

## International Journal of Innovative Research in Science, Engineering and Technology

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# Experimental Study on Flexural Behaviour of 3D Steel Fibre Reinforced Layered Concrete Beam

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**ABSTRACT:** This paper presents the hybrid beam structure using 3D steel fibres. The beam consists of three layers out of which two of SFRC external layer of 3D steel fibres and RC internal layer. Flexural behaviour of different thickness of layers are made for comparative study of effect of layers. The third point bending test is used to determine the mechanical properties of the beam. Percentage of steel fibres used are 0.75% of total quantity of cement content for corresponding layer for M30 grade concrete. The flexural load capacity, deflection and energy absorption capacity of layered beams are high compared to RC and SFRC beams. While the stiffness is less for layered beams comparing to the SFRC due to the large deflection of layered beams. Increase in thickness of layer increases the properties of the beam.

**KEYWORDS:** Layered beams, reinforced concrete beams, 3D steel fibre, flexural behaviour, stiffness, energy absorption, crack.

### I. INTRODUCTION

Concrete is a widely used construction material with annual production of over 7 billion tons. Composite concrete structures are available with reinforcements and different types of fibres like materials. In order to expand the possibilities in using concrete as a construction material, the development of new types of concrete and innovative structural solutions is required. Steel fibres are widely using in concrete for many years for increasing ductility, structural integrity, energy absorption capacity. Reinforced concrete is better at dissipating the earthquake energy and transferring it through ductile load paths to the ground. FRC could be used for concrete elements such as beams and columns for buildings in earthquake prone locations, due to its high energy absorption properties. Steel fibres are known to enhance the ductility of a brittle material like concrete. This is useful to avoid brittle modes of collapse such as shear failure. The improvements to ductility and energy dissipation are particularly beneficial for structures under seismic loading. The studies reveal that steel fibres improve the resistance to crack growth and decrease the deflections under cyclic loadings. But steel fibres are costly product. The use of steel fibres alone causes high cost. Hence combination of reinforced concrete with steel fibres will provide more effective results by their combined action with less amount of steel fibres as external layers. 2D steel fibres of different types are commonly used. In this study 3D steel fibres of stainless steel wire with high aspect ratio (230) is used for concrete layer. The results of mechanical properties shows the effect of both reinforcements RC and SFRC in layered beams.

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## II. LITERATURE REVIEW

The literature review is carried out to find the studies on steel fibres and layered beams. The available literatures collected are explained below.

**Alan and Marcus Heather (2013)** conducted an experimental study to improve the transfer of post crack forces in concrete using fibre technology. The closed loop fibres used in this test were in the form of square loops of size 50 mm x 50 mm. The loops were created using stainless steel wire of diameter 1.2 mm and grade 316L. From the results, the closed loop fibre beams used at an equal fibre dose per  $m^3$  of concrete; outperformed the straight steel fibre concrete in terms of toughness, peak force redistributed and total impact energy.

**Abdul Ghaffar, Amit S. Chavhan and Dr. R. S. Tatwawadi (2014)** The objective of the study was to determine and compare the differences in properties of concrete containing with and without fibres. This investigation was carried out using compressive test and flexural test. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths. Ductility of concrete was found to increase with inclusion of fibres at higher fibre content.

**Juozas Valivonis, Remigijus Šalna & Alfonso Cobo-Escamilla (2017)** developed the theory of layered beams with steel fibre reinforced concrete (SFRC) in the external and conventional reinforced concrete (RC) in the internal layer represents an economical alternative of structures effectively using SFRC. The steel fibres, used in testing programme is 2D fibres, with a length of 30 mm and a diameter of 0.55 mm. The test results show the mechanical properties of layered beams are much better than other types.

**Linn Grepstad Nes, Jan Arve O. Pverli (2015)** The hybrid concrete structures investigated in this project were beams composed of two layers of different types of concrete. Normal density concrete (NC) was used in the top layer combined with a layer of fibre-reinforced lightweight concrete (FRLWC). This study shows steel fibre reinforcement of the lightweight concrete increased the ductility in tension, so the amount of conventional shear reinforcement could be reduced. The concept provides a low self-weight of the structure, practical solutions in the construction phase and good premises for more efficient building.

**Milind V. Mohod (2012)** In this study 2D steel fibres of different percentages (0%-2% by volume of cement content) are used to evaluate mechanical properties of concrete. The results show that optimum percentage for 2D steel fibre is 0.75% which is better for flexural strength. While testing the specimens, the plain cement concrete specimens have shown a typical crack propagation pattern which led into splitting of beam in two piece geometry. But due to addition of steel fibres in concrete cracks get ceased which results into the ductile behaviour of SFRC.

**Patil Shweta, Rupali Kavilkar (2014)** studied the properties of steel fibre reinforced concrete like flexure and compressive strength. Tests were conducted to study the flexural and compressive strength of steel fibre reinforced concrete with varying aspect ratio (40-70) and varying percentage of fibre (0.5%-2.5%). With the addition of steel fibres to cement concrete, the flexural strength significantly increased. It was also seen that as aspect ratio increases, the deflection increased for the same percentage volume of fibres.

## III. EXPERIMENTAL INVESTIGATION

### Materials

The cement used for the entire experiment was Ordinary Portland Cement of grade 53 conforming to IS 12269:1987. The coarse aggregates conform to IS 2386:1963 and were of crushed angular type passing through 20 mm sieve and retaining on 4.75 mm sieve. The fine aggregate used was M sand conforming to zone II of IS 383:1970. The reinforcement bars used are 8mm diameter and stirrups at two ends used are of size 6mm diameter. The 3D steel

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fibres(fig 1) are of stainless steel wire 669 MPa made by spot welding. The properties of steel fibre used is shown in table 1.



Fig 1:3D steel fibre

Table 1:3D steel fibre properties

|                  |               |
|------------------|---------------|
| Fibre perimeter  | 230 mm        |
| Fibre diameter   | 1 mm          |
| Temper           | Soft annealed |
| Tensile strength | 669 MPa       |

## Concrete Mix Details.

The grade used in this study is M30. Various test had been done for the materials used in the concrete mix. The mix design was done according to the IS recommendation mentioned in IS 456:2000 and IS 10262:2009. The slump obtained for the mix is 73mm and w/c ratio considered is 0.465. The mix proportion obtained is shown below table 2.

Table 2 Mix proportion

| Cement<br>Kg/m <sup>3</sup> | Fine aggregate<br>Kg/m <sup>3</sup> | Coarse aggregate<br>Kg/m <sup>3</sup> | Water<br>Litre |
|-----------------------------|-------------------------------------|---------------------------------------|----------------|
| 1                           | 1.7                                 | 3                                     | 0.465          |

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## Preparation Of Specimens.

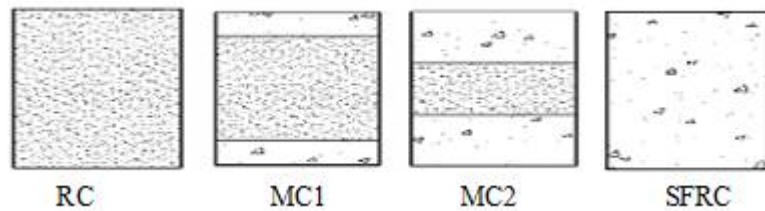


Fig 2: Types of beams.

This study consists of flexural behaviour of layered beams of 15mm and 30mm external layer thickness and RC internal layer(MC1 and MC2), 3D steel fibre reinforced beam(SFRC beams),normal reinforced beams.Fibre content used is0.75% of steel fibres by weight of cement.The beam size is 1000mmX150mmX150mm for all types of beams with M30 grade concrete.Third point bending test is used to determine ultimate load and deflection.The details of beams are shown in fig 2.The reinforcement bars are provided 70mm c/c with 35mm covering.The stirrups provided are one number in both ends.The size of stirrup reinforcement is 6mm dia bars.

Table 3:Beam details.

| Sl. no | Specimen designation | Mix | Thickness of layer |
|--------|----------------------|-----|--------------------|
| 1      | control RC           | M30 | 0                  |
| 2      | SFRC                 | M30 | 0                  |
| 3      | MC1                  | M30 | 15mm               |
| 4      | MC2                  | M30 | 30mm               |

## Experimental Setup.

The project work consisted of an experimental investigation on the flexural performance of beams reinforced with 3D steel fibres. The ultimate load for four types of beams was determined using third point bending test in the Universal Testing Machine of capacity 400kN. The experimental setup is shown in fig:3.The third point bending flexural test provides value for the flexural strength in terms of modulus of rupture. The specimens were arranged with simply supported conditions with an effective span of 76 mm. Deflection of the beam was measured using a dial gauge of least count 0.01mm at centre of the specimen.

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Fig 3: Experimental setup

## IV. EXPERIMENTAL RESULTS

The results obtained from the third point bending tests conducted on concrete beam specimens of grade M30 and 3D steel fibre reinforced layered beam is given below.

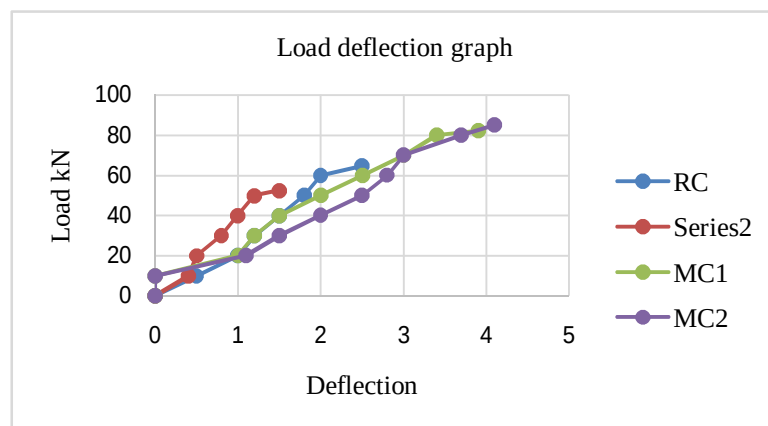


Fig 4: Load deflection comparison graph

From the above fig we can find that ultimate load of layered beams are more compared to RC control beam and SFRC beam. The deflection is more in layered beams than SFRC and RC beams. This signifies that the 3D steel fibres impart more ductility to the layered beams. The 3D steel fibres can be attributed to the ductile behaviour of the concrete beams. The 3D steel fibres can ensure reinforcement along all the directions and hence it can make concrete more ductile. In layered beams the effect both reinforcement will give more strength to the beams.

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## Energy absorption capacity of layered beam:

Steel fibres are added to concrete not to improve the strength, but primarily to improve the toughness, or energy absorption capacity. Energy absorption is one of the key indicators of structural response as it indicates the structure's ability to absorb deformations. As per ACI 544.2R-89, energy absorbed by the concrete beam specimen is represented by the area under the complete load – deflection curve.

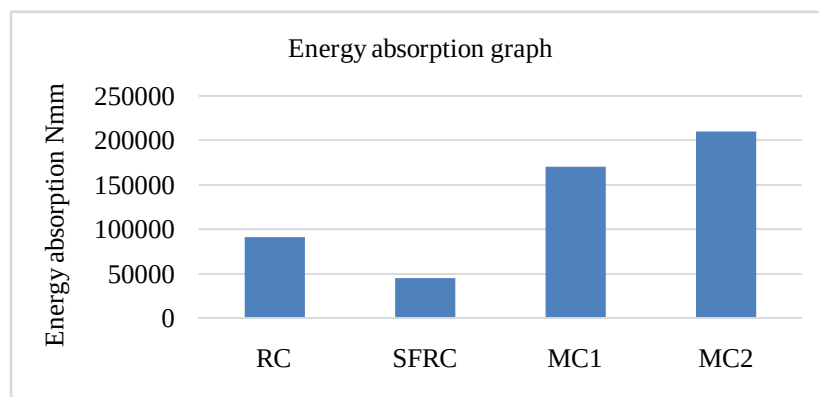


Fig 5: Energy absorption capacity of beams

The energy absorption capacity is maximum for layered beams with 30mm thick. SFRC alone have low energy absorption capacity. But when it combine to form layered beams it have very high energy absorption capacity than RC and SFRC. This is due to the addition of 3D steel fibres in to the concrete. In layered beams two types of reinforcements are provided. Hence the effect of both reinforcements reflects in energy absorption capacity of layered beams.

## Modulus of rupture of layered beams:

Modulus of Rupture, frequently abbreviated as MOR, (sometimes referred to as bending strength), is a measure of a specimen's strength before rupture. It can be used to determine a species' overall strength; unlike the modulus of elasticity, which measures the deflection, but not its ultimate strength. The third point bending flexural test provides value for the flexural strength in terms of modulus of rupture.

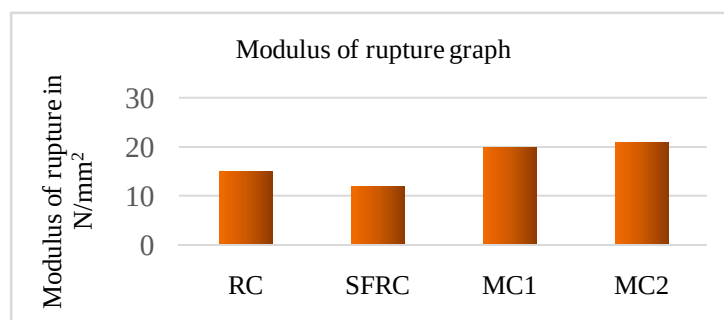


Fig 6: modulus of rupture

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In layered beams there is an increase in modulus of rupture compared to normal RC and SFRC beams. Effect of both types are reflected in layered beams. The maximum value obtained is 21 and it is in the case of layered beam of thickness 30mm. There is almost a similar pattern in modulus of rupture in all cases. Anyway the effect is more in the case of layered beams.

## Stiffness of layered beams:

**Stiffness** – The ability of the material to distribute a load and resist deformation or deflection (functional failure).

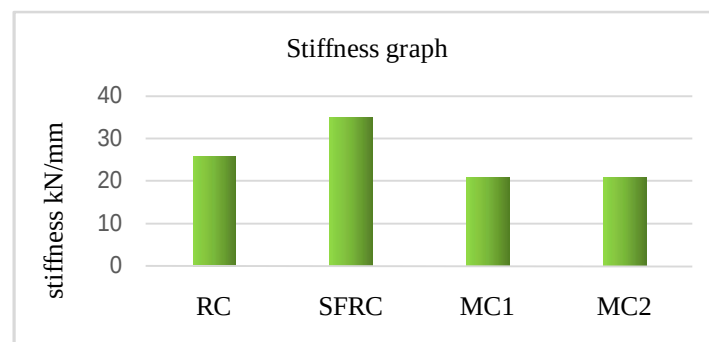


Fig 7: Stiffness of layered beams

The effect of stiffness is maximum in SFRC beam and the value is 35kN/mm. Here the deflection is reduced. In case of layered beams the stiffness is minimum due to large bending or deflection. Stiffness decreasing by increase in deflection. The stiffness of the layered beams is 20–25% less than that of the monolithic beams due to the cracking in the middle RC layer. It should be taken into account when calculating deflection.

## Crack pattern:

The crack pattern in tested beams are flexural shear combination. These cracks will form when a beam bends under loading from top, it develops tensile stresses on its bottom face and compressive stresses on its top face. As a result of these stresses, a diagonal tension develops near the supports of the beam. The diagonal tension pulls apart the beam at an angle from the supports. Diagonal cracks start to form rising from bottom towards the top. A flexure shear failure is the result of a crack which begins as a flexural crack, but as shear increases, the crack begins to turn over and incline towards the loading point. Failure finally occurs when the concrete separates and the two planes of concrete slide past one another. This mode of failure is common in beams which do not contain shear reinforcement.



Fig 8: Crack pattern in RC.

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The width of the crack is more in case of RC beams and it is about 5-6mm width at the tension face. In RC beams shear reinforcements are not provided. Hence large cracks of shear are formed. Towards the top the width of crack is reduced.



Fig 9: Crack pattern in SFRC.

The width of the crack is minimum in SFRC beam than other three types. It is because of the addition of 3D steel fibres. Steel fibres can delay the formation and propagation of cracks by improving the effectiveness of the crack arresting mechanisms present in beams when applied under high shear stresses.



Fig 10: Crack pattern in layered beams (MC1).

In this case crack width is more than SFRC and less than that of RC beams. Mode of failure is flexural shear failure. Addition of steel fibres reduced width and propagation of cracks. The cracks are moved in to layer and bond cracks are formed before reaching in to top portion of beam.



Fig 11: Crack pattern in layered beams (MC2).

The width of crack is less in MC2 (30mm thick layer) compared to MC1 (15mm thick layer) and it will be due to the presence of extra amount of 3D fibres. In this the crack width is about 2-3mm at tension zone. In case of layered beams the cracks are extended towards the layers at top portion and the bond between them are separating due to the crack. These cracks are extended to top surface after breaking the bond between the layers. Hence bond crack is occurred between the layer.

## V. CONCLUSION

In comparison with normal RC and SFRC the ultimate strength of layered beams are increased by 27% for MC1 and 31.17% for MC2. Modulus of rupture is high for layered beams. In case of 30mm thick layer there is an extra 5% increase in modulus of rupture by the more amount of steel fibres. Energy absorption capacity is more for layered beams due to large deflection of beams. Stiffness is less for layered beams than RC and SFRC. For both thickness of layers stiffness is same. Crack width is less in case of SFRC than other beams. In layered beams the effect of cracking is less compared to normal RC due to the presence of 3D fibres. When thickness of fibre layer is increasing the crack



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width is reducing. The crack formed in all beams are by flexural-shear failure. 3D steel fibres can be regarded as advancement in the field of Fibre Reinforced Concrete.

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