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# Bending Behaviour of Concrete Beams with Composite Reinforcement

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**Abstract:** Massive quantities of finite resources have been depleted due to the construction and building sectors. Using bio-products to reduce raw materials use is seen as a major step toward a sustainable building sector. In this regard, the current research developed a novel composite beam reinforced and double-confined using a flexural and shears continuous FRP-Jacket. The suggested method involves swapping out conventional Portland cement-based concrete with a greener variant made with a different mix percentage that includes dry clay and hydraulic lime. Experimental testing and theoretical modeling based on shear stress and deformation composite beams are used to assess the bends & shear performance of the suggested design with four-point flexural load. The double-confinement approach used resulted in a noticeable improvement in strength and deformability compared to conventional concrete beams, as shown by strong agreement between experimental and modeling results in terms of effective stress, pressure concentration, and cement reduction.

**Keywords**: Double-confinement, Experimental, behaviour, modelling.

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## Introduction

The construction industry is solely responsible for the planning, design, construction, and maintenance of buildings such as homes, flats, factories, offices, schools, etc. It is also practical for building government buildings such as highways, bridges, harbors, ports, drains, tunnels, etc. Keeping such buildings in good repair falls within the purview of this division as well[1-2]. The industry is consequential not only because it provides the structures and facilities upon which almost every other industry depends, but also because it is a sizable division in and of itself. In the United States and Japan combined, the construction industry employs more than forty million people, but in Europe, it accounts for just seven percent of all jobs (OECD 2008). The construction industry accounts for an average of 6.47 percent of GDP across all OECD (Organization for Economic Co-operation and Development) nations (Gross Domestic Product).

The building sector in India is second only to agriculture in terms of importance to the country's economy. Current credible sources indicated that over 65% of the nation's total investment went into the construction sector's development of infrastructures.

In addition, the building industry contributes roughly 12% of India's GDP on average. With these advancements, academics have turned to the field in an effort to improve the quality of building construction by focusing on concrete, a primary building material. Modern globalization has led to the construction of enormous, skyscraping towers. rules enacted to ensure safety and counteract the effects of unforeseen disasters are spreading over the world.

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Hence, there was a significant uptick in the study of steel buildings combined with concrete composites, Although the combination of materials may not be directly responsible for increasing bulk strength, it may improve strength via other means, such as shared properties. From the existing literatures, it is clear that many investigations were conducted on steel concrete composite structures under the concern of various ideas and applications to enhance the strength and dependability of various elements. The purpose of this research is to examine the response of constrained steel concrete composite beams with shear connections subjected to a range of loading conditions, including pure bending, pure torsion, and the combined impact of bending and torsion on various concrete grades. While the other ongoing research may only use a small subset of possible permutations[3-5].

Research on steel-concrete composites has progressed through the first stages. In this section, we lay down the foundation for the research that will be conducted using the technique. Further parts will continue the full details. Because of these issues, people are quite worried about how long reinforced concrete (RC) buildings will last[6].

Decreased mechanical strength and subpar bond performance in RC constructions.corrosion of steel reinforcement is a common source of voids between steel and concrete. Substantial work has efforts have recently been made to fix the issues with steel reinforcement corrosion[7].

Fiber Reinforcing Concrete (FRC) also includes anti-rust measures, such as galvanized steel reinforcement[1] and rust inhibitor[2].It is widely agreed that Fiberglass Reinforced Polymer (FRP) bar is superior than steel bar[3]. When put next to the standard Compared to steel bars, FRP bars excel in not rusting, having a high specific strength, and being lightweight. manufacturability [4]. Yet, there is no discernible yield point in the stress-strain behavior of FRP bars.Moreover, FRP bar reinforced concrete components often break easily. Moreover, when contrasting with steel.Compared to conventional reinforcing bars, the FRP bar's modulus of elasticity is noticeably lower, and the connection between the FRP bar and The strength of concrete is low. As a result, FRP bars that are strengthened often show significant deflection and fracture breadth buildings made of concrete[5]. The FRP bar's low modulus of elasticity and linear stress-strain characteristics.In most cases, the serviceability limit state is what determines how FRP bars are integrated into the design of reinforced concrete buildings.The shortcomings of FRP bars were addressed by developing a new FRP bar and FRP reinforcing system examined in a small number of studies. Hybrid FRP bars, for instance, were made using a variety of continuous fibers.Combining FRP with steel bars was an efficient method of boosting the durability and flexibility of the former strong concrete pillars. There have been several recent observations in studies on the deflection and The ductility and fracture width of FRP bar reinforced concrete beams were both enhanced by the fibers are added in a random pattern[9,10]. The strength of a composite element might be greater than the strength of its component parts because of the strength mitigating physical properties. Steel-concrete hybrids are useful in many different contexts. structure were plain to see in the books. Composite beams, such as steel-wood, wood-concrete, and plastic-concrete or advanced concrete composite materials, are also now used in the building industry[8-10].

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**Steel Concrete Composite Beam**

Composite beams used to be made of concrete slabs and steel I-beams, back in the stone era. This innovation increased the risk of concrete and steel slippage during the fusion process, resulting in substantial damage, while the usage of both materials in tandem would have prevented such slips. Since 2003 Composite beam, which uses the T-beam concept, was developed as a solution to this problem by combining steel reinforcements with concrete. Timbers were originally utilized as beams in lieu of steel, but contemporary buildings swapped them out for steel and concrete out of safety concerns[11]. Compressive stresses can be better handled by concrete, while tensile stresses are better handled by steel reinforcement; hence, composite beams are well suited to withstand the combined impacts of compression, tension, and buckling. Combinations of steel and concrete structural beams have been shown to be the most cost-effective in recent years when considerations of durability, strength, and dependability are also taken into account[12]. The advancement of theory surrounding steel concrete composite beams additionally motivates more research into the improving efficiency of steel concrete buildings. As a result, scientists started using shear connections in their composite constructions[13]. The stiffening effect of the composite beams is significantly enhanced by the introduction of shear connections. The primary goal of this study is to enhance the structural performance of composite beams. The composite beams are designed using a mix of concrete and cold formed steel sheet with shear connections based on a review of the relevant literature. To improve the seismic performance and structural strength, shear connections might be installed[14].

Concrete of varying strengths (M20, M25, M30, and M35) and cold-formed sheets make up the bulk of the construction process. Beams measuring 2300mm x 150mm x 230mm were fabricated using cold-formed sheets, and shear connectors with various gap sizes (75mm, 100mm, 125mm, and 150mm) were cast. Curing and behavior testing were completed on the cast composite beam combinations. After curing, the composite beams were put through tests that measured their resistance to bending, torsion, and a combination of the two. The outcomes of the experiment were monitored, documented, and analyzed. In the meanwhile, ABAQUS was used for the numerical analysis of the composite beams. Figure 1.2 displays the study's planned research framework[15].

**Literature Review**

**Zhuang Liu *et al.*, (2022** In this study, researchers investigated the stress-time avalanches that take place in reused polyethylene terephthalate (PET) nylon concrete by making use of signals with a high temporal resolution. PET fibers are utilized to strengthen concrete. The phase - field model was applied to the 100 kHz data in order to extract stress drops, and they were modeled as avalanches when the modeling was complete. During the flexure of PET fiber beams, it was observed that little rockslides crumbled on the scaling zone, whilst enormous avalanches erupted outside of it. Both of these phenomena happened simultaneously. Avalanches have been simulated using mean field theory, and the theory's predictions were shown to be compatible with the stress drop patterns documented for micro rockfalls in the scaling domain. If the peak stress is reached after the bottom concrete has

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cracked, it is conceivable for the postpeak avalanche size to be bigger than the avalanche volume at the bottom fracture. This is because the postpeak avalanche size is measured after the peak stress has been reached. The findings of this experiment may shed some insight on the bending behaviors of fiber-reinforced concrete if they turn out to be accurate**.**

**Hayder A. Rasheed *et al.*, (2021)** A unique technique of analysis is presented here by the researchers in order to estimate the behavior of deep beams built of reinforced concrete and augmented with fiber-reinforced polymer when subjected to shear, flexure, or shear-flexure loading (FRP). The technique of analysis takes into consideration the fact of FRP-enhanced deep beams are comparable to an imagined, statically indeterminate truss. As a consequence of this, the yielding or ultimate loads are modeled by using two determinate trusses that are parallel to one another. The contribution of the second truss is evaluated in comparison to the load that was created by the first truss by the imposition of the comparability of deformations here between the two trusses just at yield and ultimate levels.

**T. Xie *et al..*, (2020**) This work, which summarizes the findings of both analytical and experimental research into this issue, focuses on the structure of horizontally curved ultra high nylon polymer (UHPFRC) beams that are subjected to compressive pressures applied perpendicular to the plane of the beam. On four fixed-ends supported UHPFRC beams, curvatures of zero degrees, sixty degrees, ninety degrees, and one hundred twenty degrees were assessed. Under a variety of loading circumstances, experimental measurements were taken to determine the displacement, out-of-plane rotation, the structural response of UHPFRC curved beams.

**Wen-Jie Ge *et al.*, (2019)** In this study, the above such of concrete beams reinforced with fibres polymer (FRP) bars or steel bars was examined. Experimental flexure testing is conducted to failure on 32 assisting with the gratification composite beams using a range of ECC height replacement ratios and FRP and steel reinforcement combinations. The exceptional tensile capabilities of ECC materials are evident in the test results, which reveal that hybrid and ECC beams are superior than conventional concrete beam with the same reinforcement in terms of cracking, yield, ultimate moments, and stiffness. In general, the average crack spacing and breadth become less as the ECC height replacement ratio is higher. Hybrid reinforced composite beams have more ductility than conventional RC beams, although having equal reinforcement ratios in practice. As ECC may be deformed very easily, reinforced ECC beams have a high energy dissipation capability.

**Peng Zhu *et al.*, (2017**) When concrete elements are reinforced with GFRP bars made of glass and steel fibers, the beams' strength, usefulness, and lifespan all see considerable improvements. There is a paucity of information on the fatigue resistance of beams with hybrid reinforcing. This investigation creates an experimental plan to examine the fatigue flexural performance of longitudinally stressed concrete beams reinforced with steel and GFRP bars. One flexural sample is analyzed at rest, and another three are subjected to fatigue testing. Researchers examine how fatigued actions change with increases in both stress and flexural modulus. Fatigue life depends on the ratio of support measures and the fatigued load level. Fatigue loading seldom modifies the depth of the neutral axis. The curved and midspan

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deflection both increase considerably around 0.01 million fatigue cycles, but then plateau. A widening crack is typical over the fatigue lifetime. Midspan displacement of concrete beams with composite reinforcements under fatigue loading is modeled in many ways, and their accuracy is compared to experimental results.

## Materials and Methods

### Cement

In the experiments, regular Portland cement according to IS4031-1988 specifications was employed. The characteristics of the regular Portland cement shown in Table 1.

Table 1 Properties of cement

| S. No. | Particulars | Result |
|---|---|---|
| 1 | Specific gravity | 3.15 |
| 2 | Initial setting time | 36 minutes |
| 3 | Final setting time | 260minutes |
| 4 | Fineness | 5% |

River sand from the area, tested according to IS:2386-1963, with the fine aggregate fraction passing a 4.74 mm screen and being retained on a 600 micron filter. Table 2 displays the measurable characteristics of fine aggregate sourced domestically. 1. River sand is consistent with IS: 383-1970's grading zone II

**Table 2 Properties of Fine aggregate**

| S.No | Properties | Fine aggregate |
|---|---|---|
| 1 | Fineness modulus | 2.41 |
| 2 | Specific gravity | 2.67 |
| 3 | Density(kg/m$^3$) | 1675 |

### Preparation of CSCC Beam

Cold-formed steel is used to produce the trough portion of the CSCC beam, and concrete is poured within the trough with the help of the steel frame on the side walls of the beam's T-shaped structure. The chamber's vertical walls had bracing riveted to their edges. Figure 1&2 depict cross-sectional details and cross-sectional views of troughed CSCC beams.

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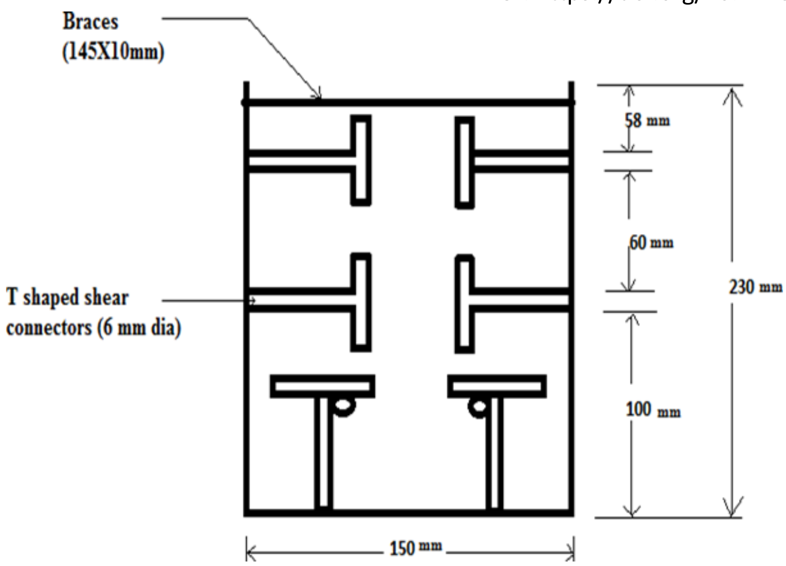


**Figure 1 Trough Section details of CSCC Beam**

**Figure 2 Trough Section of CSCC Beam**

The lightly reinforced sheet has the following dimensions and thickness: 2300 mm x 150 mm x 230 mm x 1.2 mm. The beam has a circular cross section with a 6 mm diameter, and T-shaped shear connections are welded all along it to increase its strength and bonding qualities. The bracing were also manufactured with a consistent thickness of 1.2 mm over their whole 148 x 10 mm cross section. Nevertheless, these shear connectors could only accommodate distances of 75mm, 100mm, 125mm, and 150mm. Upon the arrival of the mix percentage, the concrete was mixed, poured into the trough, and vibrated to increase density. The beam was aired out for 24 hours after being cast and then cured for 28 days. Each specimen was treated using the same protocol

**Table 3 Beam specimen combinations for the study**

| Grade of concrete | Specimen | Spacing of shear connectors |
|---|---|---|
| M20 | A1 | 75mm |
| | B1 | 100mm |
| | C1 | 125mm |
| | D1 | 150mm |
| M25 | A2 | 75mm |
| | B2 | 100mm |
| | C2 | 125mm |
| | D2 | 150mm |
| M30 | A3 | 75mm |
| | B3 | 100mm |
| | C3 | 125mm |
| | D3 | 150mm |
| M35 | A4 | 75mm |
| | B4 | 100mm |
| | C4 | 125mm |
| | D4 | 150mm |

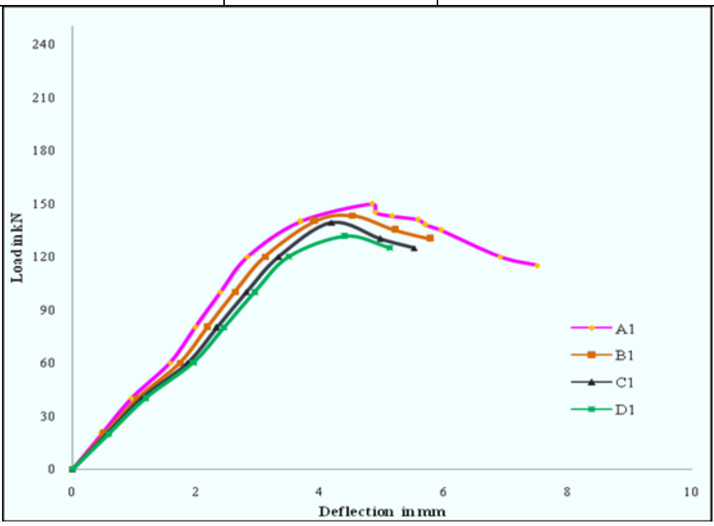

**Figure 3 Load vs deflection curve – M20 grade under pure bending for different spacing of shear connector**

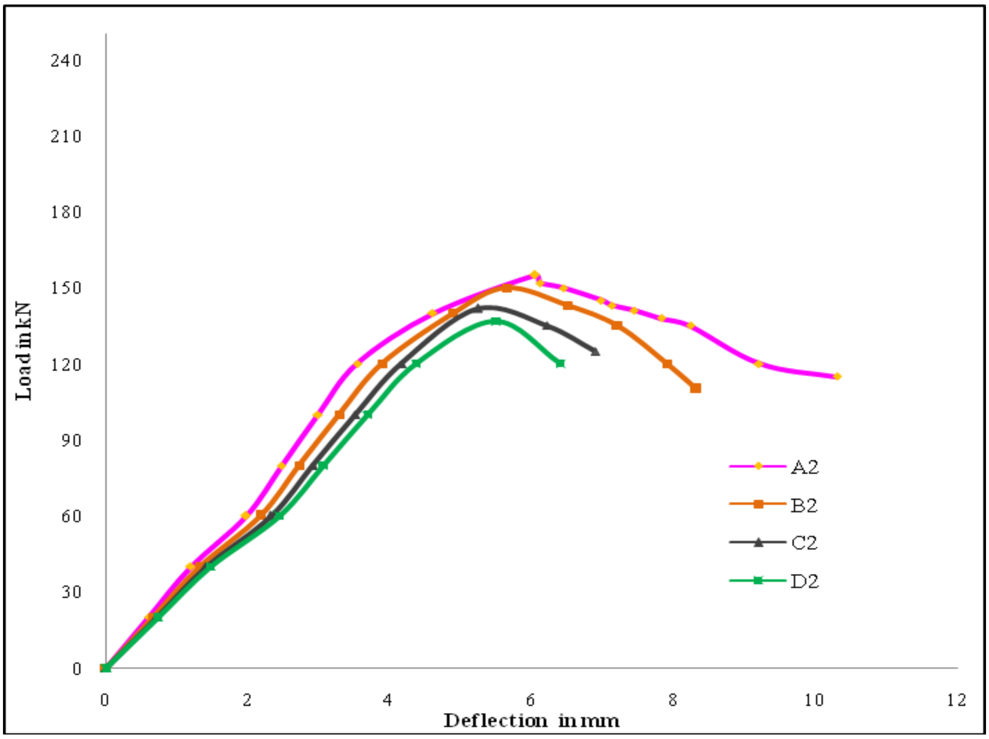


**Figure 4. Load vs deflection curve – M25 grade under pure bending for different spacing of shear connector**

The load deflection curves of CSCC beams made from M20 grade concrete and varying distances between shear connectors are shown in Figure 3. At 75mm, 100mm, 125mm, and 150mm shear connection spacing, the ultimate load was determined to be 150 kN, 143 kN, 139.24 kN, and 131.69 kN, respectively. It was shown that increasing the distance between shear connections decreased load bearing capability by around 5%, 10%, and 16% for the B1, C1, and D1 combinations, respectively.

Load deflection curves for CSCC beams filled with M25 grade and various shear connection spacings, similar to M20 concrete, are shown in Figure 4. We measured ultimate loads of 155kN, 150kN, 141.8kN, and 136.73kN, and we discovered that their carrying capacities dropped by around 3%, 8.5%, and 12%. Yet, as compared to M20 grade CSCC beams, the ultimate load bearing capacity rose by 3.2%, 4.67 %, 1.8 %, and 3.69 %.

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**Table 4. Performance measures of various grade of concrete in Bending**

| Grade of Concrete | Spacing of shear connectors, mm | Deflection at Yield point, mm | Deflection at Ultimate Point, mm | Ductility Ratio | Stiffness, kN/mm | Energy Absorbed, $x10^3$kN-mm |
|---|---|---|---|---|---|---|
| $M_{20}$ | 75 | 0.95 | 4.83 | 5.08 | 28.17 | 0.78 |
| | 100 | 1.05 | 4.51 | 4.31 | 38.10 | 0.54 |
| | 125 | 1.12 | 4.18 | 3.73 | 35.71 | 0.47 |
| | 150 | 1.18 | 4.39 | 3.73 | 33.90 | 0.27 |
| $M_{25}$ | 75 | 1.19 | 6.44 | 5.41 | 33.61 | 1.11 |
| | 100 | 1.31 | 5.64 | 4.31 | 30.53 | 0.83 |
| | 125 | 1.40 | 5.23 | 3.74 | 28.57 | 0.64 |
| | 150 | 1.47 | 5.49 | 3.73 | 27.21 | 0.51 |
| $M_{30}$ | 75 | 1.43 | 7.33 | 5.13 | 42.11 | 1.56 |
| | 100 | 1.57 | 7.00 | 4.46 | 25.48 | 0.97 |
| | 125 | 1.68 | 7.45 | 4.43 | 23.81 | 0.83 |
| | 150 | 1.76 | 6.58 | 3.74 | 22.73 | 0.65 |
| $M_{35}$ | 75 | 1.55 | 8.82 | 5.69 | 80.00 | 2.26 |
| | 100 | 1.70 | 7.16 | 4.21 | 33.33 | 1.14 |
| | 125 | 1.8 | 7.00 | 3.89 | 22.22 | 0.93 |
| | 150 | 2.01 | 8.40 | 4.2 | 19.90 | 0.76 |

## Conclusion

In this research, the structural characteristics of RC beams that have been modified using hybrid FRPs are examined. FRP retrofitted beams were subjected to two-point bending tests.Deformation versus load curves were studied. Preloading's impact on the Rc structure during the retrofitting process is also studied. Here is a quick rundown of what we learned from our experiments.The ultimate strength may be increased by using hybrid FRPs. The durability and strength of RC beams retrofitted with hybrid FRPs are affected by the sequence in which the various FRPs are attached. Tests demonstrate that the beams' strength and ductility are significantly enhanced when glass fiber is connected to the beam's outside.Third, the hybrid FRP sheets will crack before the refurbished RC beams do. Because of this, the hybrid FRPs aren't as strong as they may be. So, in order to fully use the capacitance of hybrid FRPs, a new retrofitting design approach is still required.

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