



## Combined Effect of Fiber Content and Fly Ash on Low Velocity Impact Resistance of Slurry Infiltrated Fibrous Concrete

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### ABSTRACT

Cement is the most expensive and energy-intensive ingredient in concrete. Partially replacing cement with fly ash can help lower the unit cost of concrete. Additionally, fly ash disposal poses a significant environmental challenge, as its accumulation as waste leads to serious ecological concerns. Additionally, it improves concrete properties by lowering water demand for the same workability, minimizing bleeding, and reducing heat generation. The influence of a mineral admixture on concrete strength varies considerably depending on its characteristics and the percentage of replacement. Slurry infiltrated fibrous concrete (SIFCON) is used in constructing structures that require high strength, superior concrete quality, and durability. SIFCON offers excellent ductility and impact resistance. The present study is to investigate the combined effect of fiber content and fly ash on impact strength of slurry infiltrated fibrous concrete (SIFCON). The experimental program was carried out on low velocity impact resistance of slurry infiltrated fibrous concrete containing different fiber volumes (0, 6, 8, 10%) with partial substitution of cement by fly ash (0, 10, 20, 30, 40, 50%). Hooked-end steel fibers of an aspect ratio of 30 and a constant mix proportion 1:1 and water binder ratio of 0.4 were used. Energy absorption capacity at the initiation of first crack and ultimate failure was evaluated by testing specimens of 150mm diameter and 60mm height as per ACI Committee 544.2R-89 guidelines using a self-fabricated drop weight impact test apparatus. The first crack and ultimate energy absorption capacity of SIFCON containing different fiber volumes with binary blend of fly ash were determined and the results were compared to SIFCON without fly ash. The test results revealed that the first crack and ultimate energy absorption capacities of SIFCON with addition of 30% of fly ash were superior compared to all other replacement levels.

**Keywords:** SIFCON, Fly ash, Drop weight impact test, Energy absorption, Impact residual ratio, Crack resistance.

### INTRODUCTION

Concrete structures are routinely exposed to impact loads throughout their service life, particularly in modern civilian infrastructures. These loads can stem from a variety of sources, including vehicle collisions with transportation structures, ship impacts on bridge

piers, debris strikes, falling objects on concrete slabs, aircraft movements on runways, as well as dynamic forces from wind and explosions. Such scenarios can lead to significant structural damages, emphasizing the need for enhanced impact-resistant concrete systems through specialized engineering solutions.

In 1983, Lankard introduced Slurry Infiltrated

Fibrous Concrete (SIFCON), a unique high-performance composite also referred to as high-volume fiber-reinforced concrete. Unlike conventional fiber-reinforced concrete—which typically contains from 1% to 3% fiber volume—SIFCON can accommodate from 5% to 30% fiber volume. SIFCON is produced by first placing steel fibers into a mold and then infiltrating the voids with a flowable cementitious slurry. The high fiber content, along with its orientation and distribution, significantly influences the mechanical properties, particularly ductility, energy absorption, and toughness. Fiber alignment—whether random, parallel, or perpendicular to the direction of loading—further enhances SIFCON's structural efficiency.

Lankard (1986) evaluated the mechanical performance of SIFCON and found that with fiber volumes from 15% to 20%, it exhibited superior ductility, tensile strength, energy absorption, and modulus of rupture compared to conventional fiber-reinforced concrete. Key design parameters, such as grout strength, fiber type, dosage, and orientation, were identified as crucial to SIFCON's performance. Naaman et al. (1991) analyzed the elastic modulus of SIFCON under tension and compression. Their results indicated that elasticity is influenced by not only the compressive strength, but also by fiber volume, geometry, orientation, and testing methods. In a further investigation, Naaman et al. (1992) tested reinforced concrete beams with SIFCON matrices. The results showed over three times higher ductility and more than four and a half times greater energy absorption compared to conventional beams. The inclusion of SIFCON also significantly reduced crack width and spacing, suggesting the potential for replacing stirrups in flexural elements. Naaman and Baccouche (1995) also explored SIFCON's shear performance with and without dowel reinforcements. Dowel-reinforced SIFCON reached ultimate shear strengths of up to 35 N/mm<sup>2</sup> and exhibited energy absorption 1200 times higher than plain concrete and 12 times greater than dowel-reinforced conventional concrete.

Halit-Yazici et al. (2006, 2010) studied the effects of high-volume Class-C fly ash and mineral admixtures on autoclaved SIFCON, finding improvements in toughness, flexural strength, and fracture energy. A remarkable 3107-fold increase in fracture energy was observed with steel fiber addition. Rafat Siddique (2008) assessed natural fiber-reinforced concrete

containing high Class-F fly ash volumes. They found that while fiber addition increased impact strength and fracture toughness, excessive fly ash reduced compressive strength and fracture properties. Nili and Afroughsabet (2010) examined the synergy between silica fume and steel fibers. Results demonstrated enhanced mechanical performance and impact resistance, particularly in terms of ductility. Sudarsana Rao et al. (2010) experimentally compared SIFCON slabs with PCC, RCC, and FRC under impact loading. SIFCON slabs containing 12% fiber volume outperformed those containing other percentages in both strength and energy absorption. Regression models were developed to evaluate energy dissipation. Murat Tuyan and Halit Yazici (2012) observed that longer and hooked-end fibers improved bond strength and durability in SIFCON. Tarek Almusallam et al. (2013) concluded that hybrid fibers reduce cracking and spalling under projectile impact. Senthilvadivel et al. (2014) showed that adding 6% waste rubber enhanced ductility and impact resistance. Similarly, Trevor Hrynyk (2014) reported that steel fiber-reinforced slabs performed better under impact than conventional RC slabs, with reduced crack width and spacing. Murnal and Chatorikar (2015) using ACI-544 guidelines, found that increasing hooked-end fiber content (0.5-2.5%) improved FRC's impact resistance. Mastali et al. (2015) tested functionally graded concrete slabs and concluded that impact resistance can be optimized by controlling fiber content and layering. Trilok Gupta et al. (2015) observed that rubber fibers improved energy absorption and ductility, while silica fume enhanced impact resistance, but slightly reduced ductility. Saravana Raja Mohan and Sumathi (2015) highlighted the balancing role of fibers in offsetting strength loss due to fly ash, identifying an optimal mix with 0.15% polypropylene fibers and 15% fly ash. Vijaya Bhaskar Reddy Sudha and Srinivasa Rao (2016) confirmed that steel fibers in ternary blended concrete improve impact resistance. Javad Yahaghi et al. (2016) showed that polypropylene fiber-reinforced oil palm shell concrete gained better crack and impact resistance with increased fiber content and slab thickness.

Hai Cao (2017) demonstrated that basalt fibers improved all strength aspects—compressive, tensile, and flexural—and significantly enhanced toughness and durability. Doo-Yeol Yoo and Nemkumar Banthia (2017) showed that ultra-high-performance fiber-

reinforced concrete (UHPFRC) displayed superior energy absorption, especially when fibers aligned with tensile stress directions. Grzegorz Ludwik Godlewski (2017) studied coal fly ash (CFA) in green concrete and observed an initial improvement in fracture toughness, which declined at 30% CFA replacement. Wenjie Wang and Nawawi Chow (2018) found that flax fiber-reinforced polymer (FFRP) strengthened coconut fiber-reinforced concrete (CFRC) slabs offered superior impact resistance and structural integrity. Elavarasi and Raja Mohan (2018) examined the low-velocity impact response of thin SIFCON slabs, with and without reinforcement, using drop-hammer tests. PCC and RCC slabs were tested for comparison. The study evaluated crack resistance, energy absorption, ductility, and failure patterns. SIFCON slabs with silica fume and slag blends demonstrated superior strength and durability. Sancheti et al. (2020) explored sustainable alternatives using marble waste and fly ash. They identified optimal replacement ratios—10% marble powder and 20% fly ash for enhancing concrete durability and mechanical properties, contributing to environmental sustainability. Msheer Hasan Ali et al. (2022) investigated the mechanical performance of SIFCON, focusing on compressive, flexural, and splitting tensile strengths. Their study revealed that fiber volume plays a critical role in strength development. Under standard curing, a 7.5% steel fiber content yielded optimal performance, while under accelerated (boiling water) curing, strength peaked at 10% fiber content. The addition of high-silica Class-F fly ash further enhanced mechanical properties, especially when used with higher fiber volumes. Fengshan Liu et al. (2025) studied the compressive behavior of SIFCON reinforced with arc-shaped (IBA) and hooked-end (2BS) fibers using uniaxial compression tests. The results indicated that lower hydrogel content led to increased compressive strength, and a reduced water-cement ratio improved strain capacity. SIFCON with arc-shaped fibers demonstrated superior ductility and energy absorption compared to hooked-end fibers, likely due to better fiber interlocking.

Due to its exceptional ductility and energy absorption capabilities, SIFCON is a promising candidate for applications subjected to high impact or dynamic loading. Despite encouraging findings, limited research exists on SIFCON's performance under impact loading. This study addresses that gap by investigating the combined effect of binary cementitious materials

and fiber content on SIFCON under impact conditions.

## RESEARCH SIGNIFICANCE

Although some studies have explored the impact response of Slurry Infiltrated Fibrous Concrete (SIFCON), the available information remains fragmented and lacks comprehensive correlation. This gap in the literature makes it difficult to draw consistent and reliable conclusions regarding the impact behavior of SIFCON. As a result, there is a clear need for focused research that provides deeper insights into its mechanical performance under dynamic loading. In particular, experimental investigations that simulate real-world impact scenarios—such as drop-weight loading—are essential to better understand the material's structural response. This study addresses this gap by evaluating the performance of SIFCON under falling weight impact conditions. Key parameters under investigation include the number of blows required to initiate visible cracking, the number of blows leading to failure, and the corresponding energy absorption capacity at each stage. By quantifying these factors, the study aims to enhance understanding of SIFCON's suitability for applications where impact resistance is critical.

## EXPERIMENTAL PROGRAM

### Materials Used

#### Ordinary Portland Cement

Ordinary Portland Cement (OPC) with 53 grade obtained from local market was used. The physical properties, such as specific gravity, initial setting time and final setting time, were examined conducted in accordance with IS 12269 (1987). The specific gravity, initial setting and final setting times were found to be 3.10, 30 minutes and 360 minutes, respectively.

#### Class-F Fly Ash

In the present study, Neyveli F-Class fly ash was utilized. Its physical properties are listed below as per ASTM C618 standard (1989).

#### Steel Fiber

Hooked-end steel fiber of 1.00 mm diameter and 30 mm length giving an aspect ratio of 30, was used. The hooks at the ends provide better bond with the matrix.

This controls cracking which occurs in the hardened state. The fiber is oriented in a random manner.

**Fine Aggregate**

Sand used for the experimental program was locally procured and confirmed to grading III of Indian Standard Specifications IS: 383-1970. Sieve-analysis test was conducted to find the fineness modulus of fine aggregate which was obtained as 3.39 as per IS 2386-IS Code of Practice for Methods of Test for Aggregates.

**Water**

Fresh and portable water, which is available from local sources, having a pH value of 7 conforming to IS 456-2000 is used in the test program.

**Chemical Admixture**

In combinations, a high-range water reduction agent,

known as CONPLAST-430, has been applied when well-dispersed particle suspensions are required to enhance SIFCON's performance. These polymers are employed as dispersants to enhance flow properties and inhibit particle separation.

**Mix Proportions**

The primary variables in the mix proportioning are fiber content and matrix composition. The fiber volume fraction is commonly controlled by the placement technique and the fiber geometry. Superplasticizers (SPs) can be used, if necessary, to improve the flowability of the slurry, which should be liquid enough to flow through the dense fiber bed without leaving honey combs. The mix proportions of SIFCON matrix from the wet density of SIFCON are presented in Table 1.

**Table 1. Mix proportions of SIFCON with binary blend of fly ash**

Type of mix	Cement kg/m <sup>3</sup>	Fly ash kg/m <sup>3</sup>	Sand kg/m <sup>3</sup>	Fiber kg/m <sup>3</sup>	Water lit./m <sup>3</sup>	SP lit./m <sup>3</sup>	Mode of compaction
SIF6FA0	950	-	950	471	380	19	Hand
SIF6FA10	855	95	950	471	380	19	Hand
SIF6FA20	760	190	950	471	380	19	Hand
SIF6FA30	665	285	950	471	380	19	Hand
SIF6FA40	570	380	950	471	380	19	Hand
SIF6FA50	475	475	950	471	380	19	Hand
SIF8FA0	950	-	950	628	380	19	Hand
SIF8FA10	855	95	950	628	380	19	Hand
SIF8FA20	760	190	950	628	380	19	Hand
SIF8FA30	665	285	950	628	380	19	Hand
SIF8FA40	570	380	950	628	380	19	Hand
SIF8FA50	475	475	950	628	380	19	Hand
SIF10FA0	950	-	950	785	380	19	Hand
SIF10FA10	855	95	950	785	380	19	Hand
SIF10FA20	760	190	950	785	380	19	Hand
SIF10FA30	665	285	950	785	380	19	Hand
SIF10FA40	570	380	950	785	380	19	Hand
SIF10FA50	475	475	950	785	380	19	Hand

SIF6, SIF8 & SIF10 indicates SIFCON containing 6, 8 & 10% fibre content by volume fraction

FA0, FA10, FA20, FA30, FA40 & FA50 indicate the replacement level of cement by fly ash (0, 10, 20, 30, 40 & 50%).

**Mixing and Casting of Specimens**

SIFCON, also known as pre-placed fibre concrete, is produced by first placing steel fibers into a form or mould. During this stage, a slight external vibration is

applied to assist with fiber installation. The amount of steel fiber used depends on the packing density, which is influenced by the fiber's length and aspect ratio. Once the fibers are securely positioned, a fine-grained

cement-based slurry is poured over the packed fiber bed. A vibrator is then employed to ensure that the slurry fully penetrates the fiber network. To achieve the appropriate slurry viscosity, the high-range water reducer Conplast-420 is added.

**Low-velocity Impact Test**

The energy-absorption capacity and crack resistance of SIFCON containing different fiber contents with partial substitution of cement by fly ash concrete were conducted on a cylindrical specimen of 150-mm diameter and 60-mm height subjected to impact test. A self-fabricated drop-weight impact test setup was used to assess the impact resistance of slurry-infiltrated fibrous concrete with partial fly ash substitution, following the ACI 544-89 (1989) standard, as shown in Fig. 1(a) & (b). The device includes a 4.5-kg steel ball attached to a steel rope, which passes through a frictionless pulley. The ball is manually released from a height of 457 mm, striking the center of the specimen on the holder. The number of blows at the initial and ultimate cracks was recorded, and the total crack

lengths, widths, and depths at both the first crack and the ultimate (failure) crack were measured using a feeler gauge. The computation of impact and crack resistance parameters is based on Equations (1-3), which establish the relationship between the potential energy of the drop-weight projectile and the strain energy dissipated during crack formation.

$$E = m * g * h \tag{1}$$

$$E_1 = E * N_1 \tag{2}$$

$$E_2 = E * N_2 \tag{3}$$

where

m = ball mass (4.5 kg).

g = acceleration due to gravity (9.81 m/s<sup>2</sup>).

h = dropping height (457 mm).

N<sub>1</sub> & N<sub>2</sub>= Number of blows at first crack and at ultimate failure.

E<sub>1</sub> & E<sub>2</sub> = Energy absorption at first crack and at ultimate failure in Joules.



**Figure (1a): Drop-weight impact loading test setup**



**Figure (1b): Specimen details  
150 mm diameter & 60 mm  
height**

The width, depth, and length of the developed crack, along with its failure mode, were recorded, and the corresponding energy absorption and crack resistance were calculated. A relationship between the potential energy (PE) of impact loading from a falling body and the strain energy dissipated in the resulting cracks within a target can be derived using fundamental principles of

the strength of materials, and is expressed as follows. The ultimate Crack resistance was calculated using Equation (4) as proposed by Kankam (1999).

$$R_u = E_2 / (L_c * D_c * W_c) \tag{4}$$

where

$R_u$  = ultimate crack resistance ( $N/mm^2$ ),  $L_c$  = total length of all cracks (mm).

$D_c$  = maximum crack depth (mm).

$W_c$  = maximum crack width (mm).

The impact residual strength (IRS) ratio was defined as the ratio of the ultimate impact energy to the first-crack energy, as presented in Equation (5) as proposed by Ramakrishna and Sundararajan (2005).

$$IRS = E_2 / E_1 \quad (5)$$

where,

$IRS$  represents the impact residual strength ratio,

$E_1$  is the service impact energy (J), and  $E_2$  is the ultimate impact energy (J).

The impact residual strength ratio facilitated the evaluation of the post-crack behaviour of the composites and served as an indicator of the ductility imparted by the fibre incorporated into the matrix

## RESULTS AND DISCUSSION

### Energy Absorption Capacity

Figures (2, 3, and 4) illustrate the energy absorption of SIFCON at first crack and ultimate failure for varying fiber contents and fly-ash replacement levels. The results confirm that the impact strength of SIFCON improves with optimized fiber volume and partial cement replacement using fly ash.

SIFCON with 6% fiber content consistently demonstrated superior energy absorption across all fly-ash replacement levels, as illustrated in Figure (2). Notably, the inclusion of 30% fly ash yielded the highest improvement in both first crack and ultimate energy absorption. This enhancement is primarily attributed to the improved flowability of the slurry with fly ash, which facilitates better infiltration into the fiber network and promotes stronger fiber-matrix bonding. At 6% fiber content, the increase in energy absorption at the first crack stage with 10%, 20%, 30%, 40%, and 50% fly-ash replacement was 33.3%, 66.7%, 116.7%, 50%, and 50%, respectively, compared to the mix without fly ash. The corresponding increases at the ultimate-failure stage were 44.8%, 48.3%, 82.7%, 37.9%, and 44.8%, respectively. These findings highlight the effectiveness of a 30% fly-ash replacement in enhancing SIFCON's impact resistance performance.

Figure (3) presents the energy absorption capacity of

SIFCON with 8% fiber content at various fly-ash replacement levels. The results show that incorporating fly ash enhances energy absorption at both the first crack and ultimate failure stages, primarily due to improved slurry flowability and better fiber-matrix bonding. The refinement of pore structure through C-S-H gel formation also contributes to this improvement. At 8% fiber content, the first-crack energy absorption increased by 0%, 28.6%, 42.8%, 28.6%, and 0%, while the ultimate energy absorption rose by 29%, 16.1%, 48.4%, 22.6%, and 19.4% for 10%, 20%, 30%, 40%, and 50% fly-ash replacement, respectively. The highest energy absorption was observed at 30% replacement. Beyond this level, excessive fly ash adversely affected strength and caused excessive workability, reducing the effectiveness of fiber bridging.

Figure (4) shows that SIFCON with 10% fiber content exhibited reduced first-crack energy absorption at all fly-ash replacement levels compared to the mix without fly ash. This decline is attributed to poor slurry infiltration due to fiber clustering, which weakens the matrix-fiber bond. However, at 30% fly-ash replacement, the ultimate energy absorption was higher than at other fly-ash replacement levels.

Overall, the experimental results indicate that SIFCON with 6% fiber content and 30% fly-ash replacement exhibited the best energy absorption performance. Thus, 30% fly-ash replacement is considered the optimal dosage across different fiber volume fractions for enhancing impact resistance.

### Post-crack Resistance

Table 2 presents the post-crack resistance of SIFCON mixes, calculated as the ratio of the difference between the number of blows at ultimate failure and first crack to the number of blows at first crack. Among all mixes, SIFCON with 6%, 8%, and 10% fiber content combined with 30% fly-ash replacement exhibited the highest post-crack resistance.

The improvement is primarily due to the synergistic effect of fly ash and steel fibers, which enhances ductility and effectively arrests crack propagation through a strong fiber-bridging mechanism. For mixes with 6% and 8% fiber content, fly ash increased the number of blows required to initiate the first crack, indicating enhanced matrix-fiber bonding. However, for the 10% fiber volume mix, the addition of fly ash

reduced the first-crack resistance. This may be attributed to poor slurry infiltration caused by fiber clustering,

which weakens the bond between fibers and the matrix.

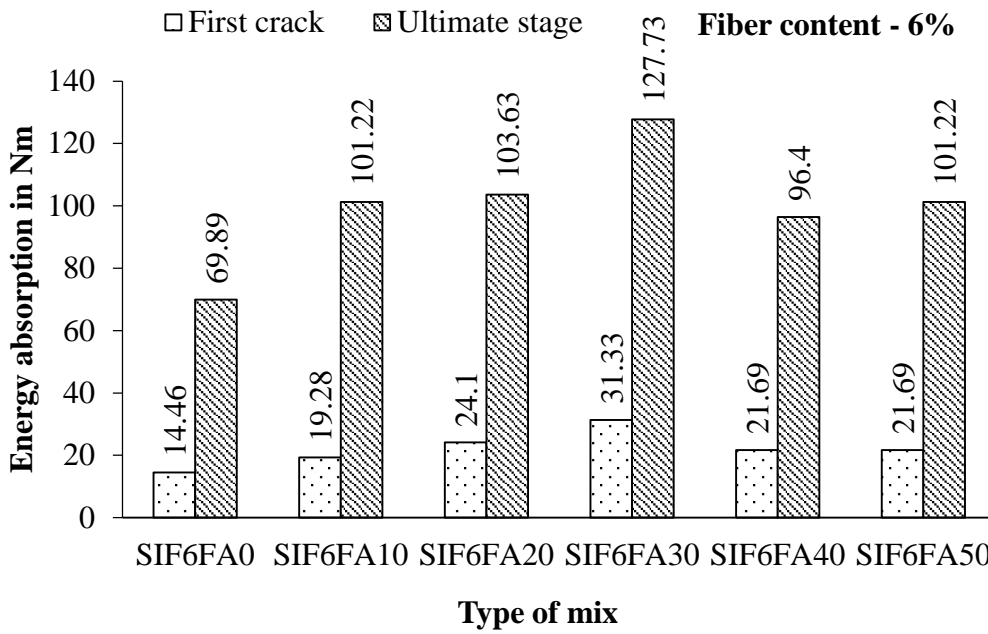


Figure (2): Type of mix vs. energy absorption (6%)

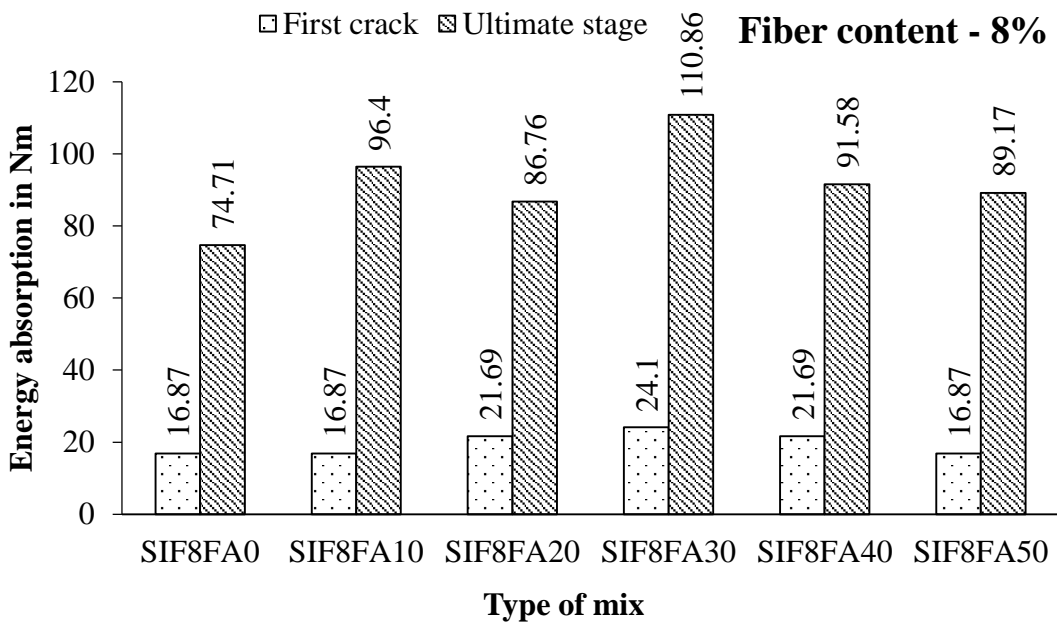


Figure (3): Type of mix vs. energy absorption (8%)

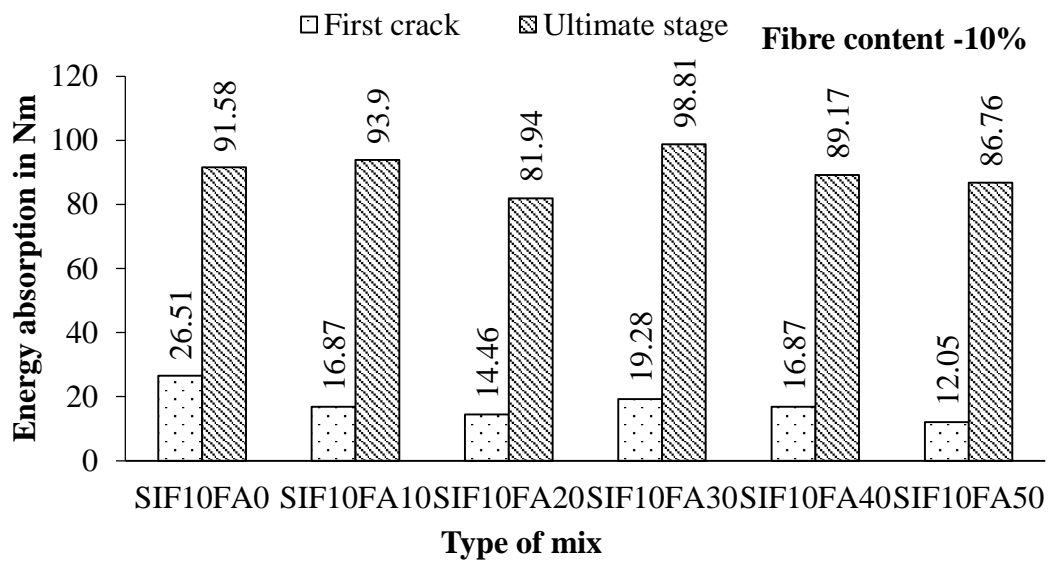


Figure (4): Type of mix vs. energy absorption (10%)

Table 2. Post-crack resistance of various mixes

Type of mix	No. of blows required at		Blows' difference $N_2 - N_1$	% of post-crack resistance $(N_2 - N_1) / N_1 \times 100$	Ductility index $(N_2/N_1)$
	First crack ( $N_1$ )	Ultimate failure ( $N_2$ )			
SIF6FA0	6	29	23	383.3	4.83
SIF6FA10	8	42	34	425	5.25
SIF6FA20	10	43	33	333	4.3
SIF6FA30	13	53	40	307.7	4.1
SIF6FA40	9	40	31	344.4	4.44
SIF6FA50	9	42	33	366.7	4.67
SIF8FA0	7	31	24	342.8	4.42
SIF8FA10	7	40	33	471.4	5.71
SIF8FA20	9	36	27	300	4.0
SIF8FA30	10	46	36	460	4.6
SIF8FA40	9	38	29	322.2	4.22
SIF8FA50	7	37	30	428.5	5.28
SIF10FA0	11	38	27	245.4	3.45
SIF10FA10	7	39	32	457.1	5.56
SIF10FA20	6	34	28	466.7	5.61
SIF10FA30	8	41	33	412.5	5.12
SIF10FA40	7	37	30	428.6	5.28
SIF10FA50	5	36	31	620	7.2

**Impact Residual Strength Ratio**

The ductility index, defined as the ratio of ultimate energy absorption to first-crack energy absorption, is illustrated in Fig. (5). Results indicate that in the absence of fly ash, the ductility index decreases with increasing

fiber content, likely due to higher energy absorption at the first crack stage reducing the ratio.

However, incorporating fly ash particularly with 10% fiber content significantly improves the ductility index. SIFCON mixes with fly ash exhibited higher

residual impact strength at all replacement levels, with the 10% fiber and 10% fly ash mix showing the most notable enhancement. This improvement is attributed to

reduced energy required for crack initiation and better matrix-fiber bonding.

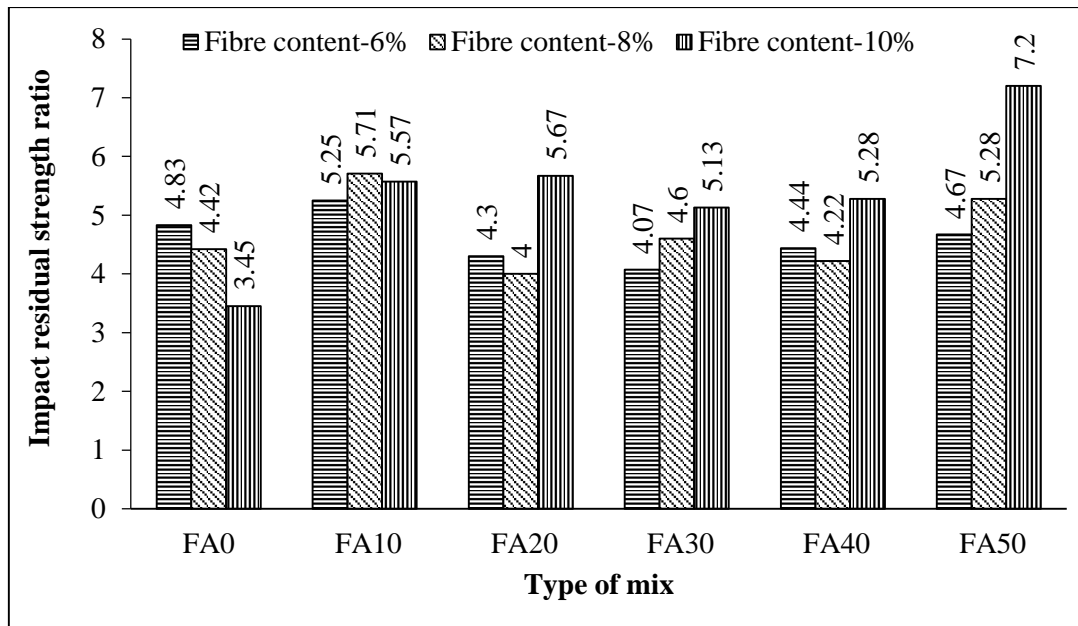


Figure (5): Impact residual strength ratio

**Crack Resistance at Ultimate Failure**

Figure (6) illustrates the ultimate crack resistance of SIFCON with varying fiber contents and fly-ash replacements. Results show that increasing fiber content reduces crack resistance, likely due to greater energy absorption causing wider cracks. However, the addition

of fly ash enhances matrix bonding and helps control crack propagation. Among all mixes, SIFCON with 6% fiber and 30% fly ash exhibited the highest crack resistance, attributed to its superior energy absorption at the ultimate stage.

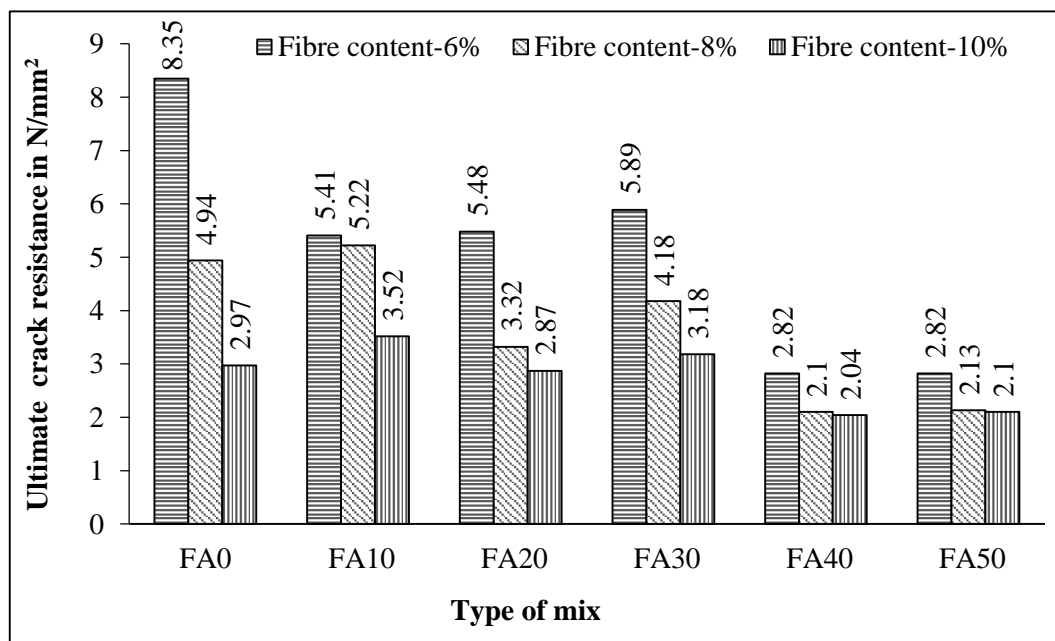


Figure (6): Ultimate crack resistance

**Mode of Failure**

Table 3 shows the ultimate crack lengths and maximum crack widths measured using a feeler gauge. In SIFCON without fly ash, both crack length and width increased with higher fiber content due to greater energy

absorption. However, the incorporation of fly ash enhanced the fiber-bridging mechanism, improving matrix bonding and reducing crack width by limiting crack formation and propagation.

**Table 3. Measurements of cracks at the ultimate stage**

Type of mix	Total length of cracks (Lc) mm	Max. width of crack (Wc) mm	Max. Depth of crack (Dc) mm	Ultimate energy absorption in Nm	Ultimate crack resistance in Nmm <sup>2</sup>
SIF6FA0	310	0.45	60	69.89	8.35
SIF6FA10	260	1.20	60	101.22	5.41
SIF6FA20	300	1.05	60	103.63	5.48
SIF6FA30	280	1.29	60	127.73	5.89
SIF6FA40	320	1.78	60	96.4	2.82
SIF6FA50	290	2.06	60	101.22	2.82
SIF8FA0	360	0.7	60	74.71	4.94
SIF8FA10	290	1.06	60	96.4	5.22
SIF8FA20	340	1.28	60	86.76	3.32
SIF8FA30	320	1.38	60	110.86	4.18
SIF8FA40	350	2.07	60	91.58	2.10
SIF8FA50	350	1.99	60	89.17	2.13
SIF10FA0	380	1.35	60	91.58	2.97
SIF10FA10	350	1.27	60	93.9	3.52
SIF10FA20	390	1.22	60	81.94	2.87
SIF10FA30	330	1.57	60	98.81	3.18
SIF10FA40	370	1.97	60	89.17	2.04
SIF10FA50	320	2.15	60	86.76	2.10

**CONCLUSIONS**

Based on the experimental investigation on the low-velocity impact resistance of SIFCON with varying fiber contents and partial cement replacement by fly ash, the following conclusions were drawn:

- Energy absorption at both first crack and ultimate failure increased with higher fiber content.
- The addition of fly ash significantly improved energy absorption in SIFCON containing 6% and 8% fibers, at all fly-ash replacement levels.
- SIFCON with 6% fiber and 30% fly ash exhibited the best performance in terms of energy absorption and crack resistance.

- In SIFCON with 10% fiber, fly ash enhanced ultimate energy absorption, but reduced energy absorption at first crack, likely due to changes in ductility.
- Crack resistance was highest in the mix with 6% fiber and 30% fly ash, due to improved fiber bridging and matrix bonding.
- Using 30% fly ash as a partial cement replacement is not only effective in enhancing impact strength, but also contributes to sustainable concrete production.
- For improved impact resistance and workability, a mix of 6% fiber and 30% fly ash is recommended.
- Further studies are needed to evaluate the behavior of SIFCON using steel fibers with higher aspect ratios under both static and impact loading conditions.

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