, is a composite material with enhanced strength properties due to its higher concentration of metallic fibers compared to Steel Fiber Reinforced Concrete (SFRC). It is sometimes denoted as "extensive fibrous concrete" in scholarly discourse. The inception of SIFCON can be traced to the year 1979, when Professor Lankard conducted comprehensive research at his research facility located in Columbus, Ohio, within the United States. Through his investigations, Professor Lankard successfully illustrated that by substantially augmenting the quantity of metal fibers within a cement matrix, it became feasible to produce a material possessing remarkably elevated strength. This groundbreaking material was subsequently designated as SIFCON.

The SIFCON matrix is devoid of coarse particles, yet possesses a substantial cement concentration. Nevertheless, the composition of the material may include both coarse or fine sand particles, alongside additional substances such fly ash, micro silica, even latex emulsions. The design of matric density should be optimized in order to efficiently penetrate the fiber system that is placed within the molds. Failure to achieve correct infiltration may result in the formation of significant apertures, which can subsequently lead to a considerable reduction in material properties [1]. Slurry Infiltrated Fiber Concrete (SIFCON) is a type of fiber reinforced concrete wherein framework molds are fully filled with steel fibers that are arbitrarily oriented, often in a loose arrangement. Subsequently, a cement-based slurry is used to infiltrate the resulting fiber network. According to the American Concrete Institute (ACI544.2R, 1987) [2], infiltration is commonly accomplished through the force of gravity, which can be further facilitated by slight vibrations or by applying pressure through grouting.

The fiber quantity percentage usually falls among 1% and 3% for each everyday strengthened concrete and excessive performance fiber reinforced concrete (HPFRC) [3]. Nonetheless, a number of awesome composites were produced, ranging in fiber quantity fraction from 3% to twenty% [4]. Slurry infiltrated fiber concrete, or SIFCON, is the categorization that may be used to the composites which are being studied. Owing to its very strong cementitious matrix, SIFCON has incredible traits along with stronger ductility and tensile energy [5]. Numerous investigations were done to take a look at the mechanical properties of SIFCON. These studies' top notch findings show how an awful lot stronger SIFCON is than the matrices material. Moreover, different research have proven that flexural durability may want to upward thrust in the destiny [6]

Method

This experiment exams SIFCON corbels underneath vertical load with one of a kind shear span to depth ratios and metallic fiber contents. They can be forged without or with the metallic foremost tension bars. This work goals to offer similarly insights at the behavior of SIFCON corbels. This examine additionally appears on the modulus of elasticity, splitting tensile energy, flexural energy, and compressive power of excessive strength metallic fiber strengthened concrete (HSSFRC).

1. Details of SIFCON Corbels Specimen

The details of the SIFCON corbel specimens are listed in Table 1, where C denotes corbels, S stands for SIFCON, and R denotes reinforcing bars. According to the shear span-effective intensity ratio, the numbers 1, 2, and 3 suit.

Corbel name	Steel fiber content (Vf) in percentage terms	a/d ratio	Type of Fiber	Steel reinforcement
CS6-1	6	0.6	Hooked-end	-
CS6R-1	6	0.6	Hooked-end	2Ø12 mm
CS6R-2	6	0.5	Hooked-end	2Ø12 mm
CS6R-3	6	0.4	Hooked-end	2Ø12 mm
CS6R-2	6	0.5	Hooked-end	3Ø12 mm
CSM6R-2	6	0.5	Micro	3Ø12 mm

Table 1. *Information on SIFCON corbel specimens*

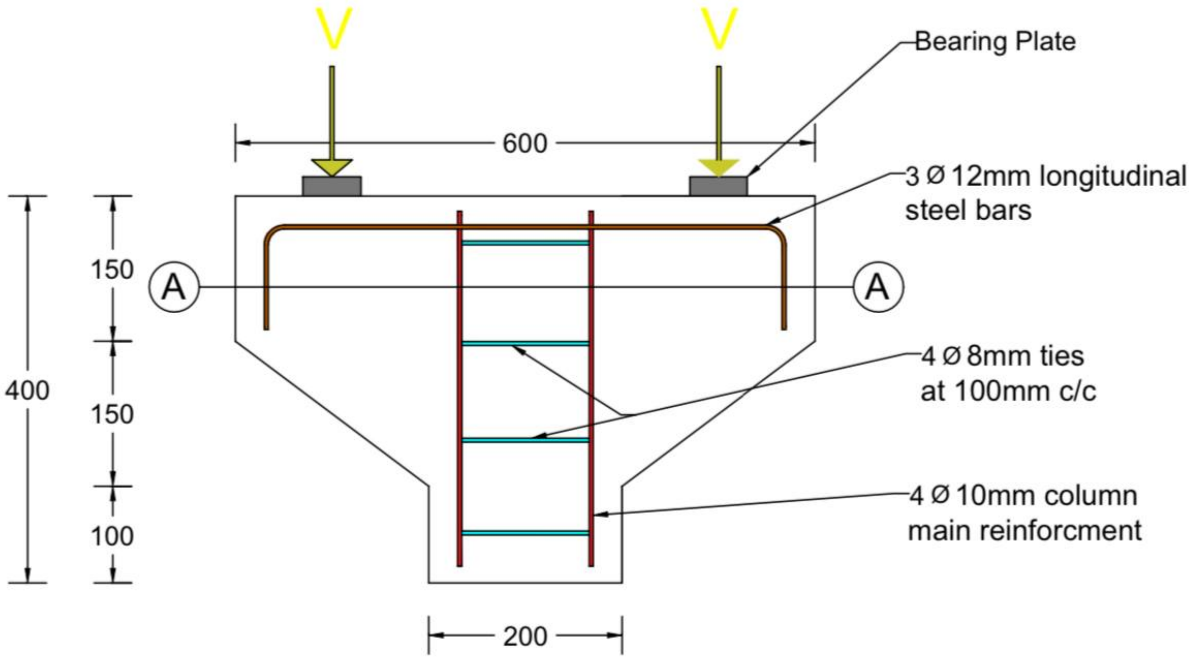

Figure 1. *The details of the SIFCON corbel (all measurements in mm)*

2. Material Properties

Karasta cement, grade 42.5R, is one of the most popular sorts. It is produced utilising sustainable production strategies and natural substances. The Iraqi Standard Specification, IQS 5/1984, is satisfied via this cement [7]. The SIFCON aggregate turned into made using pure sand that has been sieved to a 1.18 mm particle length. High-variety water reduction admixture (HRWR) and GLENIUM 54, a superb plasticizer made through BASF Construction Chemicals Company, have been the two admixtures utilized. The admixture beneath attention confirmed compliance with ASTM C494 kind F[8] standards. Furthermore, this take a look at's silica fume satisfies ASTM C 1240 [9] necessities.

In this experimental examine, small, hooked-cease metallic fibers have been used [10]. The metallic strands of the hooked variety are 35 mm long and 0.55 mm huge, even as the metallic fibers of the micro version are 12 mm long and 0.2 mm wide. The product meets the standards of ASTM C1609/C1609M-05 [11].

Oxides (%)		
L.O.I	3.38	Not more than 5
SiO2	17.94	-
Al2O3	4.57	-
Fe2O3	5.02	-
SO3	2.74	Not more than 4%
CaO	62.23	-
MgO	1.92	-
CI	0.017	Less than 0.1%
I.R	0.89	Not more than 5%

Table 2. *Chemical properties of Karasta cement*

Test	Test result	Specification limits
Finance (Blaine) m^2/Kg	4560	> 2500
Initial setting time min.	81	> 60 min.
Compressive strength Mpa 2 days curing 28 days curing	28 50	> 20 > 42.5

Table 3. *Physical Properties of Karasta Cement*

Sieve No. mm	10	4.75	2.36	1.18	0.60	0.30	0.15
Passing %	100	97.1	91.9	83.4	48	13.3	2.8
Iraqi Specification	100	90-100	75-100	55-90	35-59	8-30	0-10

Table 4. *Sand Analysis According to the Requirement of (IQS no.45/1984) zone2 [10]*

No.	Property	Result
1	Appearance	Fine powder
2	Odor	odorless
3	pH	6-9
4	Color	gray
5	Density	2.2 -2.5 g/cm³
6	Solubility	insoluble
7	Melting point/ range	2,192-2,372 °F/ 1,200-1300°C

Table 5. *Physical and chemical Properties of silica fume*

No.	Main action	Concrete super plasticizer Glenium 54
1	Commercial Name	Glenium 54
2	Appearance / colors	Whitish to straw colored liquid
3	Chloride content	None
4	pH. value	5-8
5	Density	1.07 g/cm3

Table 6. *The Super plasticizer properties (Glenium 54)*

Figure 2. *Steel fibers: (a) Microfibers; (b) Steel fibers with hooked ends*

Property	Description	Appearance	Length (L), millimeters	Diameter (d), millimeters	Aspect proportion (l/d)	Density in kilograms per cubic meter	MPa for tensile strength
The outcome of tiny steel strands	Small hooked end (Deformed shape)	Clean , and yellow wire	12	0.2	60	7850	1650
Result of hook steel fibers	hooked end (Deformed shape)	Clean and bright wire	35	0.55	64	7850	1650
ASTM C1609/C1609M-05 [11]	---	---	---	---	---	---	Min. 1100

Table 7. *Steel Fibers Properties (hooked end & micro)*

6. SIFCON Mix Proportions

Based on beyond studies on SIFCON blends and after a sequence of trial mixes to envision the proper issue portions, the optimal percent was proven in Table 8.

Fibers Vf (%)	The Cementite		Sand kg/m□□	Water Kg/m3	w/b	HRWR (%) by wt. of cement
	kg/m3 of cement	kg/m³ of SF10% rep.				
6	895.5	99.5	995	298.5	0.3	3.7

Table 8. *Specifics of the SIFCON Mix percentage*

3. Specimens Preparation

a. Mold

Samples were cast using iron molds with same dimensions of 20 mm in thickness are designed and fabricated for cast. In addition, iron cylinders were cast with 100 mm in diameter and 200 mm in height and the others with 150 mm in diameter and 300 mm in height. and cubes of (100 mm width X 100 mm length X 100 mm depth) are used, Also prism were used of (400 mm length X 100 mm width X 100 mm depth).

(a) Iron corbels molds

(b) A set of molds used

Figure 3. *Molds details*

b. Slurry Preparation

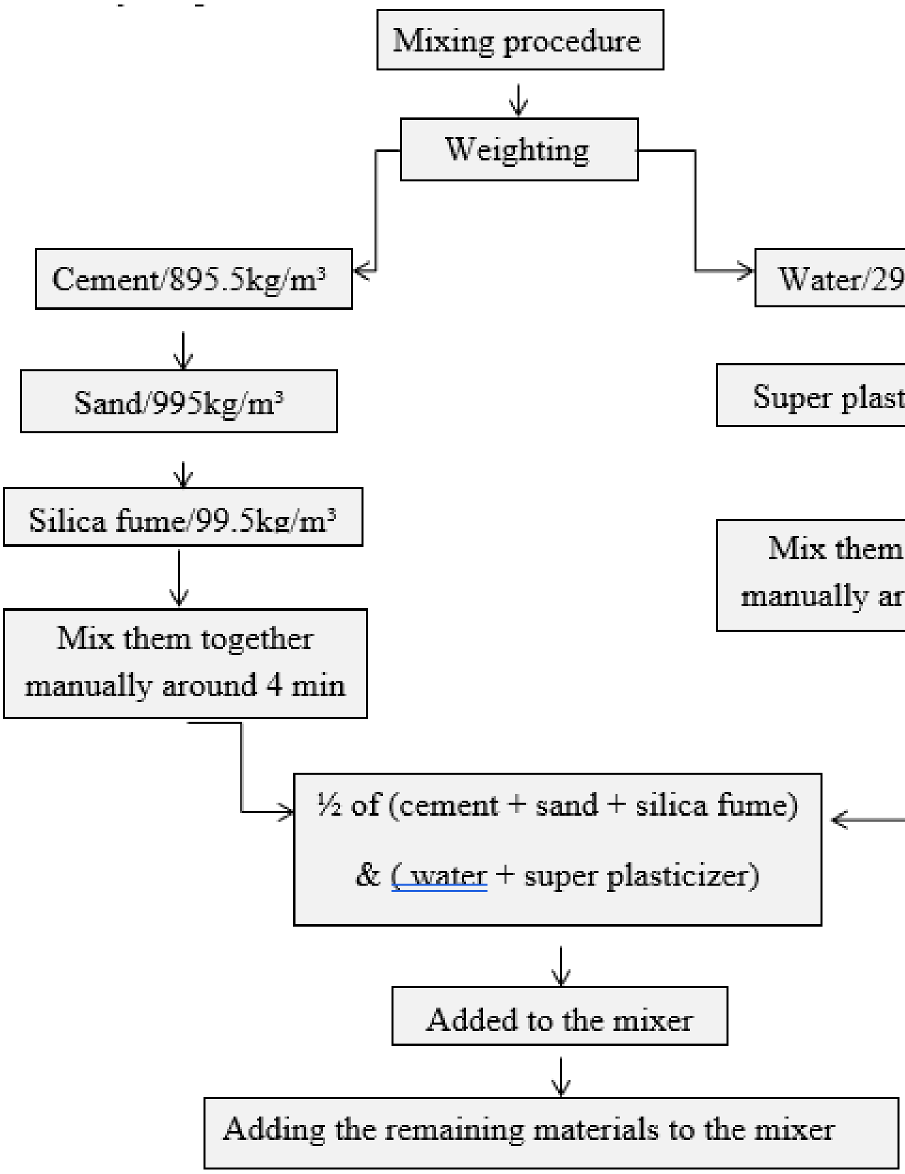

Figure 4. *Mixing steps*

c. Casting and Curing of Test Specimen

1.Once the creation of molds and SIFCON mortar is completed, the subsequent step involves determining the weights of the fibers, which is carried out during the process of making the mixture.

2.Steel bar reinforcement is placed in the mold then the casting process is conducted using a multi-layered methodology. The thickness of each layer was 10 centimeters. Initially, the fibers are randomly positioned within the mold, extending to a depth of 10 cm. Subsequently, the mortar is poured into the mold, filling it up to the aforementioned level. To ensure the absence of voids or honeycombs, a squared steel rod with a cross-section of 4 mm is employed to compact all the materials within the mold for both specimens and samples. The aforementioned procedure was iteratively performed for each layer until the entirety of the mold was completely filled with the designated quantity of fibers

3.The samples were set up on the vibrating table throughout the casting period to ensure full infiltration of the mortar into the fiber bed.

4.The SIFCON corbels, prisms, and cylinders were subjected to a curing process by immersing them in basins containing tap water at a temperature range of 20±5 °C for a duration of 28 days.

(a) Manual distribution of steel fibers

(b) Compacting with steel rod

(c) Curing Basin

Figure 5. *Casting and curing process*

Results and Discussions

The corbel samples were positioned upside-down and subjected to a vertical force in order to induce failure, as shown in Figure 6. This was accomplished using the 3000 KN maximum capacity Universal Hydraulic Testing Machine. To measure the deflection, a mechanical dial measuring device—precise to within 0.01 mm—was positioned at the corbel's center column.

Figure 6. *The testing machine*

1. Experimental Properties of Hardened SIFCON

The compressive strength (f´c) and split tensile strength (ft) tests were performed at 28 days in accordance with ASTM C39 [12] and ASTM C496-04 [13], respectively, using 100 mm diameter and 200 mm height cylinders. Prisms of (100 mm width X 100 mm length X 500 mm depth) were used to determine the flexural strength (fr) in accordance with ASTM C-78 [14]. While the modulus of elasticity was determined by utilizing (150 mm diameter X 300 mm height) cylinders according to ASTM C469-02 [15]. Both the flexural strength and the modulus of elasticity are tested at 28 days of water curing. Figure7 shows the crack patterns of the cylinders and prisms, and the mechanical properties of the SIFCON mix are tabulated in table9.

Vf %	Compressive strength in MPa (f´c)	Tensile strength of splitting (ft) MPa	MPa is the modulus of rupture (fr).	GPa is the modulus of elasticity (Ec).
6	140.5	18.7	32.7	52.7

Table 9. *The SIFCON Mix test's outcomes*

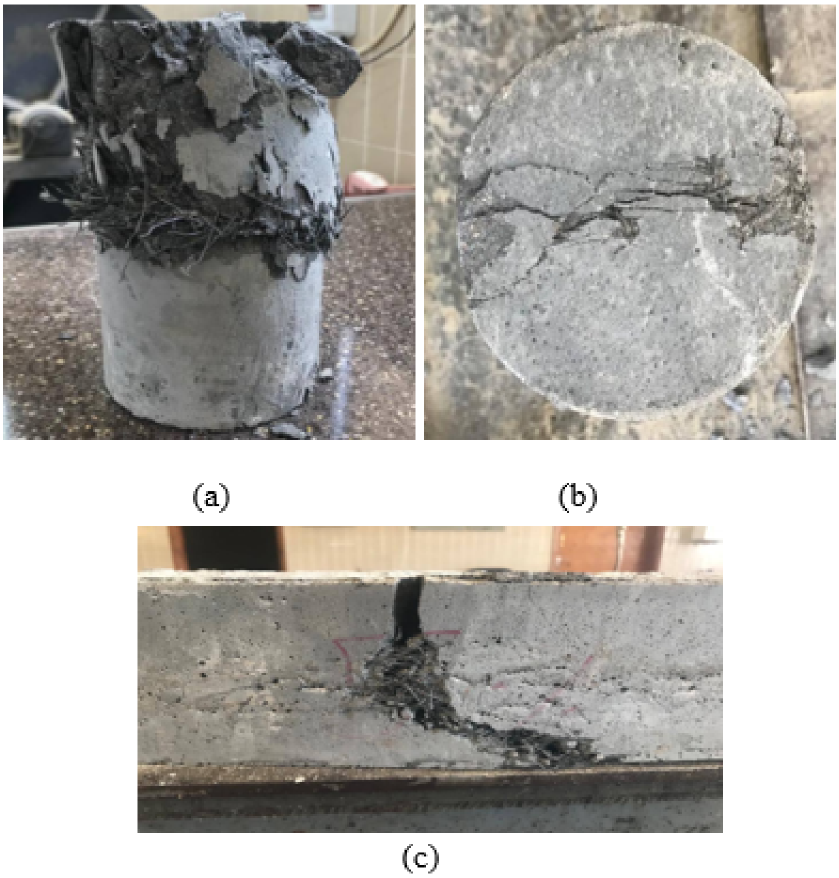

Figure 7. *Failure carcks patterns of cylinders and prisms*

2. General Behavior of SIFCON Corbels

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Figure 8. *Failure of SIFCON corbels*

Corbel name	CS6-1	CS6R-1	CS6R-2	CS6R-3	CS6R-3	CSM6R-2
a/d	0.6	0.6	0.5	0.4	0.5	0.5
Reinforced	-	2Ø12	2Ø12	2Ø12	3Ø12	3Ø12
Pcr KN	380	490	750	1250	1000	700
Pu KN	1240	1370	1460	1900	1800	1250
Δcr mm	0.159	0.21	0.16	0.2	0.19	0.18
Δu mm	0.52	0.48	0.41	0.31	0.7	0.65

Table 10. *Results of SIFCON corbels*

a. Impact of Shearing Span and Effective Depth Ratio (a/d) on Cracking, Ultimate Load, and Load-Deformation Curve

he cracking load increases by using 53.2%, sixty six.6%, and a hundred and fifty five.1% within the SIFCON corbels CS6R-1, CS6R-2, and CS6R-three while the shearing span-powerful intensity ratio decreases from 0.6 to zero.Five, zero.Five to 0.4, and 0.6 to 0.Four, respectively. Furthermore, the last load improves for the reason that maximum load rises because the (a/d) ratio falls, ensuing in a decrease in bending moment. When the (a/d) ratio is between zero.5 and zero.4, zero.6 and zero.Four, or zero.6 and zero.5. The percentage improvements are 6.5%, 30.1%, and

38.6%, respectively.

The relationship between the variable and the models is defined inside the Load-deformation curve. It is plain that the deflection values of the SIFCON corbels utilized on this studies develop in proportion to the ratio (a/d). The rise in bending moment might be the motive of this

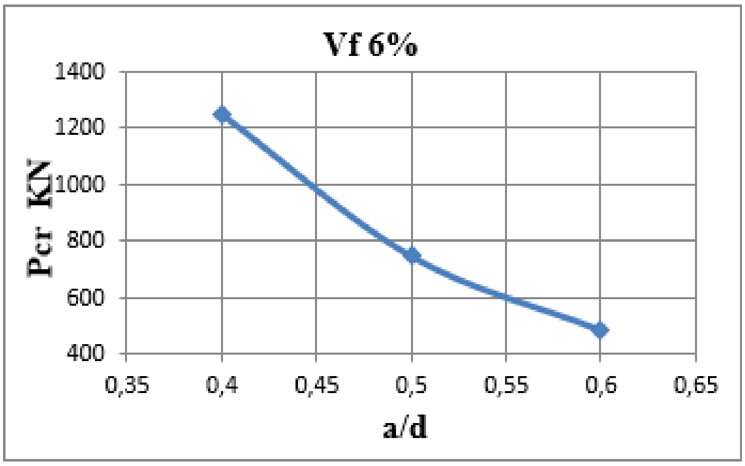

Figure 9. *Impact of effective depth ratio (a/d) on shearing span and cracking stress*

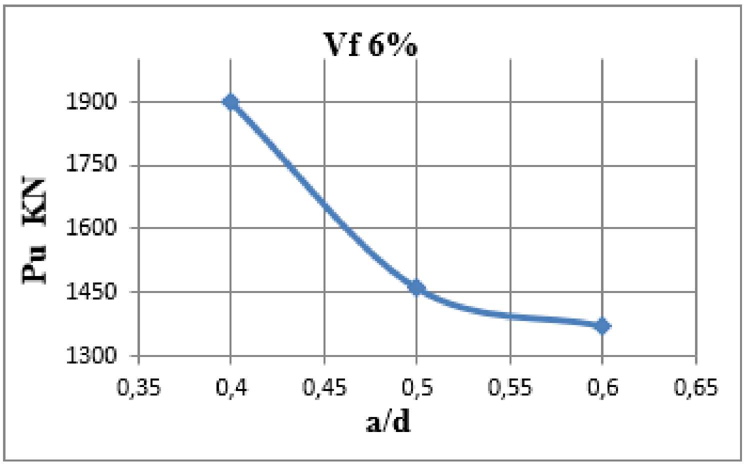

Figure 10. *Impact of effective depth ratio (a/d) on shearing span and ultimate load*

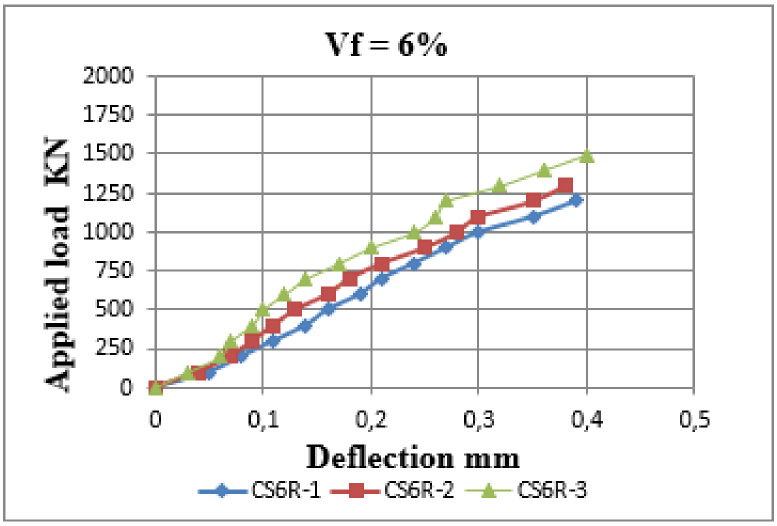

Figure 11. *Effect of (a/d) value on load-deflection curve of SIFCON corbels*

b. Effect of the Type of Steel Fiber On Cracking, Ultimate Load and Load- deformation curve

In SIFCON corbels CSM6R-2 and CS6R-2, the ultimate load is not received in a good way. In a similar vein, the SIFCON corbels' microportion of steel fiber injection reduces the cracking load by way of having an unfavorable have an impact on at the cracking load. This is probably as a result of the micro growing holes in the SIFCON corbels by way of making it more difficult for the slurry to journey through them. On the opposite hand, he constructed a sturdy model for the hook that could face up to the weight.

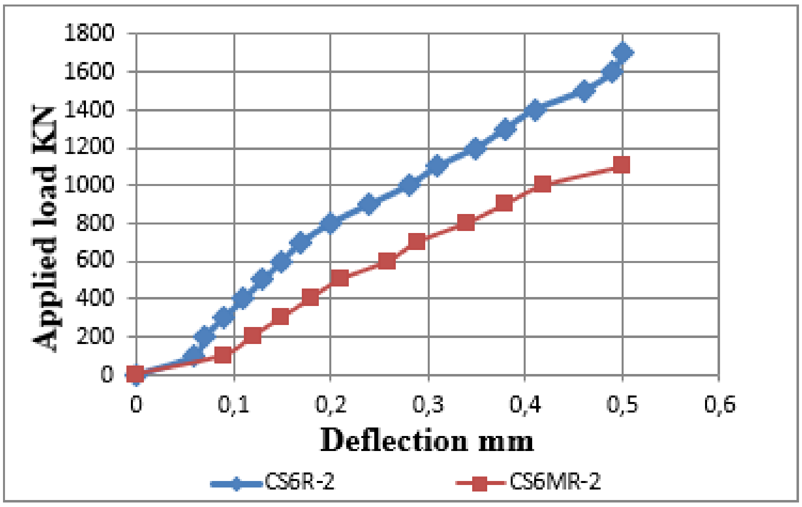

Figure 12. *Mixed steel fiber's impact on the load-deflection curve*

c. Effect of the Steel Reinforcement On Cracking, Ultimate Load and Load- deformation curve

When reinforcing metal is placed on SIFCON corbels, it complements resistance and postpones the onset of the first fracture inside the corbels at the same time as keeping the equal shear span to intensity ratio.

It has been shown that the usage of steel bars improves the deflection values. It is discovered that the deflection of corbel CS6R-1 is smaller than that of the reference SIFCON corbel CS6-1 when the load is implemented initially and the value of (a/d) is maintained constant. The end that including number one reinforcing bars boosts the corbels' tensile energy and decreases their deflection values serves as justification for this movement..

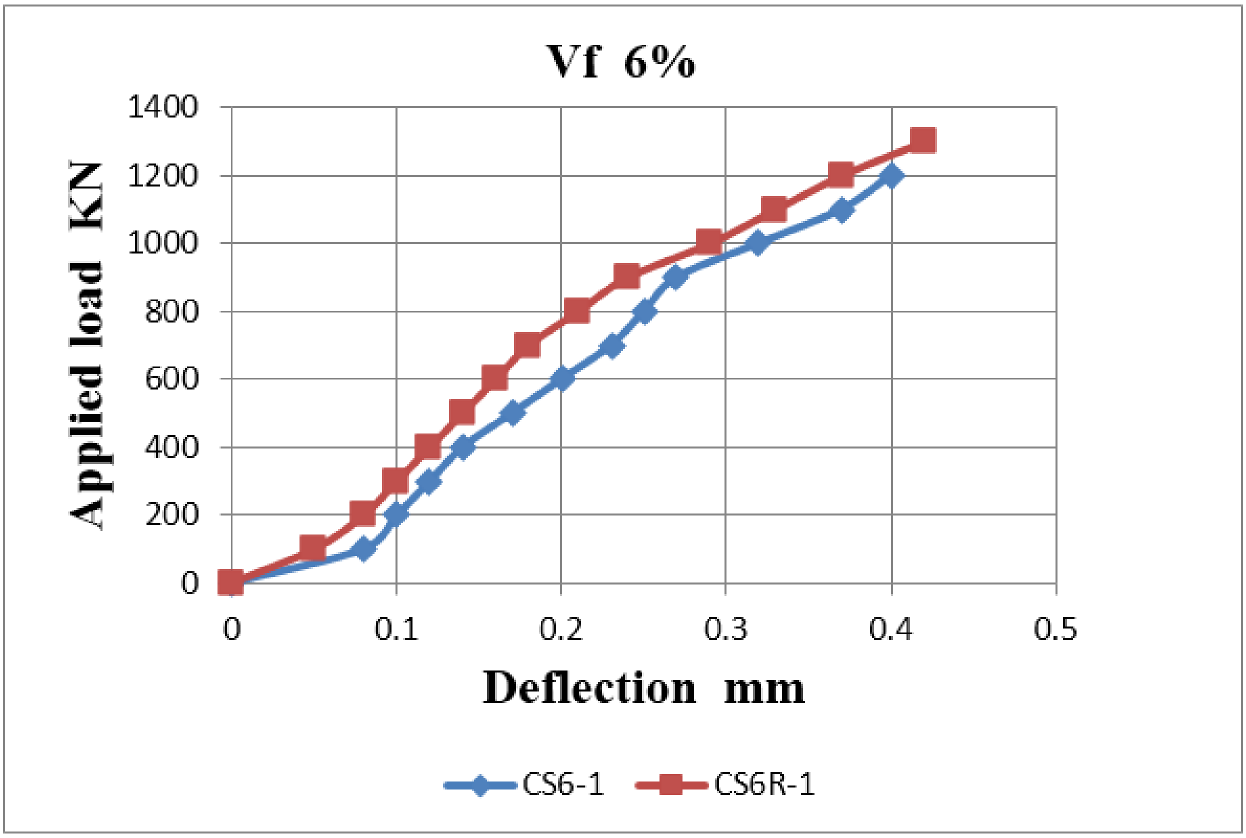

Figure 13. *Effect of reinforcement steel bars on load-deflection curve*

Conclusions

Based on the experimental findings, a number of conclusions have been derived and are presented as follows:

1. The addition of fiber notably improves the mechanical homes of the concrete combination.

2. According to this have a look at, the weight-deformation curve, last load, and cracking have the maximum impacts at the SIFCON corbels.

3. The failure load and fracture load boom because the shear span/powerful depth ratio decreases. By keeping the steadiness of the fiber %

4. The introduction of primary steel bars has altered the SIFCON corbels' failure mechanism.

5. There is a effective correlation between the deflection of SIFCON corbels and the shear span to powerful depth ratio, indicating that a bigger ratio corresponds to a better diploma of deflection.

6. It is proven that SIFCON corbels with metal bar reinforcement showcase lower deflection values than SIFCON corbels with an equal element ratio (a/d).

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