RESEARCH ARTICLE OPEN ACCESS

Analytical Investigation on External Beam-Column Joint Using ANSYS By Varying The Diameter Of The Longitudinal Reinforcement In Beam

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ABSTRACT
The beam-column joint has been a topic of study for over 30 years now and still there are many things that yet to be completely understood. The joint was considered to be rigid, however researches have shown that failure may occur at the joint instead of the beam or column. This study was carried out to determine the effect of the diameter of longitudinal reinforcement of the beam on the strength, deformation and ductility in the beam-column joint using ANSYS. It was seen that the load carrying capacity and the deformation increases as the diameter of reinforcement in the beam increases.
Keywords – ANSYS, Beam-column Joint, Diameter of Reinforcement, Finite Element

I. INTRODUCTION

The beam-column joint (BCJ) is one of the most critical region in a multi-storey building. The beam-column joint were usually considered as rigid frames. But over the past 30 years, various researches have indicated that the joint is not rigid. Also, the failure may occur at the joint instead of the beam or the column, hence the joint must also be considered as a structural element. The Indian Standard defines a joint as the portion of the column within the depth of the deepest beam that frames into the column.

Computer simulation offers the potential to understand the behavior of the RCC beam-column joint to various loadings. The research presented here focuses on ANSYS software to investigate the beam-column joint. The current research aims to study the effect of the variation of diameter of the longitudinal reinforcement in the beam in an exterior beam-column joint.

The literature on the above topic were less however some of the literature which are very near to the topic are given below :

Scott et. Al. [1] performed studies by varying the reinforcement pattern using bent up, bent down and U-bars. It was observed that the U-bars show highest load carrying capacity while the bent up and bent down bars fail due to pull out.

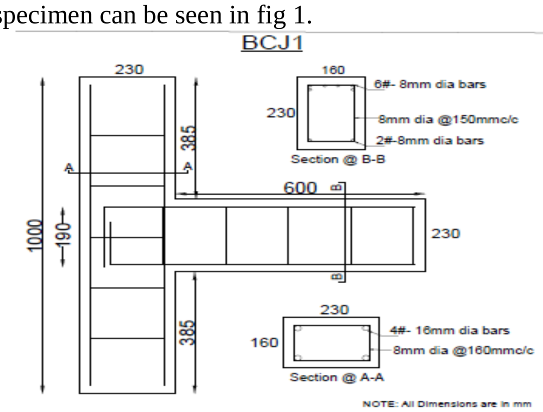
Kang and Mitra [2] proved that the increasing development length, head thickness, head size and decreasing joint shear demand gives better beam-column joint performance.

Murty et al [3] have tested the exterior beam column joint subject to static cyclic loading by changing the anchorage detailing of beam reinforcement and shear reinforcement. It was reported that the practical joint detailing using hairpin-type reinforcement is a competitive alternative to closed ties in the joint region.

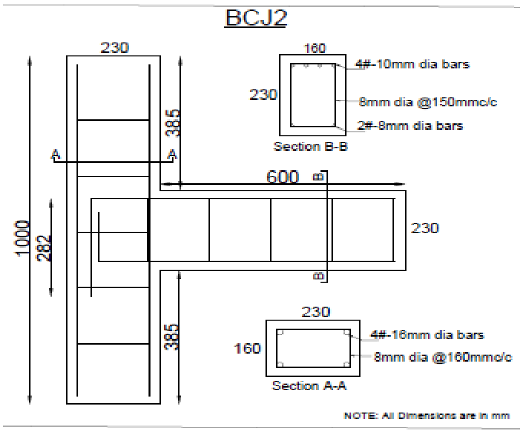
II. DETAILS OF SPECIMEN

The six beam-column joints which were analysed in the CAD lab of Civil Engineering Dept. research centre at MSRIT were modeled and run using ANSYS. Each joint was designed as IS 456: 2000 and detailed as per SP34: 1987.

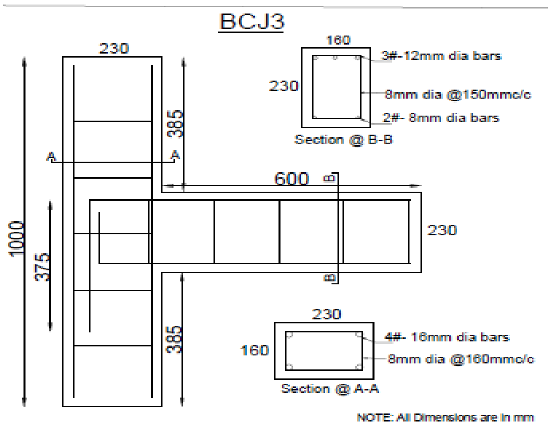
All the six beam-column joints had identical beam and column sizes. The beams were 160 mm wide and 230 mm deep and the columns are 230 mm by 160 mm. The column height was fixed to 1000mm and the beam length was fixed at 600mm. The clear cover for the reinforcement was considered as 25 mm. The 28 day cube strength of concrete was taken as 42.85 N/mm2. The yield stress in steel was considered to be 500 N/mm2. The details of the specimen can be seen in fig 1.



(i) 8 mm Longitudinal reinforcement



(ii) 10 mm Longitudinal Reinforcement



(iii) 12mm Longitudinal Reinforcement

Fig. 1 : Reinforcement Details of Beam-Column Joint

III. ANALYTICAL MODEL

3.1 Elements for ANSYS

The beam-column joint was modelled in ANSYS with SOLID 65 and LINK 180 elements. The SOLID 65 was used to model the concrete. The LINK 180 was used to model the reinforcement in the concrete.

The various parameters required in modeling is shown in table 1.

Table 1: Material Properties and Element types for ANSYS

Material Number	Element Type	Material Properties
1	**Link 180**	**Linear Isotropic**
Ex		2100000 N/mm2
Prxy		0.3
Bilinear Kinematic		
Yield Stress		500 N/mm2
Tangent Modulus		10
2	**Solid – Concrete 65**	Linear Isotropic
Ex - M 30		32729.96 N/mm2
Prxy		0.2
Concrete		
Shear Transfer Coeffecients for an Open Crack		0.3
Shear Transfer Coeffecients for a Closed Crack		0.7
Uniaxial Cracking Stress		4.58 N/mm2
Uniaxial Crushing Stress		42.85 N/mm2

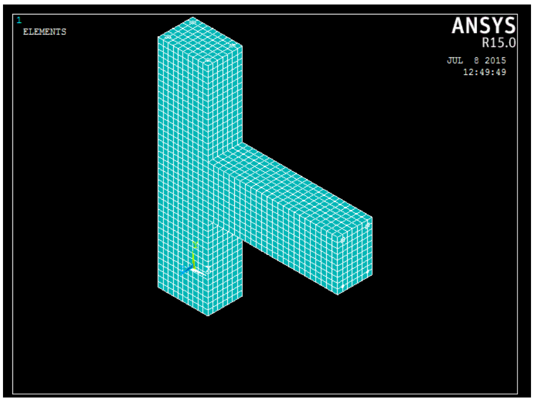
Typical shear transfer coefficients represent conditions of the crack face, It has value ranges from 0.0 to 1.0, with 0.0 representing a smooth crack (complete loss of shear transfer) and 1.0 representing a rough crack (no loss of shear transfer). The shear transfer coefficients for opened and closed cracks are determined using the work of Kachlakev, et al. (Kachlakev 2001) as a basis.

3.2 Modeling In ANSYS

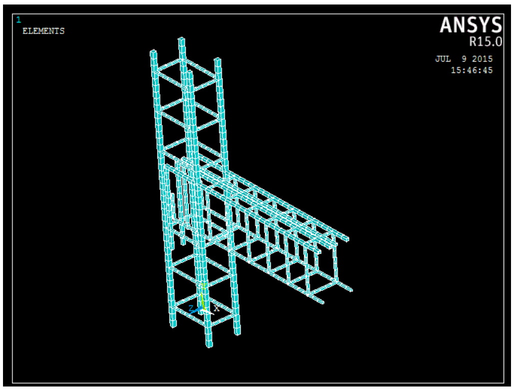
The beam-column joint was modeled in ANSYS using the above material properties and element types. The column was considered to be fixed and a constant axial load of 130 kN, which was the calculated working load, was applied at the top of the column. The column was fixed at the top and the bottom. The load at the beam was applied at a distance of 100 mm from the free end of the cantilever portion, in incremental proportions. Even though the load can be applied at the centroid of the structure, the loads are applied at the respective points in order to simulate the actual behavior of the beam-column joint. The models were analysed applying monotonic load in the downward direction. The mesh size was fixed at 25mm. A total of 6 beams were analysed. The variation made for the beam-column joint were variation of diameter of longitudinal reinforcement and the shear reinforcement. The details of the joints are given below in table 2. Fig 2 represents the ANSYS models.

Table 2: Details of Reinforcement for the specimen

Specimen	Set No.	Column Reinf.	Beam Reinforcement	
			Longitudinal	Shear
BCJ 1	1	4 Nos-16ϕ	6 Nos - 8ϕ	8mm@ 100c/c
BCJ 2	1	4 Nos-16ϕ	4 Nos – 10 ϕ	8mm@ 100c/c
BCJ 3	1	4 Nos-16ϕ	3 Nos – 12 ϕ	8mm@ 100c/c
BCJ 4	2	4 Nos-16ϕ	6 Nos - 8ϕ	8mm@ 150c/c
BCJ 5	2	4 Nos-16ϕ	4 Nos – 10 ϕ	8mm@ 150c/c
BCJ 6	2	4 Nos-16ϕ	3 Nos – 12 ϕ	8mm@ 150c/c



(i) Meshed Model in ANSYS



(ii) Reinforcement Configuration
Fig 2: ANSYS modelling

IV. RESULTS AND DISCUSSION

4.1 Load Deflection Characteristics

The load deflection characteristics for 6 exterior beam column joints which were analysed are shown in figure 3. It was seen that as the diameter of the longitudinal reinforcement increases, the cracking load and the ultimate load carrying capacity reduces as seen in table 3 (BCJ 1 to BCJ 2 to BCJ 3, BCJ 4 to BCJ 5 to BCJ 6). It was observed that normalizing of loads are necessary as the area of steel provided is not constant, the normalized Ultimate load and Cracking load are shown in table 3. Fig 3, shows the combined load deflection characteristics of the joints.

From the cracks, in Fig 4., it can be seen that the failure occurs at the beam and not at the junction. This implies that the beam-column joint has been designed as a strong column weak beam and the plastic hinge is formed in the beam.

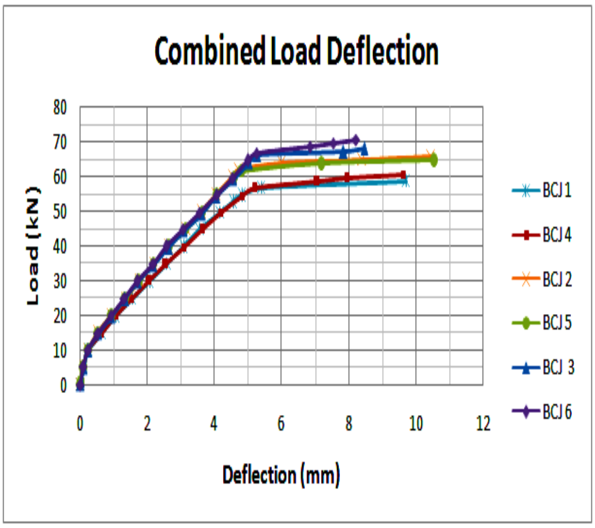


Fig 3 : Load Deflection Graph

Table 3: Normalized Loads

Specimen	Set No	Ultimate Load (kN)	Cracking Load (kN)
BCJ 1	1	58.38	9.08
BCJ 2	1	58.12	8.80
BCJ 3	1	54.95	8.22
BCJ 4	2	57.03	9.09
BCJ 5	2	56.95	8.67
BCJ 6	2	52.87	8.14

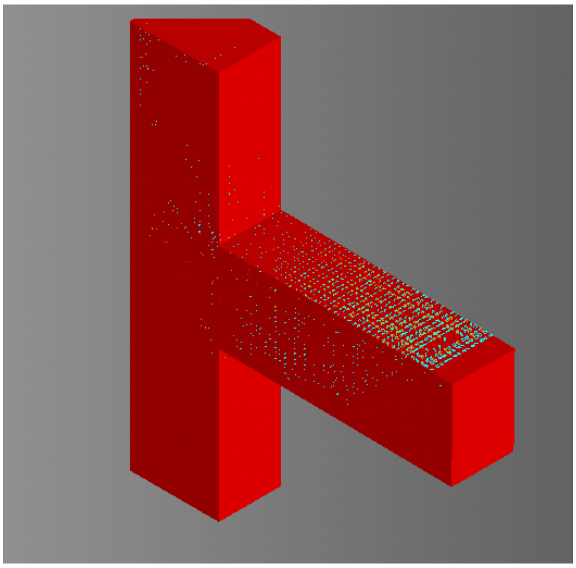


Fig 4: Cracks in Beam Column Joint

4.2 Ductility Characteristics

Ductility is generally measured in terms of displacement ductility. It is the maximum deformation a structure can undergo without significant loss of initial yielding resistance. It is the ratio of maximum deformation to the deformation at yield.

The displacement ductility for the six specimen are given in table 4 along with the yield deformation and ultimate deformation. The plot of ductility vs reinforcement percentage shows that as the diameter of reinforcement increases, the ductility reduces. And as the shear reinforcement spacing is reduced the ductility reduces. This can be observed in fig. 5. To determine the yield deformation, bilinear method of approximation was used as shown in fig 6. It is observed that ductility of the joint reduces as the diameter of the longitudinal reinforcement increases.

Table 4 : Ductility of Beam-Column Joints

Specimen	Set No.	Displacement		Disp. Ductility
		Yield (Δy)	Ultimate (Δu)	(μd)
BCJ 1	1	3.89	9.71	2.50
BCJ 2	1	4.34	10.45	2.41
BCJ 3	1	3.87	8.45	2.18
BCJ 4	2	3.3	9.62	2.92
BCJ 5	2	3.93	10.52	2.68
BCJ 6	2	3.64	8.21	2.26

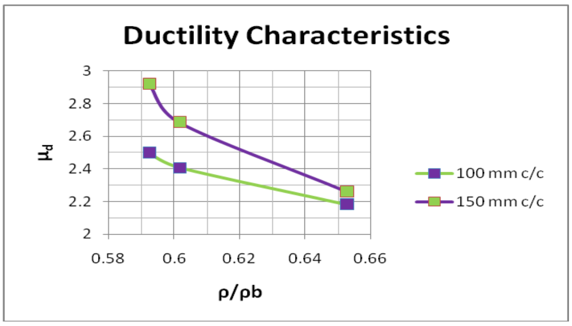


Fig 5: Ductility versus Reinforcement

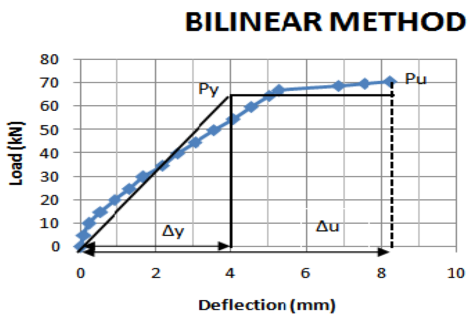


Fig 6: Bilinear Method For Ductility

4.3 Deflection at Working Load

The deflection at working load is shown in table 5.

Specimen	Set	Pcr (kN)	Deflection (mm)
BCJ 1	1	9.08	2.22
BCJ 2	1	8.80	2.45
BCJ 3	1	8.22	2.87
BCJ 4	2	9.09	2.37
BCJ 5	2	8.67	2.52
BCJ 6	2	8.14	2.97

V. Conclusions

The following conclusions are drawn from the study of the external beam-column joint applying monotonic load:

(i) The cracking load reduces as the diameter of the bar increases. For set 1 the reduction from 8mm to 10mm bars was 3% and for 8mm to 12mm was 10%. Whereas for set 2, for 8mm to 10mm it was 4.76% reduction and from 8mm to 12mm it was 10.43%.

(ii) The load deflection characteristics show that at working load, as the diameter increases the deflection increases.

(iii) The ductility of the joint reduces as the diameter of the bar increases. For set 1, the ductility reduces by 3.6% for 8mm to 10mm and there was reduction by 12.8% from 8mm to 12mm. Also for set 2, the ductility reduces by 8.21% for 8mm to 10mm and there was reduction by 29% for 8mm to 12mm. Also it was seen as the spacing of stirrups decrease the ductility reduces, comparing BCJ 1 and BCJ 4 there was an increase in ductility by 14.38%.

(iv) The displacement at working load increases as the diameter of the reinforcement increases. The deflection for set 1, increases by 10.36% for 8mm to 10mm bars and increases by 27.28% for 8mm to 12mm. For set 2, it was seen that the deflection increases by 6.30% for 8mm to 10mm and there was an increase of 25.32% for 8m to 12mm bars.

(v) The ultimate load carrying capacity also decreases as the diameter of the bar increases. For set 1 the reduction of ultimate load for 8mm to 10mm bars was 3% and for 8mm to 12mm was 10%. Whereas for set 2, the ultimate load carrying capacity for 8mm to 10mm it was 4.76% reduction and from 8mm to 12mm it was 10.43%.

Thus, it is concluded that the diameter of the longitudinal reinforcement in the beam plays a major role in the behavior of the beam-column joint. Further research can be carried out by considering variation of column and beam dimension, varying the percentage of steel and this will further enhance our understanding of the beam-column joint.

VI. ACKNOWLEDGEMENT

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