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Effect of Grade of Concrete in Shear Strength of Exterior Beam Column Joint of Reinforced Concrete Building

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Abstract
The Joint core of Beam and Column are very crucial zones in a reinforced concrete moment resisting frame. The behavior of such joints greatly influences the strength and ductility of the overall frame. Beam column joints are critical regions for frames designed for inelastic response to severe seismic attack .The present work aims to study the influence of grade of concrete in shear strength of exterior beam column joint of Seismic analyzed reinforced concrete building of Zone V. In this research, seismic analysis of six storey reinforced concrete Building of Zone V is done using SAP2000 Software and Exterior beam column joints are designed as per IS13920:2016 for different Grade of concrete, shear capacity and shear strength of joint core is determined.
Keywords: *Beam column joint, joint shear, Joint shear strength, strong column weak beam concept.*

1. Introduction

Recent earthquakes has shown the consequences of weak performance of beam column joints Seismic response analysis of reinforced concrete structures requires reference models that can predict strength, stiffness, and ductility characteristics of members under lateral loading. Beam-column connections are critical regions in reinforced concrete framed structures in seismic prone area. Proper grade of concrete, adequate Shear reinforced and Size of adjoining members is essential to enhance the performance, Innovative design can reduce the severity of joint core failure under seismic loading. A design code recommendations and analytical expressions for calculating the joints shear strength of exterior beam-column under earthquake loading are used as per IS 13920:2016. The priority in lateral loading is strength and ductility. Therefore, joints in an ordinary structure are designed on the basis of strength to resist gravity and earthquake loads. Several researches has been done so far which gives an idea for intensive research work can be carried out, as we know beam column joint failures that occur due to severe earthquakes can be reduced by increasing joint strength.

1.1 Development of Beam column joint

The beam-column joint is defined as the portion of the column within the depth of the deepest beam that frames into the column [ACI 352-02]. The behaviour of framed structures depends not only upon the individual structural elements but also upon the sub-assemblage of the joints. Mainly, joints of framed structures are subjected to the severe loading under seismic conditions, hence the joints should have proper adequate strength and stiffness to resist the inner forces induced by the framing members. As we all know beam-column joints are the weakest in RC moment resisting frame. Design and detailing of beam-column joints of RC frames are critical in assuring the safety of these structures in earthquakes. Such joints should be designed and detailed to conserve the integrity of the joints adequately to develop the optimum strength and deformation capacities of the connecting beams and columns and restrict excessive degradation of joint stiffness under seismic loading by minimizing cracking of the joint concrete and by preventing the loss of bond between the concrete and longitudinal beam and column reinforcement; and forbid brittle shear failure of the joint.

Due to seismic forces, moments and shear forces of opposite signs are developed in each connecting member ends which induces large shear stresses in the joint core of Exterior beam column joint. Diagonal cracking and crushing of concrete in the joint core are results of Principal tension and compression stresses due to action of lateral loads.

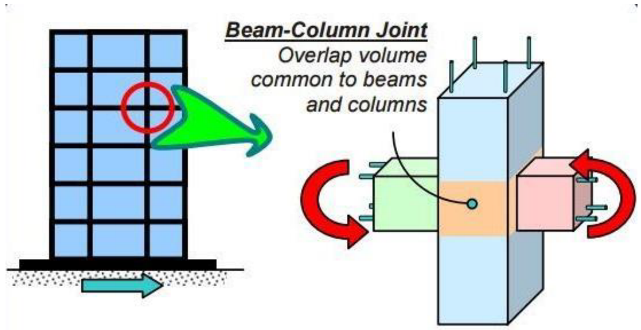

Figure 1.1 Beam-column joints of RC building

The design of Beam-column joint is mainly focused on providing adequate anchorage and joint shear strength within the joint core. IS 13920:2016 code of ductile detailing of reinforced concrete structures subjected to earthquake forces has given recommendations for the strengthening of the joint and grade of concrete is one of the parameters.

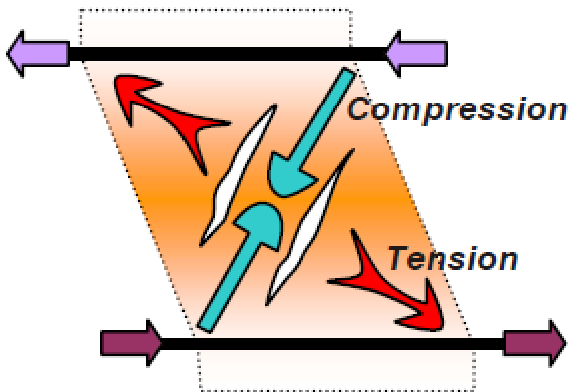

Figure 1.2 Distortion of joint

1.2 Types of Beam-Column Joint

Beam column joints are classified on the basis of number of beam ending into column and are enlisted below:

- Interior joint
- Exterior joint
- Corner joint

1.2.1 Interior joint

When four beam ends into the vertical face of column is called an Interior joint.

1.2.2 Exterior joint

When one beam frames into the vertical face of a column and two more beams frame into the column in the perpendicular direction it is called an exterior joint.

1.2.3 Corner joint

The beams which frame into two adjacent vertical faces of a column is called corner joint.

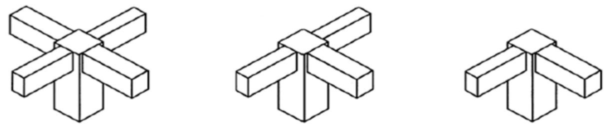

Figure 1.3 (a) Interior joint (b) Exterior joint (c) Corner joint

2. Literature Review

Meinheit and Jirsa (1981) has investigated the factors influencing the shear capacity of the beam-column joints. Different parameters (i) spacing and size of transverse reinforcement in the joints, (ii) percentage of longitudinal reinforcement in column, (iii) axial load on columns, (iv) Effect of transverse beams and (v) aspect ratio of joints, are considered to understand the influence on joint shear capacity of beam column joint.

N.Subramanian and D.S.Prakash Rao (2003), discussed the behaviour and style of two-, three- and four-member beam – column joints in framed structures are; obtuse and oblique angle joints are included. Detailing of the joints supported experimental investigations is additionally explained. The specifications of yankee, New Zealand and Indian codes of practice are appraised. An equation for calculating the world of joint transverse reinforcement has been proposed for the Indian code.

Uma and Meher Prasad (2006) has presented a review of the postulated theories related to the resoonse of beam column joint and suggested that in seismic design, the damages within the style of plastic hinges are accepted to be formed in beams instead of in columns. They reported that the factor for bond transfer depends on extent of axial load and adequate shear reinforcement in the joint. The high internal forces developed at plastic hinges cause critical bond conditions within the longitudinal reinforcing bars passing through the joint and also impose high shear demand within the joint core.

S. Rajagopal (2014) has carried out experimental study on the behaviour of T-type exterior beam-column joints subjected to cyclic loading, simulating seismic loading. Variables were the mechanical anchorage, conventional 90 degree standard bent hooks anchorage and full Anchorage. He reported that mechanical anchorage as per ACI352 gives better ductility to structure. He recommended that combination with X-cross bar plus U-bar shows lesser cracks and much better control of crack capacity with improvement in seismic performance for higher seismic prone areas where moderate and severe ductility is in demand.

3. Performance assessment of six storey RC building by Equivalent static method using SAP2000 Software

In this the Response spectrum Analysis of RC building of Zone V for Different grade of concrete (M25, M30, M35) is done and maximum shear force, bending moment and axial forces are determined using SAP2000 software and one exterior beam column joint is selected from reference building for designing as per IS 13920:2016.

3.1 Modelling of Building Frame

A G+5 storey building having panel aspect ratio 1.00 for all bays is analyzed and designed for seismic forces in Zones V as SMRF respectively using SAP2000.The plan and sectional elevation of the building is shown in the Figure 3.1 and 3.2.

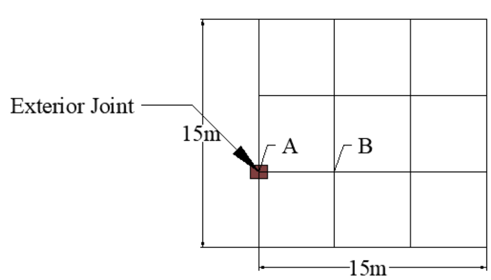

Figure 3.1 Plan view of G+5 RC building

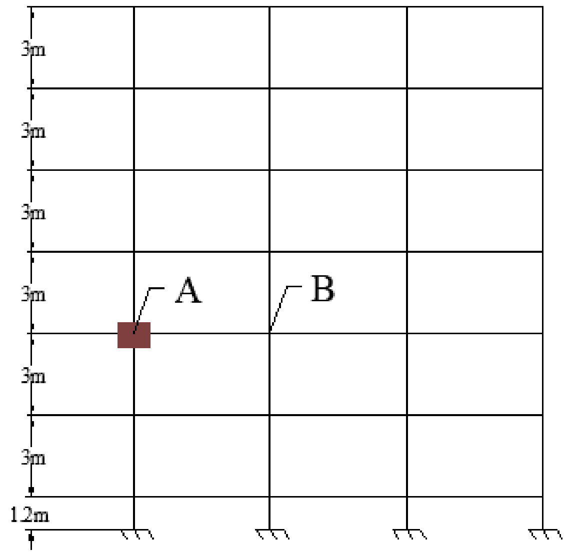

Figure 3.2 Elevation of G+5 RC building

3.2 General data

Table 3.1Load and Properties of G+5 RC building

Grade of concrete	M25, M30, M35,
Grade of steel considered	Fe415
Live load on roof	1.5 KN/m^2 (Nil for earthquake)
Live load on floors	3.5 KN/m^2 (50 % for earthquake)
Floor finish	1.0 KN/m^2
Brick wall in Peripheral direction	250mm thick
Brick wall in Innerl direction	150mm thick
Parapet wall	150mm thick
Density of concrete	25 KN/m^3
Density of brick wall including plaster	20 KN/m^3
Transverse Beam	300mm X 600mm
Longitudinal Beam	400mm X 600mm
Column	500mm X 500mm

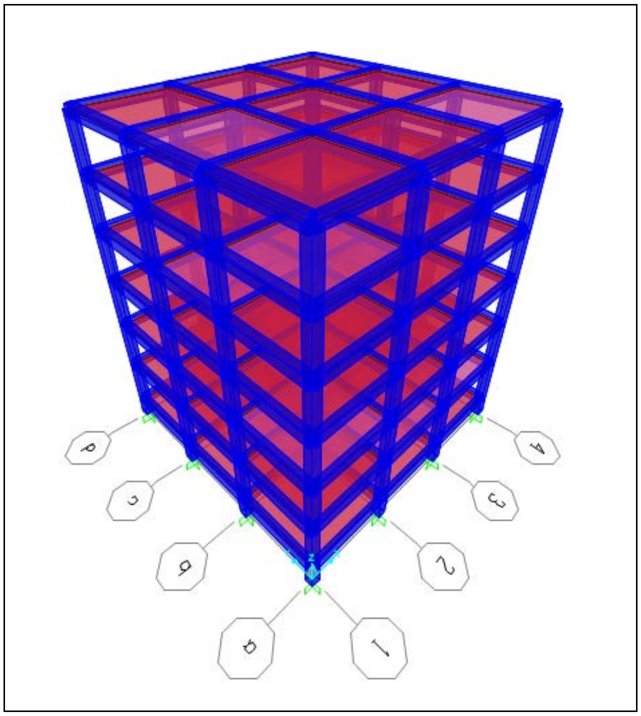

Figure 3.3 SAP model of G+5 RC building

3.3 Equation used as per Joint strength calculation as per IS13920:2016

In an exterior Joint, the column shear, *Vcol*, tension force in the reinforcement (T_{b}) And horizontal shear force (V_{jh})

$$V_{col} = \frac{M_h}{l_c}$$

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$$T_b = 1.25 f_y A_{st}$$

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$$V_{jh} = T_b - V_{col}$$

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Nominal shear strength of the joint

$$V_{nj} = \gamma \sqrt{f_{ck}} A_{ej}$$

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Where, ϒ=1.2 for confined on three face.

- F_{ck} = characteristic strength
- A_{ej} = bj*hj (joint area)
- Fy = yield strength of steel
- Ast = area of steel used.
- Mh = hogging moments on beam end.

4. Result and Discussion

This section represents the report on beams and column of G+5 RC building, Base shear of G+5 storey RC building Zone V for M25, M30 and M35 Grade of Concrete, joint demand of exterior beam column joint for M25, M30 and M35 Grade of Concrete, joint shear strength for M25, M30 and M35 Grade of concrete used for design of G+5 RC building as per IS13920:2016. The results have been discussed for the influence of key parameters on the joint shear strength and improvement of joint performance with different Grade of concrete.

4.1 Report on Transverse Beam

This section shows the Analysis result of G+5 RC Building using SAP2000 software for Transverse beam.

Table 4.1 Force Results in Transverse beam

S.No.	Grade of concrete	Left End (A) of exterior beam column joint (Critical)		
		Shear force (KN)	Bending moments Hogging (KNm)	Bending moments Sagging (KNm)
1	M25	213	400	265
2	M30	217	414	282
3	M35	221	417	285

4.2 Report on Longitudinal Beam

Table 4.2 Force Results on Left Longitudinal Beam

S.No.	Grade of concrete	Left Longitudinal beam from End (A) of exterior beam column joint (Critical)		
		Shear force (KN)	Bending moments Hogging (KNm)	Bending moments Sagging (KNm)
1	M25	201	357	232
2	M30	207	370	245
3	M35	202	376	264

Table 4.3 Force Results on Right Longitudinal Beam

S.No.	Grade of concrete	Left Longitudinal beam from End (A) of exterior beam column joint (Critical)		
		Shear force (KN)	Bending moments Hogging (KNm)	Bending moments Sagging (KNm)
1	M25	211	359	246
2	M30	217	373	261

3	M35	202	373	248

Hence, these are the values of shear force and bending-moments on Beam for different Grades of concrete.

4.3 Report on column

Table 4.4 Force Results on Column

S.No.	**Grade of concrete**	**Bottom from End (A) of exterior beam column joint (Critical)**		
		Axial force (KN)	Bending moments (M2) (KNm)	Bending moments (M3) (KNm)
1	M25	1662	313	224
2	M30	1756	329	231
3	M35	1759	330	232

Hence, in this reports it is clear that as grade of concrete increases Axial force, bending moments and shear force at the exterior beam column joint is increasing which helps to cause disintegration of joint core.

4.4 Report on Exterior Beam column joint

In this section results are represented for various seismic loads in X and Y direction with column sway towards Right and Left of exterior beam column joint as shown in figure 3.2.

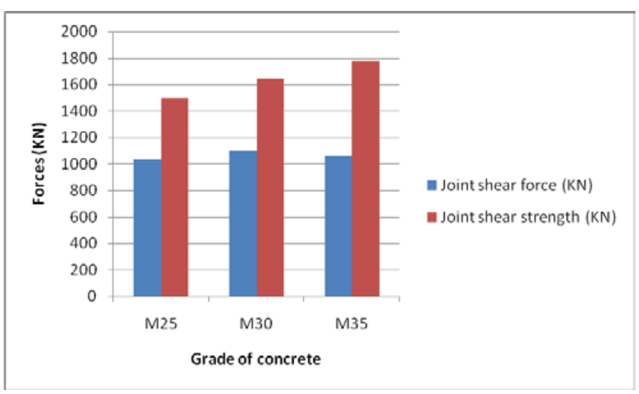

Figure 4.1 Earthquake -X direction with column sway to Right

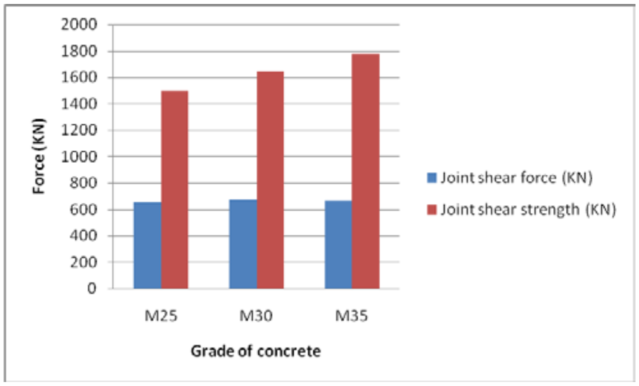

Figure 4.2 Earthquake -X direction with column sway to Right

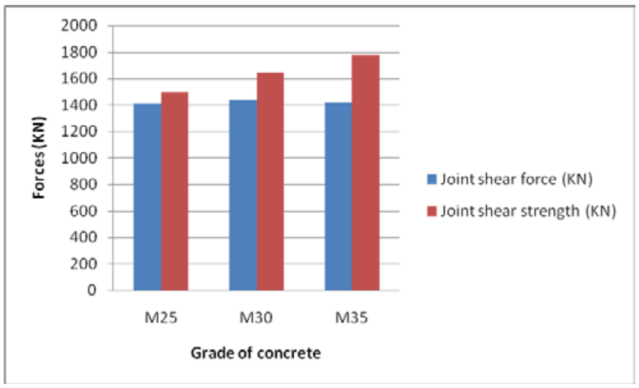

Figure 4.3 Earthquake -Y direction with column sway to Right

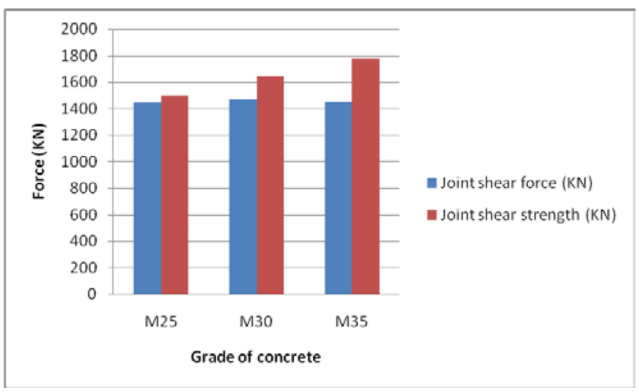

Figure 4.4 Earthquake -Y direction with column sway to Right

5. Conclusions

Following observation and conclusion are enlisted below:

- Increment of Grade of concrete helps to improve the joint core by proper utilization of concrete strength.
- As Grade of concrete Increases the joint shear capacity of Exterior beam column joint increases simultaneously.
- From Figure 4.1,4.2 4.3,4.4 it is clear that M35 Grade of concrete is giving maximum joint shear capacity as compared with other two grades of concrete.

- From the overall study, it can be concluded that the strengthening with Grades of Concrete structure will increase the serviceability of the structure.

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