Experimental Study on Diagonally Loaded Steel Fibre Reinforced Cement Concrete Frames

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Abstract

Many failures of framed structures have been attributed to the failure of beam column joints during the past earth quakes. During the analysis process of reinforced concrete frames, the joints between beams and columns assumed as rigid in general. In practise much attention is not given and the joint is usually neglected for specific design with attention being restricted to the provisions of sufficient anchorage for longitudinal reinforcement in beams. This is quite acceptable when the frame is not subjected to seismic loads. When these structures are subjected to seismic loads the performance of beam column joints leads to failure. The poor design practice of beam column joint is compounded by the demand imposed due to the adjoining members in the event of mobilising their inelastic capacities to dissipate seismic energy. This may be achieved by enhancing the properties of fibre reinforced concrete at these joints. An attempt is made in this paper to study the beneficial influence of steel fibres in reinforced concrete frames subjected to diagonally applied ultimate loads. Concrete specimens with adequate reinforcement are prepared and corrugated steel fibres of aspect ratio 50, with 0%, 1%, 2%, 3% and 4% dosages are introduced at the beam column joints. Concrete used in this study are M20 grade and M25 grade for which the mix design is done by using IS method. Specimens are subjected to ultimate loads. Non destructive tests are also conducted before and after the failure of specimens. From the test results conclusions are drawn.

Keywords: steel fibre, beam column joints, fibre reinforced concrete, non destructive test

1. Introduction

1.1. General

During the process of analysis and design of reinforced concrete frames the connectivity between beam and column are assumed as rigid in general. These joints are usually neglected in practise and the attention is restricted to the provisions for longitudinal anchorage reinforcement in beams [1]. This procedure is quite acceptable when the frame is subjected to gravity loads, whereas this is not acceptable when the members are subjected to seismic effects. The type of failures due to the improper and insufficient design of beam column joints is reported in many cases of failure in the past. The inadequate practise of designing the beam column joint is compounded by the demand imposed due to the adjoining members in the event of mobilising their inelastic capacities in order to dissipate the seismic energy. Energy dissipation especially in seismic loading can be represented by a burst of energy applied to the structures. In conventional joints, such energy is dissipated by cracking of concrete, deformation in steel, bending in steel etc. To dissipate such energy via progressive pull out of fibre from concrete is achieved by imparting steel fibres in joints. This may be complimented by enhancing the properties of fibre reinforced concrete at these joints. Attempt is made in this paper to study the effect of steel fibres in diagonally loaded cement concrete frames subjected ultimate loads. Specimens with adequate reinforcement of M20 and M25 grade of concrete are prepared and corrugated steel fibres of aspect ratio 50 with 0%, 1%, 2%, 3% and 4% dosages are introduced at the joint. Mix design is carried by IS method.

2. Literature Review

Subramaniam et al., summarised that the opening of beam column joints are to be considered properly which will result in diagonal cracking of the joint. Such opening of joints occur due to lateral loads [2]. Jiuru et al., have found that the SFRC joint have higher shear strength than the probable shear capacity for the joint built with full seismic details. The SFRC joint dissipated 85% of energy of the full detailed joint and concluded that a steel fibre reinforced concrete joint is a possible alternative to a conventional joint [3].

3. Methodology

3.1. Materials

Ordinary Portland Cement 53 grade is used for the investigation. Locally available fine and coarse aggregates are used. Frame specimens are prepared with concrete of grade M20 and M25 for which mix proportion are arrived as shown in table 1 using IS method. Basic tests are conducted as per IS standards on the materials used for concrete, such as specific gravity, fineness, consistency, and initial setting time for cement. For fine and coarse aggregates tests such as sieve analysis, specific gravity, impact value and crushing value are conducted as per standards[4][5] and results are tabulated in table 2, 3 and 4. Corrugated steel fibres of 0.6mm diameter and 36 mm length (Aspect ratio 50) are used for the investigation as shown in fig. 1.

Φιγυρε 1. Χορρυγατεδ στεελ φιβρε

3.2. Mix Design

Concrete used for the investigation is designed in accordance with IS 10262 [6].

Design Stipulations

Characteristic Compressive Strength required in the field at 28 days	-	20 N/mm^2 and 25 N/mm^2
Maximum size of aggregate	-	10mm (Angular)
Degree of workability	-	0.85 (Compacting Factor)
Degree of Quality control	-	Good
Type of Exposure	-	Mild

Test Data for Materials

Cement used	-	OPC – 53 grade
Specific gravity of Cement	-	3.15
Specific gravity of coarse aggregate	-	2.66
Specific gravity of Fine aggregate	-	2.58
Water absorption		
Coarse aggregate	-	1%
Fine aggregate	-	2%
Free surface moisture		
Coarse aggregate	-	Nil
Fine aggregate	-	1.5%
Sieve analysis		
Coarse aggregate	-	Confirms grading of IS 383 - 1973
Fine aggregate	-	Confirms zone II

The design mix proportions for M20 and M25 grade concrete are given in table 1.

Ταβλε 1. Δεσιγν Μιξ προπορτιονσ

Grade	Cement	Fine Aggregate	Coarse Aggregate	w/c ratio
M20	1	1.54	2.54	0.52
M25	1	1.20	2.12	0.44

3.3. Details of Frame Specimen

The frame specimens are prepared to suit loading arrangements and test facilities. The outer to outer dimensions of the frame specimen are 750mm x 750mm, with the cross sectional dimension of 75mm x 75mm as shown in fig.2. The main reinforcement of 8 no. of 4mm diameter bars with stirrups of 4mm diameter are provided at a spacing of 100mm centre to centre as shown in fig. 2.

Φιγυρε 2. Φορμωορκ ανδ ρεινφορχεμεντ φορ φραμε σπεχιμεν

3.4. Casting of Specimen

The fabricated steel mould is arranged properly and placed over a galvanised Iron sheet. The exposed sides of mould are well greased to facilitate easy removal of the concrete specimen. Concrete of grade M20 and M25 with appropriate dosage of steel fibre are weighed, mixed, placed and compacted well into the mould. Care is taken to provide concrete in all the four junctions mixed with steel fibres for a distance 150mm from the inner face of joints. The specimens of M20 and M25 grade are prepared by above mentioned procedure with various dosages of 0%, 1%, 2%, 3% and 4%. The frame specimens as shown in fig. 3 are moist cured for 28 days before testing.

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Φιγυρε 3. Ρεινφορχεδ χονχρετε φραμε σπεχιμενσ

4. Experimental Investigation

The table 2, 3 and 4 show the test results conducted on cement, fine aggregate and coarse aggregate respectively.

Ταβλε 2. Τεστ ον Χεμεντ

Test	values
Specific Gravity	3.15
Fineness	97.6%
Consistency	35%
Initial Setting Time	35 min

Ταβλε 3. Τεστ ον Φινε αγγρεγατεσ

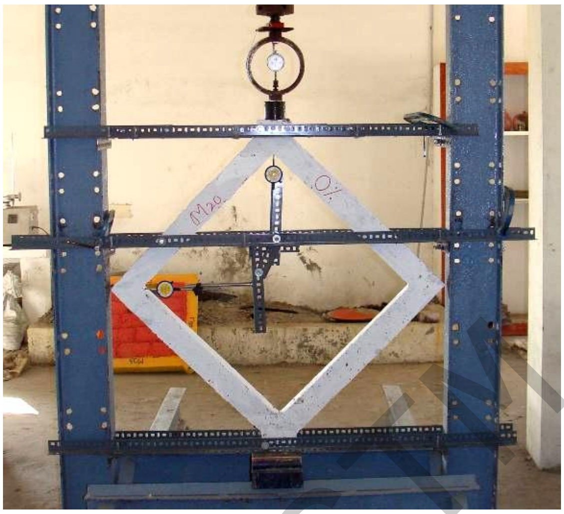
Test	values
Specific Gravity	2.58
Free Surface Moisture	2%
Gradation	Zone II

Ταβλε 4. Τεστ ον Χοαρσε Αγγρεγατεσ

Test	values
Specific Gravity	2.66
Aggregate Impact Value	26.33%
Aggregate Crushing Values	22.56%

5. Experimental Setup and Testing

The self straining load frame and the loading jack along with proving ring are arranged in such a way to apply the concentrated force diagonally on the specimen as shown in fig 4. Care is taken to avoid eccentricity during loading. The frames specimens of fibre reinforced concrete provided at joints with various dosages of 0%, 1%, 2%, 3% and 4% of steel fibre are subjected to failure and hence the ultimate loads are determined. Visible crakes first appeared at the joints and propagated along the diagonals. The ultimate loads are tabulated in table 5. From the investigations it is observed that the failure patterns of fibre reinforced concrete frames are more ductile with the increment in steel fibres compared to conventional reinforced concrete frames.



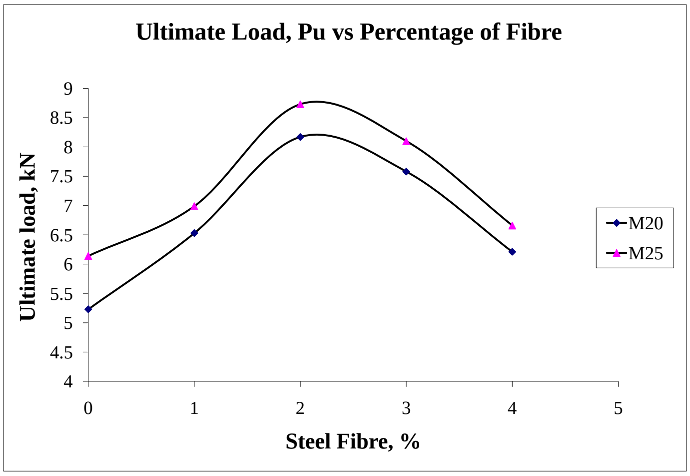
Φιγυρε 4. Φραμε σπεχιμεν δυρινγ τεστινγ

6. Results and Discussions

Table 5 shows the relation between the ultimate loads and percentage of fibre in reinforced cement concrete frame. A plot is made between ultimate loads and percentage of fibre as shown in fig. 5 for frame specimens of M20 and M25 grades.

Ταβλε 5. Υλτιματε Λοαδ ον Φραμε Σπεχιμενσ

Steel Fibre, %	Ultimate Load Pu, kN (M20)	Ultimate Load Pu, kN (M25)
0	5.23	6.14
1	6.53	6.99
2	8.17	8.73
3	7.58	8.1
4	6.21	6.66



Φιγυρε 5. Ρελατιον βετωεεν Υλτιματε λοαδ ανδ περχενταγε οφ στεελ φιβρε

It is observed that the ultimate load increases with the addition of corrugated steel fibre to a maximum of 2% dosage and then decreases for both M20 and M25 grade concrete.

7. Conclusions

The following conclusions are drawn from the test results.

i) The ultimate load on steel fibre reinforced concrete frame at joints of M20 grade concrete increases by 56% to that of conventional concrete frame for an optimum dosage of 2%.

ii) The ultimate load on steel fibre reinforced concrete frame at joints of M25 grade concrete increases by 42% to that of conventional concrete frame for an optimum dosage of 2%.

iii) The ultimate load on diagonally loaded fibre reinforced concrete frame increases with the addition of fibres for optimum dosage. Further addition of fibre decreases the load carrying capacity.

iv) It is also concluded that no incremental increase in ultimate loads on fibre reinforced concrete frames with increase in grade of concrete.

8. References

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