

Analysis of Beam Column Joint Subjected to Seismic Lateral Loading

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Abstract -

The beam-column joints are among the weakest members of reinforced concrete frames in terms of seismic resistance. Failure of beam column joints during earthquake is governed by bond and shear failure mechanism which are brittle in nature[8]. This study presents critical review of recommendations of well established codes regarding design and detailing aspects of beam column joints. This paper presents a review of the postulated theories associated with the behavior of joints under ACI 318M-02 and IS 13920: 1993 Code. Understanding the joint behavior is essential in exercising proper judgments in the design of joints. The paper discusses about the seismic actions on various types of joints and highlights the critical parameters that affect joint performance with special reference to bond and shear transfer.

Key words- Beam-column joint, shear failure, seismic action, moment resisting frame.

1. INTRODUCTION

Earthquake is a global phenomenon. Due to frequent occurrence of earthquakes it is no more considered as an act of God rather a scientific happening that needs to be investigated. During earthquake, ground motions occur both horizontally and vertically in random fashions which cause structures to vibrate and induce inertia forces in them. Analysis of damages incurred in moment resisting RC framed structures subjected to past earthquake show that failure may be due to utilization of concrete not having sufficient resistance, soft storey, beam column joint failure for weak reinforcements or improper anchorage, column failure causing storey mechanism³. Beam-column connection is considered to be one of the potentially weaker components when a structure is subjected to seismic loading⁹.

1.1 REVIEW OF CODE

Some international codes suggest expressions to prevent storey mechanism of collapse due to possible damage

locations (hinge formations) in columns. This actually aims at achieving stronger columns with moment capacities more than those of beams framing into a joint obtained considering over strength factors. Moment Calculation at centre of the joint is a very complicated task. These moments are the design moment of resistance of columns or beams calculated at outer faces of the joint and a suitable allowance for moment obtained because of shear developed at the face of joint. However due to such assumptions, the accuracy decreased is very less and the simplification achieved is considerable if the shear allowance is neglected.

1.2 Theoretical Development of R.C.C Joint

Under earthquake shaking, the beams adjoining a joint are subjected to moment in the same direction (clockwise or anti-clockwise)⁹. Figure 1 shows the moments created under the earthquake shaking. Because of these moments, the top bars in the beam column joint are pulled out in one direction and bottom bars in the other direction. Figure 1 shows the behaviour of reinforcing bars under earthquake shaking. These forces are balanced by bond stresses developed between concrete and steel in the joint region. If the column is not wide enough or if the strength of concrete in the joint is low; then there will be insufficient grip between concrete and steel bars⁸. In such circumstances, the bar slips inside the joint region, and beams lose their capacity to carry load.

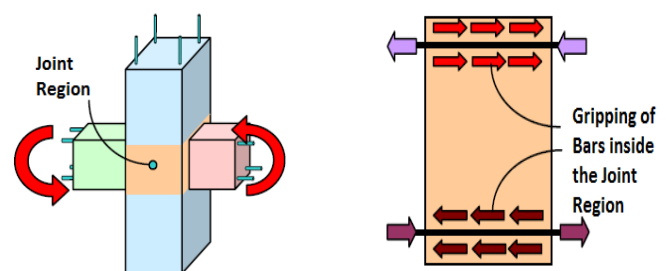


Fig.1 Moments Created and Behaviour of Reinforcing Bars under Earthquake Shaking at Joint Region

Further, under the action of the above push-pull forces at top and bottom ends, joints undergo geometric distortion. One of the diagonal lengths of the joint elongates and the other compresses. Figure 2 shows the geometric distortion of the joint. If the column cross-section size is insufficient, the concrete in the joint can develop diagonal cracks.

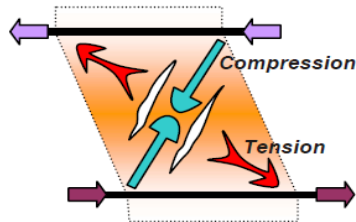


Fig.2 Geometric Distortion of the Joint

The design of Beam-column joint is mainly focused on providing joint shear strength and adequate anchorage within the joint. IS 13920:1993 code of ductile detailing of reinforced concrete structures subjected to seismic forces has given recommendations for the strengthening of the joint⁶.

2. OBJECTIVE OF STUDY

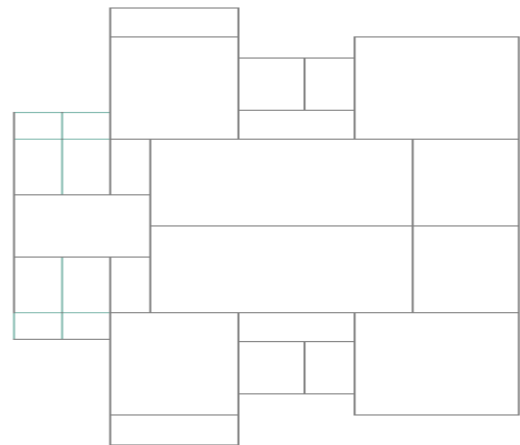
The scope of present research work is limited to following structural considerations:

- Residential G+5 RC framed building is selected.
- The analysis is carried out using STAAD-Pro. Software
- Seismic analysis is carried out by equivalent static method using IS 1893:2002.
- Design of Beam- column Joint by IS 13920:1993, ACI3198-02, EN 1998-1:2003.
- Comparison of design parameters.

1. METHODOLOGY

1. The building considered in the present report is G+5 Residential RC Framed structure. Complete analysis is carried out for dead load, live load & seismic load using STAAD-Pro. All combinations are Considered as per IS 1893:2002.
2. The Structure is designed by IS 13920:1993,ACI 318-05and EN 1998:2004
3. Ultimate flexural capacity of beam ($M_{r,b}$) is determined from the design data obtained.
4. Column reinforcement in the buildings is progressively increased to attain different

5. column to beam moment capacity ratio (MCR) at maximum moment, at zero axial load and at design axial load.
6. Beam column joints in a reinforced concrete moment resisting frame are crucial zones for transfer of loads effectively between the connecting elements (i.e., beams and columns) in the structure and hence shear strength checked and design by Draft provisions in IS 13920:1993,ACI 318-05 and E



r

Fig.3 Plan of G+ 5 RC Framed Structures

3.1. Building Properties

Site Properties:

Details of building:: G+5
 Outer wall thickness:: 230mm
 Inner wall thickness:: 150mm
 Floor height ::3 m
 Depth of foundation :: 1500mm
 Bearing capacity of Soil:: 150kN/m²

Seismic Properties

Seismic zone:: V
 Zone factor:: 0.36
 Importance factor:: 1
 Response Reduction factor R:: 5
 Soil Type:: medium

Material Properties

Material grades of M30& Fe415 were used for the design.

Loading on structure

Dead load :: self-weight of structure
 Weight of 230mm wall
 Weight of 115mm wall
 Live load:: Floor 3kN/m²
 Roof 1.5 kN/m²
 Wind load :: Not considered
 Seismic load:: Seismic Zone V

Preliminary Sizes of members

Column:: 300mm x 800mm

Transverse Beam:: 230mm x 800mm

Longitudinal Beam:: 230mm x 700mm

Slab thickness:: 125mm

4. MODELING

This building has been modelled as 3D Space frame model with six degree of freedom at each node using STAAD-Pro software for stimulation of behaviour under gravity and seismic loading. The isometric 3D view and plan of the building model is shown as figure. The support condition is considered as fully fixed.

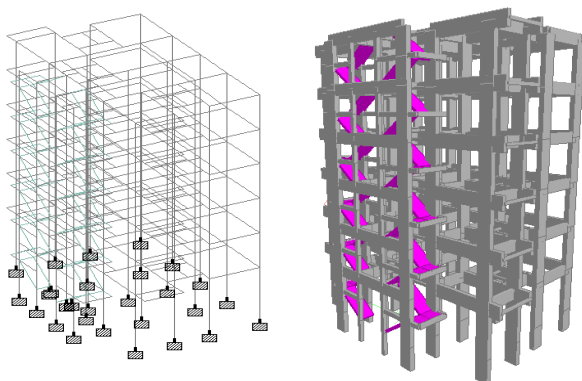


Fig.4 Different 3D View of G+5RC Structure

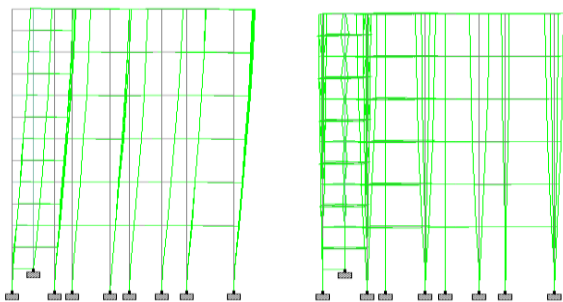


Fig. 5 Deflected shape of G+5 in X and Z- direction

4. RESULT

4.1 The comparison of column depth in x-dir and z-dir at Exterior, Interior and Corner joints Table 1, 2, 3.

Table .1 Column depth at Exterior Joint in (mm)

Comparison of Column depth at Exterior Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	800	800	850
Z - direction	500	350	350

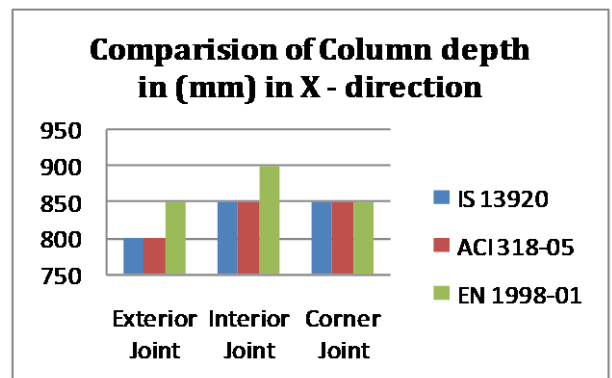
Table . 2 Column depth at Interior Joint in (mm)

Comparison of Column depth at Interior Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	850	850	900
Z - direction	350	350	450

Table.3 Column depth at Corner Joint in (mm)

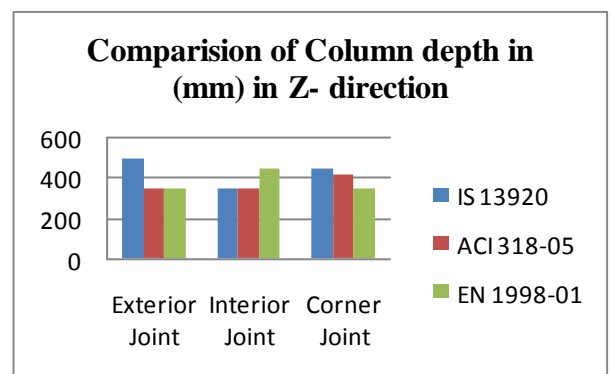
Comparison of Column depth at Corner Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	850	850	850
Z - direction	450	420	350

4.1.1 The graphical representation of column depth in x-dir and z-dir at Exterior, Interior and Corner joints are



presented in Figure – (a), (b)

Fig-(a) Comparison of Column depths in (mm) in X -



direction

Fig-(b) Comparison of Column depths in (mm) in Z - direction

4.2 The comparison of effective joint width in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Table 4, 5, 6

Table. 4 Effective Joint Width at Exterior Joint in (mm)

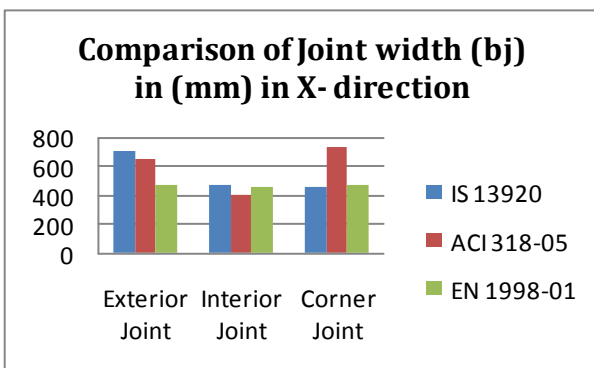
Comparison of effective joint width (bj) at Exterior Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	700	655	475
Z - direction	630	1105	350

Table.5 Effective Joint Width at Interior Joint in (mm)

Comparison of effective joint width (bj) at Interior Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	475	400	450
Z - direction	350	400	525

Table.6 Effective Joint Width at Corner Joint in (mm)

Comparison of effective joint width (bj) at Corner Joint (mm)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	455	725	475
Z - direction	450	1155	350



5.2.1 The graphical representation of effective joint width in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Figure- (c), (d)

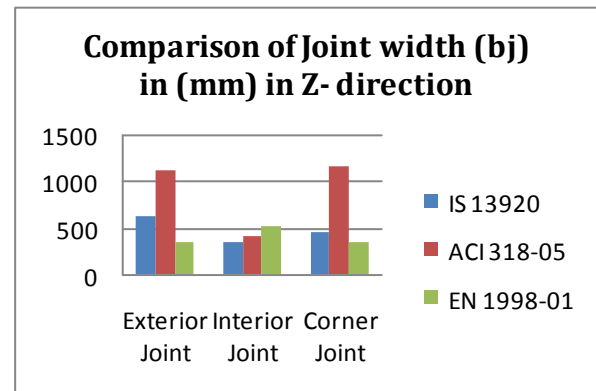


Fig-(c) Comparison of Joint width (bj) in X- direction

Fig- (d) Comparison of Joint widths (bj) in Z- direction

5.3 The comparison of joint shear strength in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Table 7, 8, 9

Table.7 Joint Shear Strength at Exterior Joint in (kN)

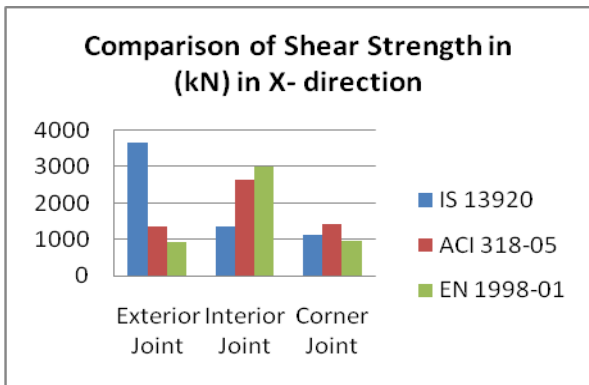
Comparison of Shear Strength at Exterior Joint (kN)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	3680.696	1352.22	911.786
Z - direction	2070.391	5204.15	1577.75

Table.8 Joint Shear Strength at Interior Joint in (kN)

Comparison of Shear Strength at Interior Joint (kN)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	1365.883	2646.41	3022.51
Z - direction	2444.212	1090.16	1763.13

Table.9 Joint Shear Strength at Corner Joint in (kN)

Comparison of Shear Strength at Corner Joint (kN)			
	IS 13920	ACI 318-05	EN 1998-01
X - direction	1121.462	1428.79	966.68
Z - direction	2095.04	4631.23	1577.75

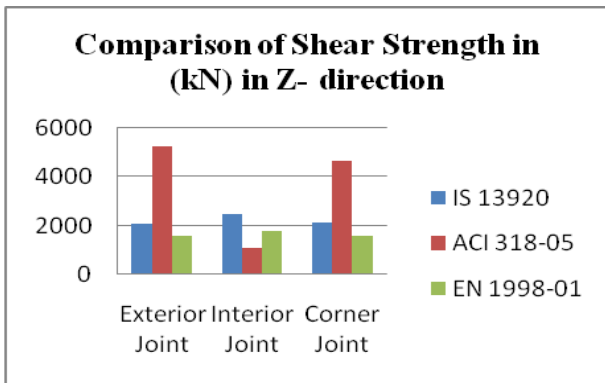


	IS 13920	ACI 318-05	EN 1998-01
X - direction	1.47	3.89	3.73
Z - direction	3.16	2.77	2.3

Table.12 Moment Capacity Ratio at Corner Joint

	IS 13920	ACI 318-05	EN 1998-01
X - direction	2.78	6.59	2.36
Z - direction	4.26	4.9	5.03

5.3.1 The graphical representation of joint shear strength



in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Figure- (e), (f)

Fig-(e) Comparison of Shear Strength in (kN) in X- direction

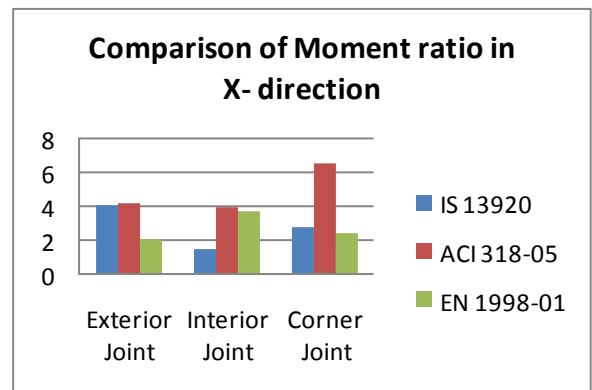
Fig-(f) Comparison of Shear Strength in (kN) in Z- direction

5.4 The comparison of moment capacity ratio in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Table 10,11,12.

Table.10 Moment Capacity Ratio at Exterior Joint

	IS 13920	ACI 318-05	EN 1998-01
X - direction	4.05	4.17	1.99
Z - direction	1.56	2.13	2.83

Table.11 Moment Capacity Ratio at Interior Joint



	IS 13920	ACI 318-05	EN 1998-01
X - direction	2.78	6.59	2.36
Z - direction	4.26	4.9	5.03

5.4.1 The graphical representation of moment capacity ratio in x-dir and z-dir at Exterior, Interior and Corner joints are presented in Figure - (g), (h).

Fig- (g) Comparison of Moment ratio in X- direction

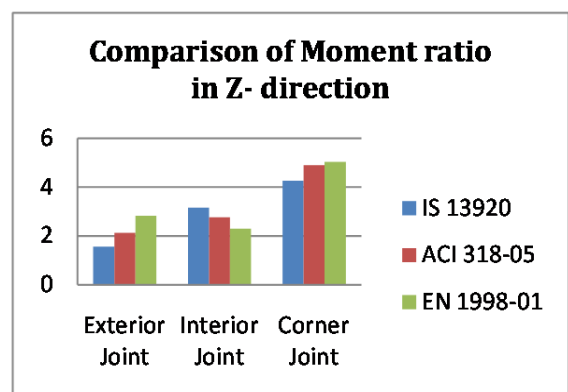


Fig- (h) Comparison of Moment ratio in Z- direction

5. SUMMARY AND CONCLUSIONS

The structural behavior will be different from that assumed in the analysis and design, if the joints are incapable of sustaining the forces and deformations induced due to the transfer of forces among the members meeting at the joint. Especially, opening of joints has to be considered properly since it will result in diagonal cracking of the joint. Such opening of joints occurs in multi-storied structures due to lateral loads. The discussions presented pertain to seismic forces, but are of general nature and can be applied to structures subjected to lateral forces.

Some conclusions are made from analytical problem are as follows:

1. Size of column at three joint is more than design section by IS 13920, ACI 318 and EN 1998 codes.
2. Depth of column at exterior and corner joint is found to be more than interior joint.
3. Effective joint width is found to be more by ACI 318 code than other two codes.
4. Size of column and beams at three joint is found to be nearly same by three codes.
5. Shear strength at joint is found to be more by ACI 318 code than other two codes.
6. Moment capacity ratio is within range by three codes.
7. Moment capacity ratio is more by ACI 318 than IS 13920 and EN 1998 codes

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