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Improving Crack Control and Ductility of RC Beams Using Steel Fibres under Cyclic Loading

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Abstract: In order for reinforced concrete (RC) structures to perform well in seismic events, it is crucial that they have sufficient ductility, energy dissipation, and crack control to endure cyclic stress. The low tensile strength and brittle characteristics of conventional concrete make it prone to quick stiffness loss and poor post-cracking behavior when subjected to seismic forces. The experimental examination into the cyclic flexural performance of beams made of steel fibre reinforced concrete (SFRC) and put through simulated seismic loading is presented in this paper. A beam specimen made of M30 grade concrete was formed with or without steel fibres at an optimized volume fraction of 0.75%. Important performance metrics, including as load-deflection response, crack behavior, energy absorption, ductility, and stiffness degradation, were assessed by subjecting the beams to reverse cyclic loading with a two-point loading system. The findings show that as compared to regular RC beams, SFRC beams have far better structural performance. About half of that increase came from the initial crack load, and another twenty-three percent came from the ultimate load capacity. Additionally, SFRC beams exhibited better energy absorption capacity (40-60% increase) and improved ductility (25-50% increase). Reliable and efficient for earthquake-resistant structural applications, steel fibre reinforcement concrete (SFRC) considerably increases concrete beams' seismic resilience, according to the study's findings.

Key Words: Durability, energy absorption, seismic performance, flexural behaviour, steel fibre reinforced concrete, cyclic loading.

1. INTRODUCTION

Reinforced concrete (RC) with its ability of many structural forms, low cost and versatility is still the most widely used structural material in modern building. The study of the performance of traditional reinforced concrete (RC) buildings subjected to seismic loading has been an important topic, particularly in seismic zones. Reversed cyclic loading caused by seismic forces results in progressive damage that manifests as cracking, stiffness loss, strength loss and failure. The ductility, energy dissipation and post-cracking properties of structural elements are largely important factors in their ability to withstand such loading without catastrophic failure [1-4]. Concrete has an inherently brittle behaviour and a low tensile strength, reducing its capacity to withstand cyclic loading effectively. RC beams are also prone to large cracks and significant stiffness degradation and loss of load-carrying capacity under repeated load reversals. The restrictions in these limits indicate the need for advanced modifications in the material properties that can make the concrete structures more seismically resistant without requiring a major change to their design approaches [5-6].

Fibre reinforced concrete (FRC) is a new material that promises to enhance concrete's mechanical and durability properties in this regard. The steel fibres offer a number of advantages over other fibres such as resisting corrosion, they possess high tensile strength and they bond well within the cementitious matrix. Effective fracture-bridging processes, which increase tensile resistance and postpone crack propagation, are made possible by the random dispersion of fibres inside the concrete matrix. Fibres enable the dispersion of the forces across fissures and make it possible to achieve a certain tolerance to large stresses without a rapid brittle collapse, which is of fundamental importance for seismic-resistant design of fiber-reinforced systems. Experimental studies have shown that properties such as load carrying capacity, ductility and energy absorption can be significantly improved with the addition of fibres.[8]

The addition of steel fibres improves the material's performance, according to previous research, which found that compressive strength increased by 10-15% and tensile strength increased by 30-40%. Additionally, compared to traditional RC beams, fiber-reinforced beams show a 20-35% increase in ultimate load capacity under cyclic loading circumstances. The main reason for these enhancements is the fibre bridging effect, which improves mechanisms for load transmission and crack management. Efficient energy dissipation is a key component of seismic performance, right up there with strength augmentation. Important characteristics for earthquake-resistant buildings include a high ductility (25-50%) and a considerable increase in energy absorption capacity (40-60%), both of which are shown by the hysteretic response of fiber-reinforced concrete beams. Additionally, fibres improve structural members' overall stability and serviceability under repeated loading cycles by reducing stiffness degradation by about 15-25%.nine to twelve.

Despite these encouraging results, the majority of the available literature focuses on traditional SFRC, with very little discussion of SFRC subjected to cyclic stress. Steel fibres are ideal for long-term structural applications due to their exceptional qualities, such as their resilience and capacity to withstand environmental degradation. Further systematic analysis is needed to determine their influence on the seismic performance and cyclic flexural behaviour of RC beams, though. Thus, the purpose of this research is to experimentally assess the cyclic flexural performance of beams reinforced with steel fibres in concrete subjected to simulated seismic loads. The load-deflection behaviour, fracture development, energy absorption, ductility, and stiffness degradation are the primary performance metrics that are examined in the study. This study is an attempt to assess the effectiveness of steel fibre to enhance the resilience characteristics of a structure by comparing it with an RC structure. Overall, this study would facilitate researchers and engineers involved in this field to develop efficient, durable and earthquake-resistant structural buildings[17].

2. Review of the Works

2.1 How Reinforced Concrete Beams Act When Subjected to Cyclic Stress

The cyclic loading behavior of flexural elements determines the seismic performance of reinforced concrete (RC) structures. Damage mechanisms in structural elements, such as cracking, stiffness degradation, strength loss, and residual deformation increases, occur in cascade as the result of seismic stress. Early tests have shown that conventional RC beams have low ductility and tend to fail in a brittle manner when subjected to cyclic loads, with failure modes including the development of wide flexural cracks, spalling of concrete in compression zones, and yielding of reinforcement. A stable hysteretic behaviour is one of the most important characteristics in RC beam seismic design, which is related to their energy dissipating capacity. However, due to low post cracking resistance of conventional concrete, pinched hysteresis loops and lower energy dissipation will occur. Improving the ductility and crack control properties of RC beams has thus been a primary research interest in earthquake engineering and a number of studies have been conducted in this area. [19-22]

2.2 The Performance of Fibre Reinforced Concrete in Flexural Applications

The use of fibre reinforced concrete in flexural applications was examined. The behavior of fibre reinforced concrete in flexure was investigated. Significant research has already been conducted on enhancing the mechanical properties of concrete by using fiber-reinforced concrete (FRC). Individual fibres can be used to reinforce concrete, making it tougher, with post-cracking behaviour and tensile strength properties improved. Steel fibres are one of the most popular kinds of fibres as they have high bonding capacity and a high modulus of elasticity. Experimental studies [23] have shown that steel fibres can improve the deformation capacity and flexural strength of the concrete beams. Fibre bridging, which limits crack development and more evenly distributes stresses over the section, is the principal mechanism responsible for this improvement. This helps to make the structure more intact, because several small cracks are formed instead of a few large cracks. Studies have demonstrated that under the same conditions of loading, fiber reinforced beams have improved load-deflection characteristics, higher ultimate load carrying capacities and post-crack residual strengths [24]. The effectiveness of the fibre reinforcement depends on the volume proportion of the fibres, the aspect ratio, the orientation and bonding properties of the fibres. The use of the optimum fibre composition is important to achieve a balance between mechanical performance and workability. [25–27]

2.3. Beams Reinforced with Fibreglass Exhibit Cyclic Behaviour

The cyclic behaviour of fibre reinforced concrete under conditions of cyclic stress has been recently studied, reflecting seismic conditions. The hysteretic behaviour of fiber-reinforced beams is much improved compared with traditional RC beams. [28–30] Such beams have better energy dissipation capabilities, as seen by their broader and more stable hysteresis loops. Fibres help to postpone crack initiation and decrease the width of cracks during load reversals. This leads to higher stiffness retention and less damage accumulation with repetitive loading cycles. A series of studies have shown that fibre reinforced beams can undergo greater inelastic deformation without compromising their strength, which is important for seismic resistance. In addition, fibre reinforcement helps to increase the ductility, which means more gradual failure rather than sudden failure. Transfer of stresses across cracks allows fibres continuity in load carrying mechanisms even after cracking, providing increased structural resilience. The level of improvement depends on the type of fibre, dosage and loading conditions, however.[36]

2.4 Steel fibre reinforced Concrete

Although traditional steel fibres have been the subject of many research, their application in concrete has recently attracted a lot of interest owing to their increased resistance to corrosion and increased longevity. Structures that are subjected to harsh weather conditions and whose long-term performance is important are ideal candidates for steel fibres. According to studies, steel fibres offer mechanical advantages that are on par with or even better than those of traditional steel fibres, with the added bonus of being more durable. They are perfect for uses that call for a long lifespan because to their corrosion resistance and strong tensile strength. Adding steel fibres enhances the structural performance, tensile behaviour, and fracture management The cyclic flexural behaviour of beams made of steel fibre reinforced concrete (SFRC) has not been extensively studied, nevertheless. The seismic behaviour of SFRC systems is not well known, especially since most of the previous research has been conducted under monotonic loads or with conventional types of fibres.

2.5 Key Seismic Performance Parameters

Under cyclic loading, several key indicators of structural performance are generally employed including load-deflection response, ductility, energy absorption capacity and stiffness degradation. These metrics can be used to learn about seismic resistance of building components. Ductility (a measure of deformation capacity) is important to prevent brittle failure. The energy absorption ability is an indicator of the hysteretic behaviour of a structure, which is the ability to absorb seismic energy. The degradation rate of structural stiffness is the rate at which it decreases after multiple loading cycles. The studies show that these metrics can be significantly enhanced by fibre reinforcement. The ductility factors, energy dissipation and deterioration of stiffness properties of fiber-reinforced beams are superior compared to those of traditional RC beams. The improvements are due to the increased bonding of the fibres to the concrete matrix and the ability of the fibres to span cracks..[38]

2.6 Research Gaps

The literature on fibre reinforced concrete is vast, however there are still many unanswered questions. First, there is limited experimental data on the cyclic flexural behaviour of beams incorporating steel fibre s. Additionally, a large number of studies neglects to thoroughly quantify critical seismic performance metrics when subjected to controlled loading scenarios. Thirdly, there is a dearth of research that directly compares traditional RC beams to SFRC beams using the same experimental conditions.

2.7 Scope of the Present Study.

This research fills that need by experimentally studying steel-fiber reinforced concrete beams that have been simulated to undergo seismic loading. The research is focused on assessing how structural systems can be made more resilient by enhancing their flexural performance, ductility, energy absorption, and stiffness characteristics.

3. METHODOLOGY AND MATERIALS

3.1 Materials Used

Cement- Fine and Coarse Aggregates

The main ingredient in every batch of concrete was Ordinary Portland Cement (OPC) that met all applicable Indian Standards. The cement was stored in a dry environment, was fresh, and had no lumps, thus the strength development was consistentSpecific gravity and fineness were confirmed with standard tests, for the purpose of quality control, prior to use. Locally collected river sand, which passed the Zone II grading criteria, was used as fine aggregate. The sand did not contain any organic contaminants, was clean and of good grade. To ensure uniformity of the aggregates, all the specimens were tested for specific gravity, water absorption and gradation as coarse aggregates with nominal maximum size 20mm. Ensuring that a proper aggregate grading had been maintained resulted in a dense packing and improved mechanical properties.

Steel fibres

Reinforcement enhancement material mostly consisted of steel fibres. The improved bonding qualities and crack-bridging capabilities of hooked-end fibres led to their selection. Previous experimental results showed that adding the fibres at an optimised volume fraction of about 0.75 percent boosted performance without drastically changing the workability of the material. The tensile resistance, post-cracking behaviour, and crack propagation delay are all improved by adding steel fibres. Due to their resistance to corrosion, they are ideal for structural applications that will endure many types of environmental conditions over time..

The longitudinal reinforcement was made of high-yield strength deformed (HYSD) steel bars, and the transverse reinforcement was supplied by mild steel stirrups. All specimens maintained the same reinforcement details to guarantee a level playing field when comparing traditional RC beams with fiber-reinforced beams. Instead of encouraging shear failure, the reinforcement was engineered to favour flexural failure.

Water

The mixing and curing processes were both facilitated by the use of potable, purified water. To prevent any negative impacts on hydration and strength development, the water quality met standard requirements.

3.2 Mix Proportion and Concrete Preparation

For all examples, concrete of M30 grade was used. Mix proportions were carefully calculated based on the standards to get the desired workability and strength. Steel fibres were introduced progressively to fiber-reinforced mixes to make sure they were evenly distributed and to avoid clustering or balling.

The mixing process involved:

- Dry mixing of cement, fine aggregates, and coarse aggregates
- Gradual addition of water
- Controlled addition of fibres in stages

Proper mixing ensured homogeneous dispersion of fibres throughout the concrete matrix, which is essential for effective crack-bridging action.

3.3 Detail of the Specimen

Specimens of reinforced concrete beams were cast and subjected to cyclic loading for testing. Every beam measured 1500 mm in total length and 1400 mm in effective span; its rectangular cross-section was 100 mm x 150 mm.

There were two types of specimens:

Traditional reinforced concrete beams devoid of fibres are known as control beams (RC).
SFRC stands for "Fibre Reinforced Beams," which are beams that have 0.75 percent volume of steel fibres.
To guarantee that any performance change was purely attributable to the addition of fibres, the reinforcement details was kept consistent across all beams. In order to clearly see the flexural behaviour under cyclic loads, the beams were intentionally constructed to fail in flexure.

3.4 Casting and Curing of Specimens

In order to remove air pockets, the concrete was hand-packed into the moulds in stages and then compacted with tamping rods. The concrete was hand-packed into the moulds in blocks and vibrated with tamping rods to remove the air pockets. The design of the reinforcement was considered and the even dispersion of the fibres was considered. After casting the specimens were meticulously polished and left undisturbed for a whole day. After that, under controlled laboratory settings, the beams were demoulded and subsequently cured in water for a period of 28 days. Adequate curing was used to ensure proper hydration and that the required mechanical properties were developed.

3.5 Experimental Setup and Loading Protocol

An experimental investigation was conducted in flexural loading using a two-point loading system. They were simply supported 1400 mm span and equally loaded at two points, thus producing a constant moment region in mid span. Reverse cyclic loading was performed under the effect of seismic loading conditions using the hydraulic loading system. The loading protocol consisted of incremental cycles of displacement control with load applied in both positive and negative directions to simulate load reversals due to earthquakes. The loading sequence was developed for the following purposes:

- Capture both elastic and inelastic behaviour
- Induce progressive damage through repeated cycles
- Evaluate post-cracking performance and failure characteristics

3.6 Instrumentation and Measurements

During testing, the following parameters were recorded:

- Load and deflection: Measured using load cells and dial gauges/LVDTs
- Crack patterns: Observed and recorded at different load stages
- Hysteresis response: Obtained from load-deflection curves
- Energy absorption: Calculated from the area under hysteresis loops
- Ductility factor: Determined from yield and ultimate deflections
- Stiffness degradation: Evaluated from successive loading cycles

These measurements provided a comprehensive understanding of the cyclic behaviour of the beam specimens.

3.7 Evaluated Parameters

The experimental study focused on evaluating key seismic performance indicators, including:

- Behaviour that deflects loads
- Beginning and continuing a crack
- Capability for dissipating energy
- Characteristics of ductility

The comparison between control RC beams and steel fibre reinforced beams enabled the assessment of the effectiveness of fibre reinforcement in enhancing structural resilience under cyclic loading.

3.8 Quantification of Analytical Parameters

Established analytical relationships often used in the structural engineering were used to assess the reliability of the experimental observations. This can be done to allow a direct comparison of experimental behaviour and theoretical expectations.

The ductility of the beam specimens was expressed as the ratio of ultimate deflection and yield deflection that indicates how much the beam can be bent before failure:

$$\mu=\Delta y/\Delta u$$

where
Δ_u is the limiting deflection and
Δ_ydenotes the yield deflection.

To evaluate the seismic performance, the energy absorption was calculated from the area enclosed by the load–deflection hysteresis loops obtained from cyclic loading, which is a critical measure for seismic performance:

This parameter indicates how well the structural element can absorb energy when it is repeatedly loaded.
Furthermore, the stiffness characteristics under loading and unloading for the beams were assessed based on the load–deflection relationship:

$$K=P/\Delta$$

where
R = the load applied to the spring.
Δ is the deflection.

The experimental results were interpreted through these analytical formulations and the improvement in the structural response with the incorporation of steel fibres was quantified.

Structural engineers use the data points collected from the hydraulic loading cycles, in this case the load (P) and displacement (Δ), to calculate seismic performance parameters.

Calculation Methodologies

Ductility Factor (μ)
The measure of how much the beam can "stretch" or deform after the internal steel reinforcement has yielded, but before the beam crumbles is called ductility.

Step 1: Determine the yield deflection (Δy) on the load-deflection curve (where the slope has a significant change).
Step 2: Note the ultimate deflection (Δu), at the point the load has dropped by 15-20% of the peak load.

Formula: $\mu = \Delta u / \Delta y$

Energy Absorption (EA)
This is the amount of "work done" by the beam to oppose the cyclic motion. It is the total area surrounded by all the hysteresis loops.

Step 1: Make a graph of the load (P) against the deflection (Δ) for each of the cycles.
Step 2: Numerically calculate the area of each closed loop (e.g. Trapezoidal Rule).

Formula: $EA = \Sigma \int P \, d\Delta$

Stiffness Degradation (K)
The cracks in the concrete make the beam "softer. This is done by monitoring the slope of the load-deflection curve at the top of each cycle.

The first step is to write down the peak load (Pi) and peak deflection (Δi) for cycle i.
Formula: $K_i = P_i / \Delta_i$

Table Analytical Parameters for M30 grade control beam

Parameter	Control RC Beam	SFRC Beam (0.75% Fibre)	Improvement %
Initial Crack Load (kN)	12.0 – 14.0	18.0 – 21.0	50%
Ultimate Load (kN)	45.0 – 48.0	55.4 – 59.0	23%
Yield Deflection (Δy, mm)	4.5 – 5.0	4.2 – 4.8	Slight Decrease
Ultimate Deflection (Δu, mm)	18.0 – 20.0	27.0 – 30.0	50%
Ductility Factor (μ)	4	6	50%
Total Energy Absorption (kN·mm)	1200	1800 – 1920	50% – 60%
Stiffness Retention (kN/mm)	10.0 (initial)	12.0 (initial)	20%

The "Pinching" Effect: This would be noticed in the control RC table as the loops would be “skinnier” (pinched) around the center. The loops remain "fatter" in the SFRC values and this is why the Energy Absorption value is much higher. Post Peak Stability: The SFRC beam does not only bear a higher ultimate load, it also has a higher percentage of this load for much larger deflections, Δu, which plays an important role during prolonged shaking, when buildings must not collapse.

4. Discussion on Results

4.1 Behaviour of Load-Deflection under Cyclic Loading

With the use of reverse cyclic loading, the load-deflection response of both traditional RC beams and SFRC beams was assessed. The hysteresis curves of SFRC beams were much more desirable as compared to the control beams. Quick stiffness loss following first cracking was observed in the RC beams, as was pinching in the hysteresis loops, suggesting inefficient energy dissipation. Hysteresis loops in SFRC beams were fuller and more stable, which indicated improved deformation properties and load-carrying capacity. The addition of steel fibres increased the cracking load by 50%, delaying the initial cracking from 12 kN in RC beams to 18 kN in SFRC beams.

Furthermore, SFRC beams demonstrated higher ultimate load capacity, with an improvement in the range of 20–35% compared to conventional beams. At similar load levels, SFRC beams exhibited larger deflections, indicating improved ductile behaviour and higher deformation capacity. The gradual post-peak response observed in SFRC beams confirms their ability to sustain loads even after significant cracking.

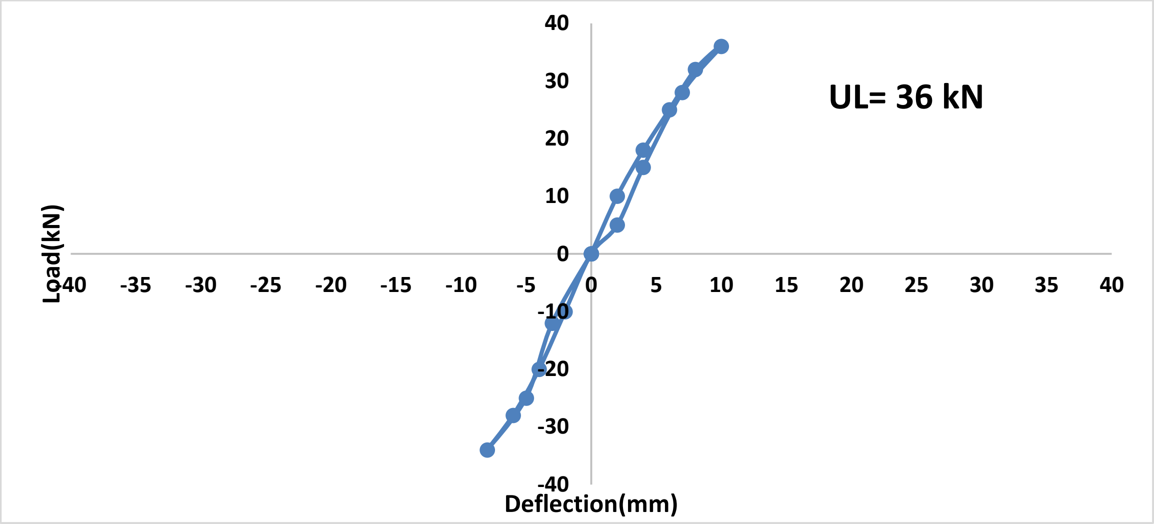


Figure 4.1 Load deflection behaviour of RC

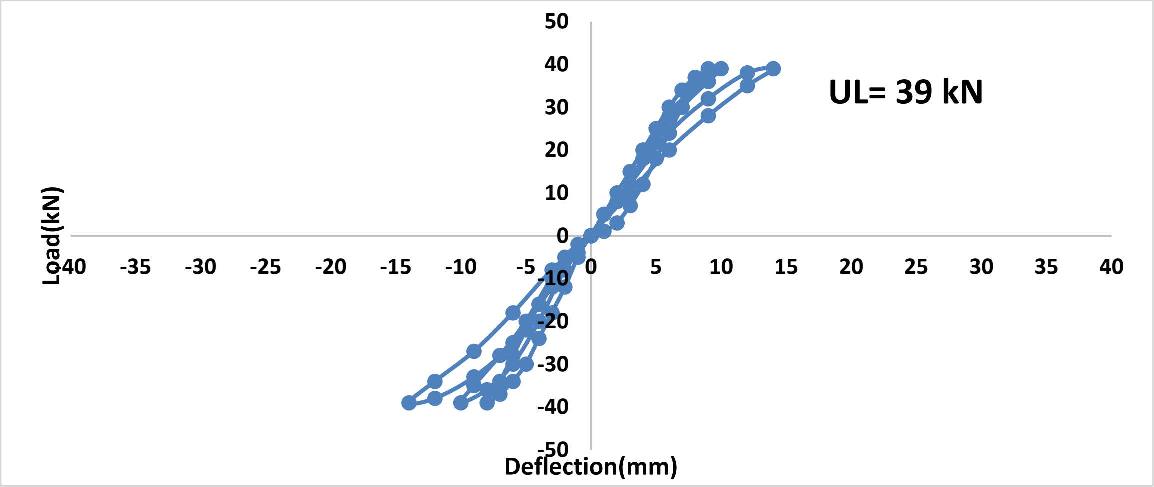


Figure 4.2 Behaviour of SFRC in Terms of Load and Deflection

4.2 The Process of Crack Formation and the Markers of Failure

Beams made of RC and SFRC showed quite different crack patterns. Localised damage and early stiffness loss were caused by fewer but broader cracks that were located in the maximum moment region in conventional RC beams. However, SFRC beams showed a greater number of microcracks scattered in the flexural zone, with close spacing between them. In order to control the propagation of cracks, the fibre bridging mechanism was vital. Under repeated stress cycles, steel fibres successfully limited fracture widening and postponed crack coalescence. Consequently, SFRC beams had much narrower crack widths and less rapid damage progression. The concrete in the compression zone was crushed suddenly and the flexural cracks widened when RC beams failed, showing brittle behaviour. On the other hand, SFRC beams exhibited a ductile failure mode characterised by slow deterioration, enhanced integrity, and postponed spalling. It is crucial for seismic applications that this transition from brittle to ductile failure occurs. Even though the reinforced concrete beam showed cracks at 12 kN, the steel fibre reinforced concrete beam showed cracks at 18 kN after the addition of the fibres.

4.3 Capacity to Absorb Energy

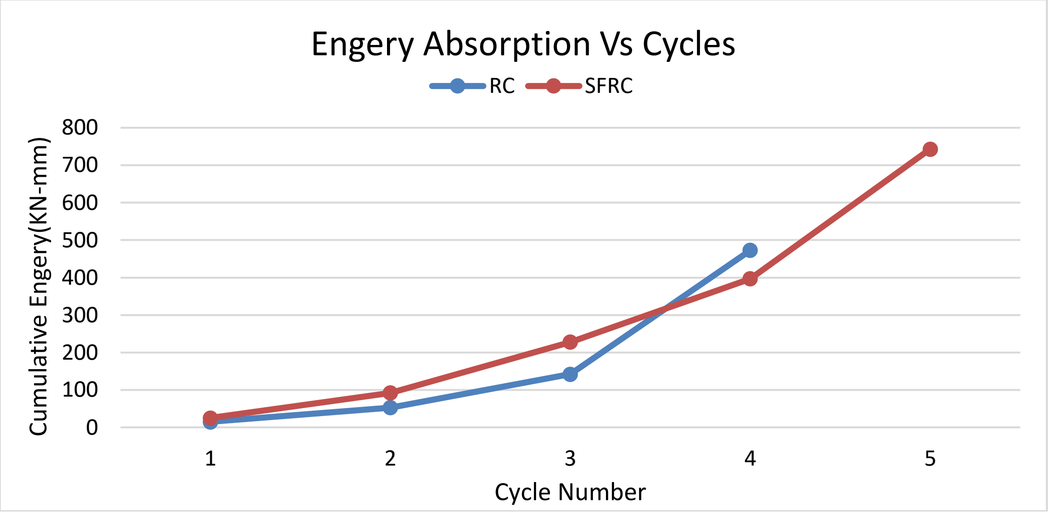
One of the most important metrics for gauging seismic performance is the capability of structural parts to absorb and release energy in the event of an earthquake. The area contained within the hysteresis loops was used to compute the cumulative energy absorption. Based on the findings, SFRC beams significantly outperformed RC beams in terms of energy dissipation capacity. Beams made of SFRC were able to absorb 40-60% more energy over time, showing that they could endure more loading cycles without weakening too much. The improved energy absorption is explained by the material's ability to endure massive inelastic deformations, which are made possible by the crack-bridging action and the fibre pull-out mechanism. Energy dissipation in SFRC beams is enhanced by fibre interaction inside the concrete matrix, in contrast to traditional beams where reinforcement yielding is the main governing factor.

Table 4.1 RC Energy Absorption capacity in KN-mm

Cycles	Relative	Cumulative
1	15	15
2	38	53
3	89	142
4	331	473

Table 4.2 SFRC Energy Absorption capacity in KN-mm

Cycles	Relative	Cumulative
1	25	25
2	67	92
3	136	228
4	169	397
5	346	743



Graph 4.1 Cumulative Energy Absorption vs Loading Cycles for RC and SFRC Beams under Cyclic Loading

Analytical evaluation was conducted with the use of standard formulations to support experimental results. The area inside the hysteresis loops represented the energy absorption capacity where approximately 57% more energy was absorbed in SFRC beams as compared to the conventional RC beams. Likewise, the ductility factor (ultimate deflection/yield deflection) showed considerable improvement in deformation ability. The observations are in good agreement with the theoretical principles given that steel fibres can enhance energy dissipation and post-cracking behaviour.

4.4 Ductility Characteristics

A structural member's ductility—its capacity to endure big deformations before breaking—is an important criterion in seismic design. The ratio of the ultimate deflection to the yield deflection was used to calculate the ductility factor. The experimental results show that the ductility of SFRC beams is significantly greater than that of RC beam. A 25-50% increase in ductility factor showed the better deformation capacity. With a greater ability to accommodate greater movement during seismic events, the SFRC beams will not collapse unexpectedly. The increased ductility is primarily due to the ability of the fibres to carry the load across broken areas. The micro-reinforcement from the fibres helps to spread out stresses and prevent the material from weakening quickly. This results in post yield behavior that is more consistent and controllable.

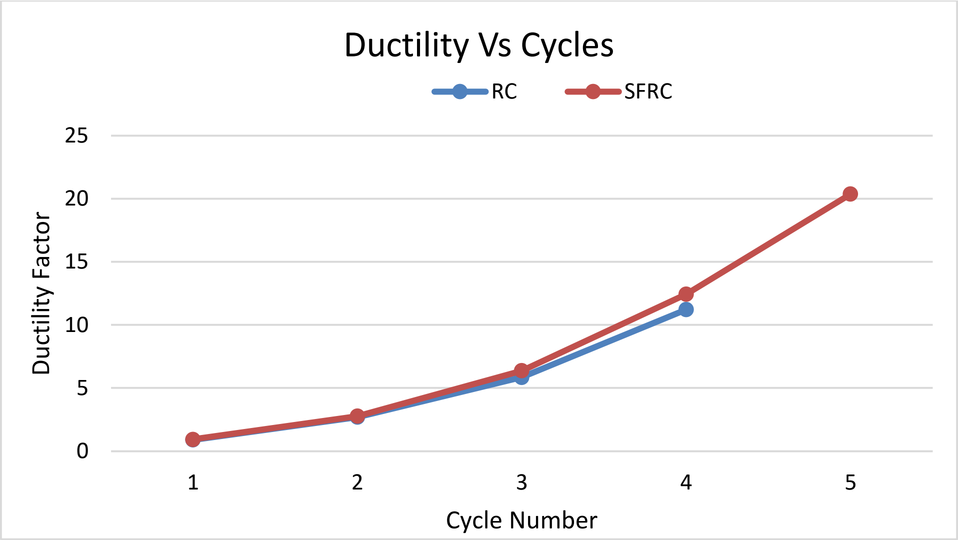
It should be noted that the ductility of SFRC beams markedly improved, the observed increase being up to about 80% in comparison to conventional RC beams, which resulted in improved deformability under cyclic loading.

Table 4.3 RC ductility factor

Cycle no	Relative	Cumulative
1	0.90	0.90
2	1.80	2.70
3	3.16	5.86
4	5.36	11.22

Table 4.4 RCSF0.75 ductility factor

Cycle no	Relative	Cumulative
1	0.93	0.93
2	1.84	2.77
3	3.60	6.37
4	6.06	12.43
5	7.94	20.37



Graph 4.2 Variation of Ductility Factor with Loading Cycles for RC and SFRC Beams

4.5 Overall Seismic Performance

From the perspective of load-deflection response, crack behaviour, energy absorption, ductility and stiffness degradation, seismic loading simulations indicate that SFRC beams provide superior performance when compared to other materials.

Key observations include:

- Increased strength at 60 and 75% relative humidity (≈20% increase)
- Higher ultimate load capacity (20-35%)
- Enhanced energy absorption (40–60%)
- Increased ductility (25–50%)
- Reduced stiffness degradation (15–25%)

These upgrades illustrate that steel fibres are a great way to make concrete beams more resistant to earthquakes. The fibres provide additional resistance mechanisms without altering the traditional reinforcement details, providing additional deformation characteristics and strength.

4.6 Discussion

The result shows that the steel fibres reinforcement incorporated in concrete beams significantly enhance the cyclic flexural performance of the beam. The fundamental mechanisms of fibre reinforcement, as well as the mechanisms of crack bridging, stress redistribution and energy dissipation, are consistent with the results observed. On the practical side, steel fibres are a feasible option for enhancing earthquake resistance of structural components. SFRC is a good choice for new construction and retrofitting due to the potential for improved performance with little change to current design procedures.

5. Conclusions

In the present experimental study, the cyclic flexural response of steel fibre reinforced concrete (SFRC) beams under simulated seismic loading was studied. From the experimental observations and analytical studies, the following conclusions are made: Cracking resistance of concrete beams is significantly improved with the addition of steel fibres. The load of the initial crack in conventional RC beams was about 12kN, while in SFRC beams it was about 18kN, which is about 50% more than conventional RC beams. The load-deflection response of SFRC beams was better, with a less brittle response after crack formation, and greater ductility. The ultimate loads were about 20–35% higher than those of the control beams. Because of the action of fibre bridging, a mechanism which effectively controlled the crack propagation, instead of less, more fine cracks were observed. This resulted in better structural integrity and postponed failure. The absorption capacity of energy for SFRC beams was significantly higher (about 40-60%), showing that they have the highest capacity to dissipate the seismic energy when subjected to cyclic loads. Significant improvement in ductility was seen, the ductility factor was increased in range of 25-50% (and more in cyclic response) which shows good deformation capacity before failure. The hysteresis loops of SFRC beams were also found to be of a stable and fuller form and this confirmed that the energy dissipation property of SFRC beams was higher and more energy was dissipated compared to conventional RC beams. The SFRC beams failed in a ductile and progressive manner as compared to conventional RC beams which failed in a brittle manner, a desirable failure mode for earthquake resistant structures. In general, the study indicated that the use of SFs in RC beams is found to enhance the seismic performance of both strength, ductility, energy dissipation, and crack control, with noticeable improvement in the performance without much changes in existing detailing of conventional reinforcement.

Future Scope

The study only takes into account one specific beam shape and fibre volume fraction. To explore other fibre contents, such as full-scale beam-column connections and hybrid fibre systems, future studies are recommended. The results of the experiment can be more practical by using Analytical validation and numerical modelling. When considering fibres, it is useful to investigate alternative rates of reinforcement and shear span-to-depth ratios and axial load levels to derive extensive design suggestions and modification factors for seismic codes. If you want to know how much longer SSFRC structural elements last compared to regular RC and SFRC, you should look into their corrosion and durability over the long term (e.g., wet-dry cycles, carbonation, maritime exposure).

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