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Study of Beam-Column Junction based on Variations in Concrete Grade at Junction

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Abstract

Objectives: A beam-column joint has to transfer the shear forces, bending moments and other related structural response parameters efficiently. The present paper aims at studying the behavior of beam-column junction based on variations in concrete grade at junction. **Analysis:** To increase the load carrying capacity of a joint, a higher grade of concrete is used at a joint and also up to 1.5D in the direction of beam from face of column, to shift or relocate the plastic hinge from the interface towards the beam. The different specimens were prepared in a T-shaped mould by changing the grade of concrete at beam-column joint and these samples were tested after 7 and 28 days. **Findings:** Study reveals that use of M20 or M25 grade of concrete at joint and up to 1.5D (D is the depth of beam) of length of beam (M15 grade of concrete in rest of mould) increases the load carrying capacity approximately to about 20% when compared with M20 or M25 grade of concrete at junction and M15 grade in the remaining mould. The most important finding is that the use of higher grade of concrete at a joint and up to 1.5D of length of beam, shifts the failure away from the beam-column interface Thus, a beam hinging mechanism is achieved which is a ductile type of failure compared to beam-column brittle interface failure and there is approximately 15-30% increase in load carrying capacity, in comparison with higher concrete grade only at a joint core. This is a simple and efficient method of preventing the beam-column joint failure. **Improvement/Applications:** Based on the test results there is remarkable increase in the load carrying capacity of beam-column joint which enhances the rigidity of beam column joint in terms of strength and stiffness.

Keywords: Beam-Column Joint, Brittle Failure, Concrete Grade, Load Carrying Capacity, Strength

1. Introduction

A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three directions and the region deserves special attention in a building because it can be the critical and possibly the weakest link according to the hierarchy of strength considerations[1]. Joints ensure continuity of a structure and transfer forces that are present at the ends of the members. A beam-column junction has to transfer the shear forces, bending moments and other related structural response parameters efficiently and has to maintain structural integrity. In reinforced concrete structures, failure in a beam often occurs at the beam-column joint making the joint one of the most critical sections of the structure. It is important to shift the plastic hinge from the face of column towards the beam to prevent the undesirable brittle shear failure of the joint[2]. The brittle failure of joints may reduce the ductility of structure and may lead to progressive collapse of a structure[3]. Beam column joint plays significant role in lateral stability of a structure[4]. Therefore seismic deficiencies in a structure due to lack of seismic design and detailing should be considered which may otherwise prove vulnerable to a structure[5, 6].

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Joints having low concrete strength, improper reinforcement bar detailing and inadequate transverse reinforcement may be identified as seismically insufficient[7]. Sudden change in geometry and complexity of stress distribution at joint are the reasons for their critical behavior and there may also be other structural failures related to reinforcement design and detailing[8]. It has to bear with the seismic forces and as a direct consequence it forms the real blood of the structure and if it is not capable of transferring the structural response, then the entire structure might fail and may lead to catastrophe.

Joints can be strengthened by using glass or carbon FRP materials in addition to steel members[9]. From experimental studies High performance reinforced concrete jacketing can also be used to improve the joint behaviour[10]. Several strengthening techniques for joints have been proposed from time to time. These include prestressed concrete jacketing, FRP materials; steel jacketing and epoxy injection repair[11–13]. The ferrocement jacket can also be used to strengthen the interior beam-column joint[14]. The strength of the joint should not be less than the maximum demand corresponding to development of the structural plastic hinge mechanism[15]. The behavior of joints is dependent on a number of factors related with geometry; amount and detailing of reinforcement, concrete strength and loading pattern[16]. In this project the efficiency of the beam-column junction based on variations in concrete grade at junction is studied. The experimental study includes the use of high concrete grade at beam-column junction to increase structural efficiency and to our best of knowledge this concept is not known to almost all. The main objective of this research is to study the behavior of beam-column junction and its failure mode by varying concrete grade at joint. This modified beam column junction may become an important tool with the course of time and we believe that our project will strike the brains of the structural engineers and with the course of time this trend will become common in our structures and there will be further modification in our work on beam-column junction .Though a beam-column junction is reinforced and there may be failure due to inadequate reinforcement and other associated parameters[17,18] but in our project work ,concrete strength parameter is varied in to study the behavior of junction. We have limited our project work to use of high concrete grade at junction for preventing the beam-column junction from failure.

2. Materials and Methods

2.1 Materials

2.1.1 Coarse Aggregate

Coarse aggregate used in experimental are combination of two nearby obtainable creased stone of 20 mm and 10 mm size in 70:30 fraction respectively. The specific gravity examined for 20 mm and 10 mm aggregate is 2.81 and 2.75 respectively.

2.1.2 Fine Aggregate

Fine aggregate used for experimental work is of Zone II examined by IS: 383-1970. The specific gravity examined is 2.45.

2.1.3 Cement

In the present study OPC 43 grade cement is taken for design mix.

2.2 Mix Design for Concrete

The main aim of experimental work is to investigate the response of joint by varying concrete grade at joint. Ordinary potable water was used throughout the investigation as well as for curing concrete specimens. The typical water cement ratio used for the project work is 0.45. The different mixes prepared for experimental study were M15, M20 and M25 ,the letter M refers to the mix and the number to the specified 28 day cube strength of mix in $\frac{N}{mm^2}$ as per 19,20 IS 456-2000.

2.3 Structure of Specimen

In order to study the behavior of beam-column joint, the specimens were prepared in a T shaped mould. Overall dimensions of test specimen are shown in Figure 1.

Figure 1. T Mould--- [50cm×10cm×10cm].

2.4 Experimental setup

The experimental program consists of five T-shaped specimens. These different specimens were prepared by changing the grade (mix) of concrete at beam-column joint and were tested after 7 days and 28 days on UTM. Different grades of concrete were varied at the joint like M25, M20, and M15 etc to study the response of beam column junction. Each specimen is provided with nut-bolt assembly (4 nuts and 4 bolts) for the purpose of fixity of beam end. A suitable arrangement is made at the time of testing for achieving the fixity condition as shown in Figure 2.

Figure 2. Nut-bolt assembly and end conditions.

The details of tests carried on different specimens are given in Table 1. In sample 1, M15 concrete grade is used throughout the specimen with no variation of concrete grade at junction. Both in samples 3 and 4, higher concrete grade M20 and M25 is used at joint respectively and M15 in rest of specimens. In sample 2, M25 concrete mix is used both at the junction as well as up to 1.5D in the direction of beam from the face of column with M15 in rest of matrix. In sample 5, M20 concrete mix is used both at the junction as well as up to 1.5D in the direction of beam from the face of column with M15 in rest of matrix. "D" refers to the depth of beam.

Table 1. Details of distribution of different concrete grades in specimens

S.NO	SAMPLE	DETAILS OF SAMPLE
1	SAMPLE 1	M15 USED UNIFORMLY
2	SAMPLE 2	M25 AT JOINT AND UP TO 1.5D IN THE DIRECTION OF BEAM FROM FACE OF COLUMN AND M15 IN REST OF SPECIMEN
3	SAMPLE 3	M20 AT JOINT AND M15 IN REST OF SPECIMEN
4	SAMPLE 4	M25 AT JOINT AND M15 IN REST OF SPECIMEN
5	SAMPLE 5	M20 AT JOINT AND UP TO 1.5D IN THE DIRECTION OF BEAM FROM FACE OF COLUMN AND M15 IN REST OF SPECIMEN

3. Results and Discussion

Using M25 concrete grade at junction and up to 1.5D of the length of beam (M15 in the remaining) increased the load at failure to about 13% when compared with M20 mix at junction and 1.5D of the length of the beam (M15 in the remaining). Using M25 concrete grade at junction and up to 1.5D of the length of beam (M15 in the remaining) increased the load at failure to about 26% when compared with M25 mix at the junction only (M15 in the remaining). Using M25 concrete grade at junction and up to 1.5D of the length of beam (M15 in the remaining) increased the load at failure to about 30% when compared with M20 mix at the junction only (M15 in the remaining). Using M20 concrete grade at junction and up to 1.5D of the length of beam (M15 in the remaining) increased the load at failure to about 20% when compared with M20 mix at the junction only (M15 in the remaining). Using M20 concrete grade at junction and up to 1.5D of the length of beam (M15 in the remaining) increased the load at failure to about 15% when compared with M25 mix at the junction only (M15 in the remaining). The comparison of peak loads for different samples is shown in Table 2.

Table 2. Comparison of peak loads

SAMPLE	SAMPLE 2	SAMPLE 5	SAMPLE 4	SAMPLE 3
PEAK LOAD	116 KN	101 KN	85 KN	80 KN

Load-Displacement curves of all the samples are shown in Figures 3–7. In each graph, load is expressed in KN and displacement in mm. Sample 1 was tested after 28 days. Samples 2-5 were tested after 7 days.

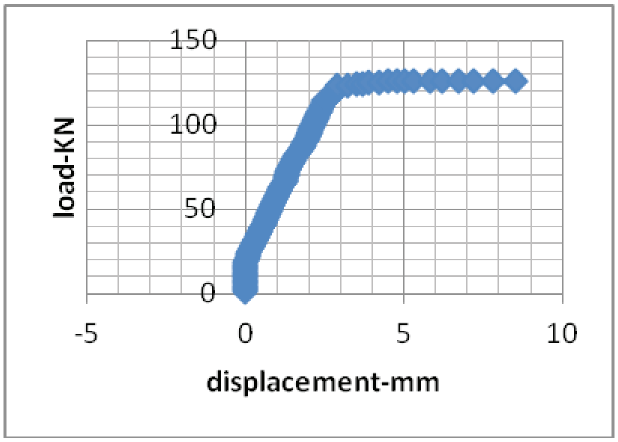

Figure 3. Load-displacement curve (sample 1).

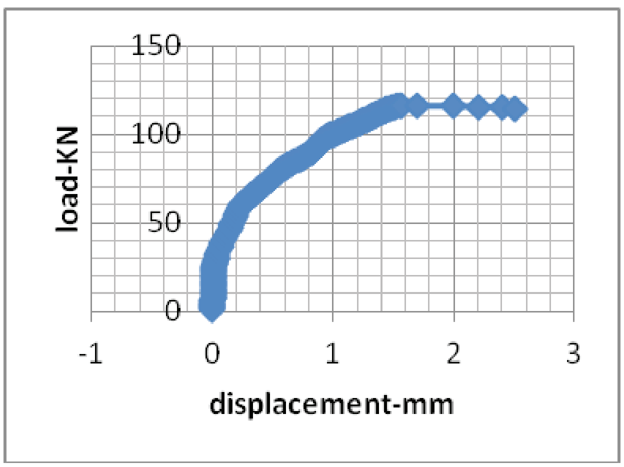

Figure 4. Load-displacement curve (sample 2).

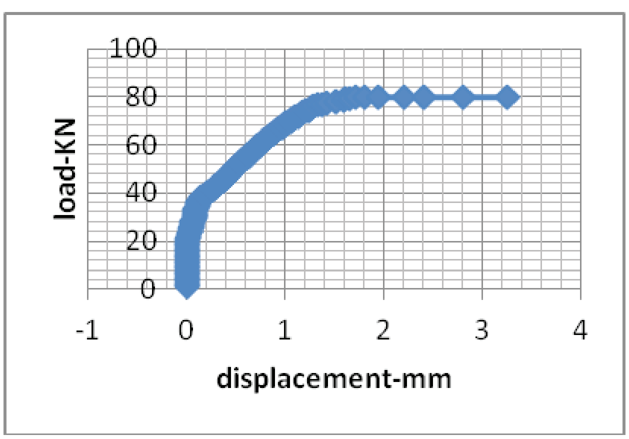

Figure 5. Load-displacement curve (sample 3).

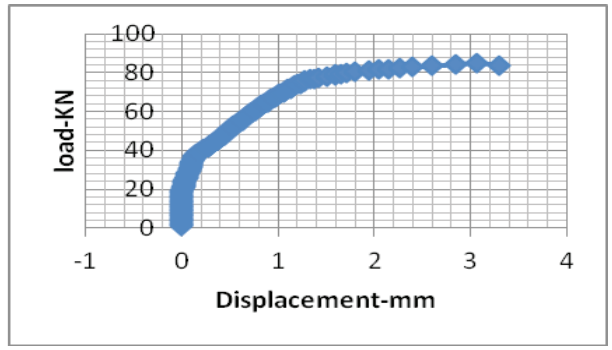

Figure 6. Load-displacement curve (sample 4).

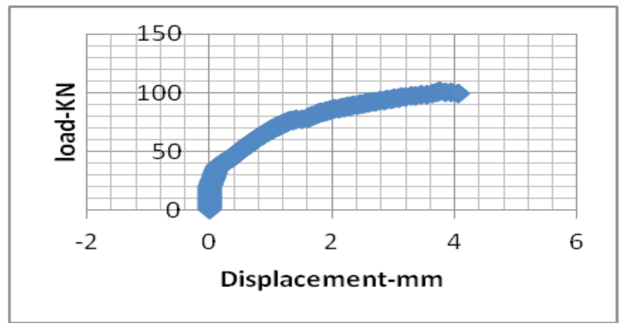

Figure 7. Load-displacement curve (sample 5).

It is clear that the efficiency of beam column-junction can be enhanced by using higher concrete grade at junction. Undoubtedly this proposed beam-column concrete junction modification is an efficient and economic technique that surely can be used to enhance the ability of the beam-column junction to bear and transfer structural response parameters efficiently[21,22]. Thus we should design the beam-column junction properly in such a manner than it is able to resist the associated forces. We should be on safer side while designing the beam-column junctions because at connections geometric imperfections, lack of fit, development of residual stresses, slip and non-linear load deformations may occur[23–25]. This technique arrests the failure via cracking of beam-column junction and shifts the failure away from joint as shown in Figure 8.

Figure 8. Failure mode away from joint.

4. Conclusion

1. Sample 2 is having superior load carrying capacity which is about 13% more as compared to Sample 5 and 26% more in comparison with Sample 4. Sample 5 has 15% more load carrying capacity as compared to Sample 4 and 20% more in comparison with Sample 3.
2. Use of higher concrete grade at beam-column junction increases the load carrying capacity to about 20–30% (average) and hence adds to the structural efficiency.
3. Strictly from detailed experimental observations we concluded that concrete has a tendency of cracking at beam-column junction if no measures are taken to improve it. From our experimental observations we concluded that use of high grade concrete at beam-column junction is an economic and feasible method of improving the properties of beam-column junction. Therefore technique is economically as well as practically feasible and at site, this technique can be applied with ease and without much complexities.
4. Varying of concrete grade at junction is a new concept in the field of research and as a modification we would like to draw the attention of the research fellows towards the use of steel fibers, carbon and glass fiber reinforced polymers in addition to higher concrete grade at beam-column junction in order to increase its seismic and shear efficiency.
5. In addition with other strengthening methods like use of FRP materials, steel jacketing and epoxy injection repair; this method can be applied with ease in producing economically modified beam-column junction resistant to cracking.
6. Due to its high load carrying capacity and higher shear resistance, it can be used in producing structurally efficient beam column-junctions.
7. As the economy is moving ahead and infrastructure development is catching its pace, demand for such new developments in civil construction is increasing and becoming acceptable.

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