INVESTIGATION ON BEHAVIOUR OF EXTERIOR BEAM-COLUMN JOINT UNDER CYCLIC LOADING

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ABSTRACT

Beam column joint is more important structural element subjected to damage during cyclic earthquake loading which risks the entire structure with insecure design. Inadequate design may lead to extensive cracks and increased shear stresses within the joint during ground shaking which affects strength and stiffness to a greater extent. This study investigates on the flexural behaviour of beam column joint with high strength reinforced and normal reinforced concrete under cyclic loading. Two test specimens modeled on 1:4 scale from a multi storey building were cast and tested using M30 and M60 graded concrete to examine the parameters such as load carrying capacity, stiffness degradation, ductility factor and energy absorption capacity. The test specimens are detailed as per the guidelines given in ductile detailing code IS13920:1993. The study indicates that the High Strength Reinforced Concrete (HSRC) enhances the seismic performance of the beam column joint to a numerous level.

Key words: Beam column joint, earthquake loading, ductility.

I- INTRODUCTION

Earthquake is the sudden force arising beneath the earth, that causes sudden acceleration of the ground which in turn causes the structures on the surface to get accelerated. If the structure is ductile enough to withstand the acceleration caused due to the motion of the earth surface without any cracks and collapse, then there won’t be need of any research work in the earthquake detailing. The care is given by every designer to make the structure with high stiffness, as stiffness is the parameter somewhat directly related to strength of the member [Deepa Shri and Thenmozhi, 2012]. The aim of every good Structural Engineer who designs building in the earthquake prone zone is to create a ductile model of frame (at the time of earthquake) with sufficient stiffness of the structure (at the normal time) [Thenmozhi and Deepa Shri, 2012]. This project also focused on creating the ductile beam-column joint with a very good stiffness degradation value and can withstand the stresses that are caused due to the abnormal loads like earthquake, wind.

By several site visits prone to earthquake, the inference is made that the beam-column junction is one of the major portion that is seriously affected by means of the earth acceleration. This projects also aims to give a perceptive view of usage of steel fiber in the vulnerable beam-column region and its effect in the energy absorption capacity, ultimate load carrying capacity, stiffness and ductility parameters. The strength of the beam-column joint specimen confining to the grade of M30 with the mixture (in addition) of the steel fiber is compared with the conventional M30 concrete beam-column joint and the High Strength Reinforced Concrete of grade confining to M60. The comparison shows aims to show the effectiveness of the usage of steel in improving the necessary strength and ductility parameters.

II-EXPERIMENTAL INVESTIGATION

The Experimental study of this paper is done by designing a G+4 reinforced concrete building in the region of Erode in the Coimbatore seismic zone. The region comes in the seismic zone-III as per the Indian Standard (IS). The building is analysed using software STAAD pro. The specimens were designed as per IS 456: 2000 and while considering the seismic load the design and detailing is done by IS 1893:2002 & IS13920:1993. The exterior beam column joint which are considered for experimental study in this project is marked with red (highlighted) in the figure-1.

III-TEST SETUP

The test specimen is made to test by means of the loading frame of 100 tonne capacity. Based on
the provisions of the loading frame the height and length of the specimens are limited to the requirement of testing. The specimens consist of monolithically cast beam-column, the column is of the height 750 mm and the clear beam span of 500 mm. According to IS 456, the minimum requirement of axial load is given by 0.1 fck of the gross area of the column. By following this provision, the axial load on the column is made a constant of 100kN [Rajaram, et al., 2010]. Then the load is given in the beam portion. The illustrated model diagram of the load setup with axial load and the load on the beam is illustrated clearly in the figure-2.

**Fig -2 Load setup of the beam-column joint**

### IV- SPECIMEN DETAILS

According to the law of simulation, the specimen which is cast is the ¼th scale down specimen. The building with G+5 Storey is analysed using the software STAAD Pro and the design of the building is completed using MS Excel. Then the prototype model is scale down to be use it as a laboratory scaled down model. The 10 mm diameter bar of 8 numbers are used as the column reinforcement and 4 numbers of 10 mm diameter bar is used as the main reinforcement of the beam. The spacing is given as per the ductile detailing code IS13920. [Mariselvam and Sakthieswaran, 2015]

The provision of the ½ of the least lateral dimension is given at the junction region and for the remaining region the spacing is least lateral dimension. Prototype specimen having beam dimension of 300x450mm including slab thickness and column dimension of 300x450mm is scaled down in the testing model of dimension in beam with 150x120mm and for the column it was 200x120mm. Height of the column is 750mm. The details of the reinforcement are given by means of the figure-3.

**Fig -3 Reinforcement details of the beam-column joint**

### V- CASTING AND CURING

**Joint-1 (M30):** Concrete mix designed for M30 concrete with the proportion of 1:1.85:3.26 with the water cement ratio of 0.42

**Joint-2 (M60):** The concrete mix designed for M 60 concrete are with the proportion of 1:1.4:2.2 with the water cement ratio of 0.3.

**Joint-3 (M30-With steel fibre):** The concrete with proportion of 1:1.85:3.26 and the water cement ratio of 0.42 is made to mix with the steel fiber of 1% of the volume.

The preparation process of the specimen is done as it could be done in a small-scale laboratory. The mould used as the formwork is of wooden material. The mould is oiled well to ensure the smooth removal of the specimen without honeycomb. The concrete is mixed together as per the mix proportions arrived until a homogeneous mixture of concrete is obtained. The reinforcement cage is kept inside the mould with the cover of 20mm leaving beneath, sideways and at the top portion. The casting is done horizontally for easiness and suitability. The reinforcement cage is kept inside as shown in the figure and then the concrete mixture is placed in layers. The proper compaction is done to ensure there won’t be any air voids inside and along the specimen. The reinforcement case and the cardboard mould is shown in the figure-4.

**Fig -4 Reinforcement which is placed in the mould**

The casting of the specimen is down with almost care and the water specimen ration is maintained as per the mix. Three layers of
tampering is done to attain proper compaction and so that honeycombs could be avoided. The compaction of the specimen is showed in the figure-5

VI- TESTING OF SPECIMENS

The specimen was tested under the loading frame and with the help of it. The axial load for the column is given by the means of the hydraulic jack. The load on the beam is given with the help of the hand operated manual jack and the readings are measured by means of means of the proving ring. The load is applied on the end (tip) of the beam on the top of the beam to mark the forward behaviour and simultaneously at the bottom of the beam to stimulate the reverse cyclic behaviour. The corresponding deflection for the load on the beam was measured using dial gauge. Loads are applied gradually to measure the forward behaviour and the corresponding deflection is measured by the dial gauge kept under the loading point [Ganesh Kumar and Prabavathy, 2015]. Then the loading is given from the underside of the beam to take the reverse cyclic load and the loading is given in the same order as in case of forward cyclic direction loading. The both forward and reverse cyclic load and deflection completes a hysteresis loop. The load vs deflection value is obtained and it gives the parameters like stiffness, ductility, energy absorption and the ductility factor. Test set up for the forward cycle loading is shown in figure-6.

VII- BEHAVIOUR OF SPECIMENS

In all the three specimens (Beam- Column Joint), cracks appeared on the specimen on a specific load that was marked as the initial crack load. On further loading the cracks develops due to yielding of the reinforced steel, the cracks develop in the specimen on subjected to the further loading. In all the specimen the crack pattern appeared is similar to that of the real case project. In our building we expect to obey the principle of ‘strong column and weak beam’. Likewise, in this project the plastic hinge is formed in the region of beam column junction. The three varieties of beam-column joints are tested in the loading frame subjected to cyclic loading and their values are taken. The Ultimate load carrying capacity of the M60 concrete, M30 concrete and M30 Concrete with Steel Fibre is 22.5kN, 18kN, 21kN respectively. The table below shows the results of various strength, stress-strain parameter that the 3 beam-column joints experiences. The values are given in table-1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>M 30</th>
<th>M 60</th>
<th>M 30 (with SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load carrying capacity (kN)</td>
<td>18</td>
<td>22.5</td>
<td>21</td>
</tr>
<tr>
<td>Cumulative Energy absorption (kN-mm)</td>
<td>197.5</td>
<td>254.7</td>
<td>286.1</td>
</tr>
<tr>
<td>Cumulative Ductility factor</td>
<td>9.18</td>
<td>17.373</td>
<td>14.83</td>
</tr>
<tr>
<td>Stiffness (kN/mm)</td>
<td>3.2</td>
<td>3.75</td>
<td>7.64</td>
</tr>
</tbody>
</table>

The Load- Deflection diagram of the forward cycle and the reverse cycle for the M60 Beam – Column joint Specimen is given as a chart in the figure-7.
The Load-Deflection diagram of the forward cycle and the reverse cycle for the M30 Beam – Column joint (With Steel fibre) Specimen is given as a chart in the figure-8.

**Fig-8 Hysteresis loop of M30 concrete with steel fibers**

The Cumulative energy absorption value is given by the summation of the energy absorption of every cycle. The energy absorption value for every cycle is represented in the form of the chart in the figure-9.

**Fig-9 Chart showing the energy absorption vs cycle for the Beam-Column joint with steel fibers**

**VIII- CONCLUSIONS**

The structural behaviour of 3 varieties of exterior beam column joint are studied experimentally. Experimental investigation shows that the usage of steel fibers in concrete reduces the crack and the overall depth of the penetration of cracks was found to be comparatively less. The addition of steel fibers in concrete of the Beam–Column specimen increases the load carrying capacity (Ultimate load carrying capacity) by the margin of 25% while comparing the M30 mix. The load parameter of M30 Grade (with steel fibers) is only 7% less when comparing the M60 Grade Beam-Column. While considering the other parameter like ductility and stiffness, use of steel fibre is recommended in the high earthquake zone rather than increasing the grade of concrete. The conclusion is arrived after studying the properties of ductility, stiffness and energy absorption parameters and more importantly the failure pattern of the specimens.

**REFERENCES**


