Influence of Beam-Column Joint on the Seismic Response of RC Frames

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***Abstract*: The beam-column joint has usually defined a portion of a column within the depth of the most profound beam that frames it. That is an integral part of reinforced concrete moment structures. In regular design practice for gravity loads, the design check for joints is not critical and hence not warranted. It is subjected to enormous forces during severe ground shaking, and its behavior significantly influences the structure's response. During earthquakes have heavy distress due to shear in the joints that culminate in the collapse of the structure. The proper functioning of this zone is critical for the satisfactory performance of an MRF in the inelastic range during a significant seismic event. The shear failure is always brittle, which is not acceptable structural performance, especially in seismic conditions. The importance of beam-column joints to the earthquake resistance of reinforced concrete RC frames was first recognized during the earthquakes of the 1960s. This triggered the research on RC beam-column joints under cyclic loading Hanson and Connor 1967. Since then, researchers in the United States and other countries have been trying to develop and improve seismic design provisions for RC joints Paulay et al. 1978.**

In the last four decades, a substantial amount of research has been carried out on estimating, modeling, and simulating the seismic performance of reinforced concrete (RC) beam-column joints. The seismic response of RC beam-column joint depends on several parameters, viz., concrete grade, column axial load, eccentricity, aspect ratio, joint transverse reinforcement, bond strength, the ratio of the column to beam flexural strength, the joint shear strength infilled frame, and the anchorage of the beam and column reinforcement in the joint, respectively. These factors influence the seismic response of the beam-column joint, and these influencing parameters of all types of joints are discussed based on available research.

***Index Terms*: Beam-Column Joint, Seismic Response, Earthquake Resistant RC frames, Bond Strength.**

I. INTRODUCTION

A beam-column joint is a crucial part of an RC frame and is subjected to an enormous shear force. The performance of the RC frame significantly depends on the joint; therefore, particular emphasis must be given to its analysis and design. Joints should be rigid and robust, enabling frame members to develop ultimate capacity. The existing analysis, design, and construction practice observed that the joints perform well under static gravity loading. However, its behavior becomes more critical under cyclic loadings, such as earthquakes. The level of earthquake demand and corresponding performance emphasizes a comprehensive study of the behavior of joints. The complex mechanism of a joint panel under seismic action depends on the bond between concrete and rebar and shear capacity.

Many catastrophic failures have been reported in past earthquakes, particularly with Türkiye and Taiwan earthquakes that occurred in 1999, attributed to beam-column joints. Various international codes of practice have been undergoing periodic revisions to incorporate the research findings into practice. The paper aims to investigate the theoretical background of beam-column joints, which influence the seismic response of RC frames.

II. CLASSIFICATION OF RC JOINTS

Beam-column joints (BCJ's) panel is the common intersection of the beam and column members. BCJ's transfer forces, such as moment, shear, and torsion, by the beam to the column, so that the frame can maintain its integrity to carry the loads for which it is designed. Accordingly, joints are classified into the interior, exterior, and corner joints depending on the geometry of the intersection, as shown in Figure 01. Beam-column connections can also be considered elastic or inelastic. From a structural viewpoint, a beam-column joint can be considered elastic if the joint panel remains uncracked and the plastic deformation occurs in the beam and column during the entire loading. Conversely, a beam-column joint is defined as plastic if, during the loading reversals (cyclic), some inelastic deformation (cracks) developed in the joint panel. The latter case of the inelastic joint is more severe and has been in research for the last few decades.

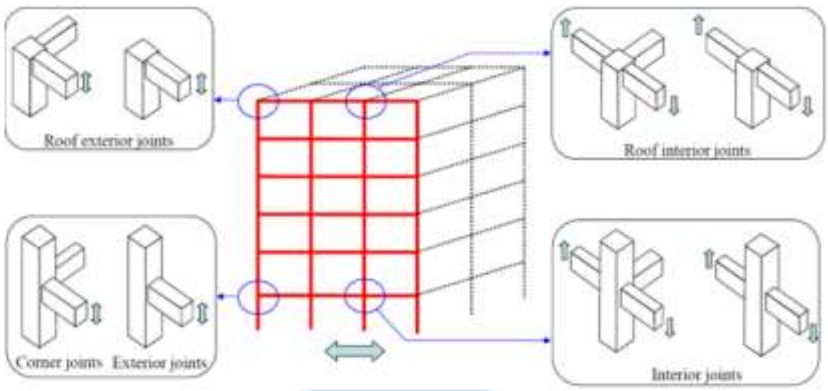

Figure 01: Considered beam-column joints and their definitions. (Adapted from Park, 2010)

III. BEAM-COLUMN JOINT TYPES

In concrete MRF, it is common to classify a joint based on its geometrical configuration as under:

- **Interior joint –** Where beams frame all four faces of a column. Bars passing through such a joint face a pull-push effect as the force in a bar change across the joint cyclically from tension to compression and vice versa. This imposes a severe demand on the bond, for which the bars need to have adequate development length to meet both tensile and compressive conditions to prevent bond failure.
- **Exterior joint –** Beams frame into a column's opposite faces and one orthogonal face. Repeated cyclic loading can cause cracks in concrete (termed yield penetration) to progress into the concrete core. To meet this demand, beam rebars should have adequate development length within the column depth measured beyond the penetration region. This can be achieved by providing a hook or a pin or extending bars beyond the column's exterior face, as shown in Figure 01. In practice, this extension option usually is feasible only if it forms a part of the original architectural scheme.
- **Corner joint –** where two orthogonal beams frame into a column. Beam bars need to be well anchored as for an exterior joint.
- **Knee joint –** where a beam frames into a column at roof level.

IV. JOINT BEHAVIOR MECHANISM

Inside the column/beam joint, the concrete experiences a complex stress pattern due to bending, compression, tension, and shear. A joint is subjected to vertical and horizontal shear forces, resulting in diagonal compression and tension in its core region. Failures at a beam-column joint are commonly due to (1) shear failure in the panel zone, (2) anchorage failure of beam rebars, and (3) bond failure of rebars going through the panel.

A cast in situ monolithic beam-column joint has to meet the following challenges:

- Under the serviceability limit state, the joint should be free of cracks induced by concrete compression and shear.
- Capacity of a joint in shear and flexure should be greater than that of the members it connects, enabling them to develop and sustain their ultimate capacities.
- There should not be over-congestion of reinforcement as it will preclude the formation of sound and dense concrete.
- Horizontal shear stress should be less than the minimum permissible shear stress in concrete.
- Column stirrups should extend right through beam-column joints to ensure that concrete is properly confined and that column bars do not buckle within the joint.

Within the joint panel, a diagonal concrete strut is formed due to vertical and horizontal compressive forces and shear forces. It can be one strut, or it can be multiple struts. A truss mechanism is formed due to the interaction between confining horizontal and vertical reinforcement and a diagonal compression field (Naeim, 2001).

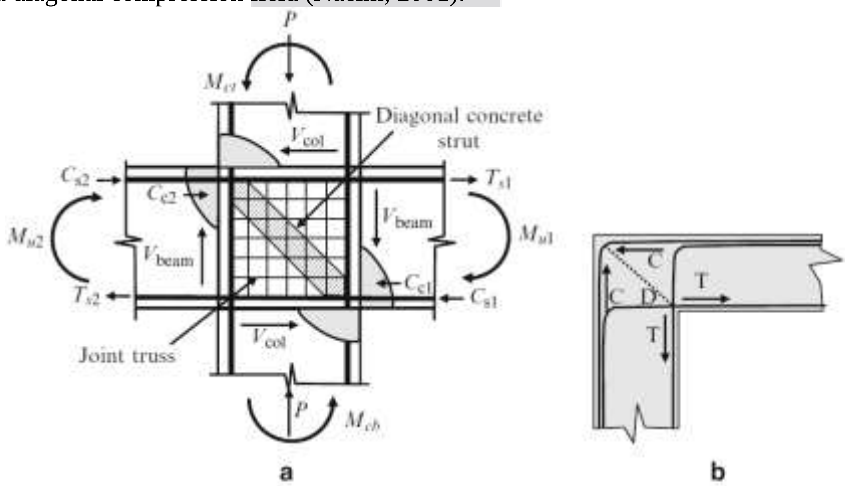

Figure 02: (a) Beam–column joint (sway to the right). (b) Corner joint. (Adapted from Naeim, 2001)

As shown in Figure 02 a corner joint deserves special attention. Compressive and tensile forces in the reinforcement change cyclically from tension to compression. Tension reinforcement tends for rebars to pull open the inner corner of a joint. At the same time, compression reinforcement will tend to force the upper corner out. Diagonal bars should be provided to hold the joint together.

V. EXPERIMENTAL EVALUATION

For the last four decades, researchers have conducted experimental investigations to predict the behavior of beam-column joints under earthquake loading. During experimental investigations, the monotonic and cyclic loadings are applied on beam-column joint specimens. A monotonic loading test usually does not provide adequate information to evaluate seismic behavior, joint shear deformability, ductility, energy dissipation, and post-peak behavior. While in the cyclic loading test, the collapse and severe damage can be observed in detail in moment resisting frames under several earthquakes, which is in the sprint of research nowadays.

Numerous experimental studies have investigated to discover the influence of beam-column joints on the seismic response of RC frames. The results of these experimental studies and experiences of past earthquakes revealed the influence factor which adversely affects the overall performance of reinforced concrete building response. The following sections identify the influence parameters of beam-column joints on the seismic response for all reinforced concrete frames.

VI. EXPERIMENTAL EVALUATION INFLUENCING FACTORS IN BEAM-COLUMN JOINT WHICH AFFECT SEISMIC BEHAVIOR OF RC FRAMES

A beam-column joint undergoes severe stiffness and strength degradation when subjected to earthquake loads. The essential requirements for the satisfactory performance of a joint in an RC structure during earthquakes can be summarized as follows (Park & Paulay, 1975; Paulay & Priestley, 1992):

1. A joint should exhibit a service load performance equal to or greater than the members it joins; that is, the failure should not occur within the joints. Suppose there is a failure due to overloading. In that case, it should occur in beams through significant flexural cracking and plastic hinge formation and not in columns (usually, the joint is considered a part of the column).
2. A joint should possess a strength not less than the maximum demand corresponding to the development of the structural plastic hinge mechanism of the structure. This requirement eliminates the need for repair in an inaccessible area of the structure.
3. The joint should respond elastically during moderate earthquakes.
4. The deformation of joints should not significantly increase the story drift.
5. The joint configuration should ensure ease of fabrication and good access for placing and compacting concrete in the joint region.

Influence of joint concrete strength

The shear strength of a joint is expressed as a function of concrete compressive strength irrespective of the amount of reinforcement derived from previous research and various international codes. The concrete strength variation also deviates from the bond stress-slip characteristic of deformed bars. From the observations, various codes restrict the shear stress to less than concrete's compressive strength. Increasing concrete compressive strength improves the joint shear resistance from force transfer to the joint panel by bearing (from beam and column compression zones) and the bond between reinforcement and surrounding concrete.

Ehsani et al. (1991) conducted experiments on high-strength reinforced concrete connections with a compressive strength between 55 to 97 MPa. The researchers found that high concrete compressive strength results in high shear capacity but lower ductility. Guimaraes et al. (1992) tested two interior beam-column-slab connection subassemblies having a concrete compressive strength of 4000 and 12000 psi, respectively. When the joint shear strengths of the connections were measured, it was inferred from the test results that joint shear strength is a function of the approximately square root of concrete compressive strength. Durrani et al. (1985) concluded through the experimental analysis that the higher strength of concrete reduces the stiffness degradation of the joint. Due to the joint's stiffness degradation reduction, the building's overall deflection is minimized in seismic events.

As the developed diagonal compressive strut faces resistance from the concrete in the joint panel zone, Hasaballa 2014 concluded that increasing the concrete strength from 30 to 70 MPa increases the sustained lateral load resistance by 36% for exterior joints; he observed that specimens with lower concrete strength developed their maximum lateral resistance earlier than those with higher concrete strength. For higher-strength concrete, however, the increase in joint strength with increasing concrete strength is reduced. The linear relation $V_j=0.25f'_c$ becomes unconservative for higher concrete strengths. Dehkoedi et al. (2019) tested joints constructed with higher material strengths, recording similar behaviour to normal joints with 27% savings in reinforcement. In addition, they demonstrated an improvement in energy dissipation for joints with identical reinforcement ratios.

Influence of joint reinforcement bonding

The flexural forces from the member's adjoined joints cause tension or compression in the longitudinal reinforcing bars passing through the joint. Large tensile forces are transferred through bonds during plastic hinge formation. Splitting cracks are formed along longitudinal bars at the face of the joint when the bars are stressed beyond yield. Adequate development length for the reinforcements must be ensured within the joint to carry developed stress. Therefore, the bond requirement is directly affected by the geometric sizes of the beams and columns framing into the joint. The bond distribution along the longitudinal bars is shown in Figure 03.

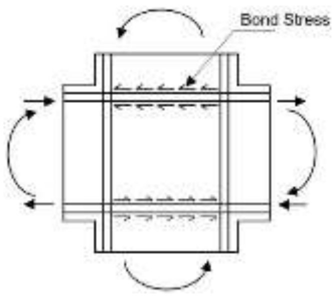

Figure 03: Bond stress on longitudinal bars in joints (Adapted from Uma & Prasad, 2006)

A deterioration of bonds within interior joints does not necessarily result in a sudden loss of strength. However, bond slip may seriously affect the systeristeric response of ductile frames; as little as a 15% reduction in bond strength along a bar may result in a 30% reduction in the total energy dissipation capacity of a beam-column subassembly (Paulay & Pristley, 1991). Because the stiffness of frames is somewhat sensitive to the bond performance of bars passing through a joint, particularly at interior columns, special precautions should be taken to prevent premature bond deterioration in joints under seismic attack. At exterior joints, anchorage failure of beam bars is unacceptable at any stage because it results in a complete loss of beam strength.

In the exterior joint, beam longitudinal reinforcement that frames into the column ends within the joint core. The bond deterioration initiated at the column face progresses towards the joint core after a few cycles of inelastic loading. Repeated loading aggravates the situation, and a complete loss of bond may occur up to the beginning of the bent portion of the bar. As a result, the longitudinal bars will get pulled out due to progressive loss of bond, and the pull-out failure results in complete loss of flexural strength, which is unacceptable at any stage. The pull-out failure of reinforcements in exterior joints can be prevented to a great extent by the provision of hooks or by some positive anchorage, as shown in Figure 04.

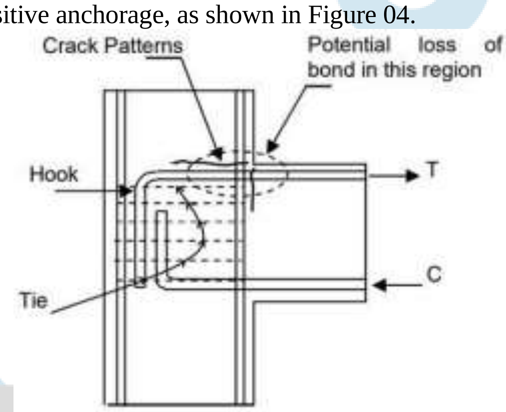

Figure 04: Detailing to improve bond mechanism at exterior joints (Adapted from Uma and Prasad 2006)

In general, bond deterioration in interior joints increases the story drift and reduces the story stiffness of the joint specimens; it is the leading cause of the pinching of hysteretic story force-story drift curves and the reduction in the energy absorption and dissipation capacity of the joint specimens.

Influence of axial load on joint

Column axial load provides confinement and increases stiffness within the joint region if it is not too high to prematurely cause crushing. From past research, it is a well-known fact that the column compression force contributes to the joint shear strength, but still, there is no consensus on how much impact the axial load generates. The overturning moment due to the lateral loading affects the counterbalancing axial load from the column.

Various researchers Kurose et al. (1988), Kitayama et al. (1991), Bonacci et al. (1993); and Vollum (1998) concluded that joint strength gets little influenced by axial column load. On the other hand, some experimental reports (Beres et al. (1992) and Clyde et al. (2000) claim that high axial load on columns increases joint strength. The ductility of exterior joints was examined by Kaku and Asakusa (1991) by varying the amount of axial load between 10 – 17 % of the column axial load capacity. It was observed that joint shear strength was higher when higher axial loads were applied to the column.

Furthermore, ductility of the joint was found higher when the axial compressive load increased. The previous experimental study found that increasing the axial load can improve the bond behavior and the shear force transfer mechanism. Also, the energy dissipation capacity can increase with axial load ratio but with a small shear level. Under the high shear crush of the joint core, concrete was observed.

Similarly, Clyde et al. (2000) experimented on four specimens, two of which were under an axial load of 0.1fc´Ac and the other two under 0.25f'cAc. According to the test results, the joint shear strength capacities of specimens with higher axial loads were approximately 8% higher than those with lower applied axial loads. Furthermore, it was observed that the specimens with an axial load of 0.1f'cAc dissipated about 20 % higher energy than those with 0.25f'cAc axial load. Bonacci and Pantazapoulou (1993) assembled data from 86 joint tests and concluded that axial column load has no distinct effect on joint strength.

Influence of joint aspect ratio

To investigate the relevance of the strength recommendations in ASCE 41, Park & Mosalam (2012) collected 62 previous unreinforced exterior or corner joint test data. Evaluation of joint shear strength for the database shows that ASCE 41 may underestimate the shear strength of unbraced external joints. This parametric study shows that the shear strength of unreinforced exterior joints is affected by the joint aspect ratio, defined as the beam to column cross-sectional height ratio. The strut-and-tie can explain the effect of the joint aspect ratio SAT idealization, where a steeper diagonal strut is developed in the unreinforced joint with a high aspect ratio; see Figure 05. Consequently, this steeper diagonal struct results in less effective shear resistance to balance the shear force of the horizontal joint. Hence, the shear strength of unreinforced exterior joints decreases with the increasing of the joint aspect ratio. Similar results are reported by Kim and LaFave (2007) and Bakir & Boduroğlu (2002).

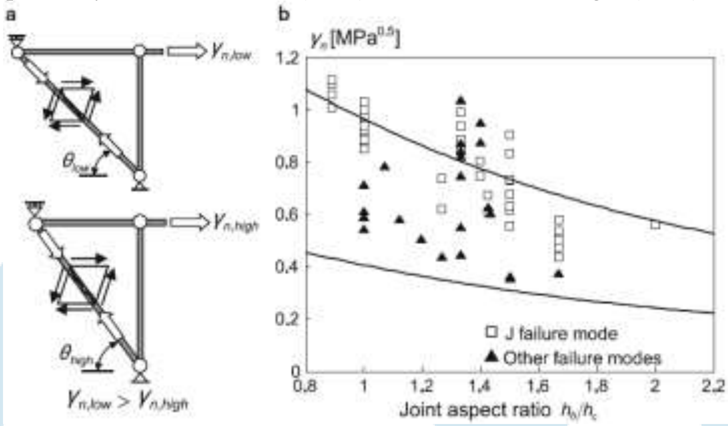

Figure 05: Effect of the joint aspect ratio: (a) SAT idealizations for two joint aspect ratios and (b) evaluation of the database against joint aspect ratio (Adapted from Park and Mosalam 2012)

Influence of joint beam longitudinal reinforcement ratio

Experimental results show that the shear strength of unreinforced joints increases with the ratio of longitudinal reinforcement of the beam. This record can be explained as follows:

(i) Increasing the beam longitudinal reinforcement ratio leads to the increase of the horizontal joint shear force without yielding the beam longitudinal bars, i.e., the more significant horizontal joint shear force is imposed with less deterioration of bond resistance around the beam longitudinal bars in the joint region.

(ii) This more stable bond resistance produces a wider diagonal strut which can carry the more significant horizontal joint shear force.

Any increase in the percentage of beam reinforcement (ρb) increases the flexural stiffness of the anchored bars hook. The increased flexural stiffness of the hook provides better confinement to the concrete core in the joint. Also, it accommodates the formation of a compression strut mechanism, increasing the joint load carrying capacity. Kemp et al. in 1968 tested four beam-column knee joints under the action of the closing moment; they observed low efficiencies for specimens with high reinforcement ratios. To this end, Nilsson, in 1973, specified 2% as an upper limit for the ratio of primary reinforcement to assure ductile failure and to control the reduction in joint efficiency with a high reinforcement ratio. Increasing beam reinforcement ratio (ρb) up to a specific limit did not show superior performance over joints with typical ratios.

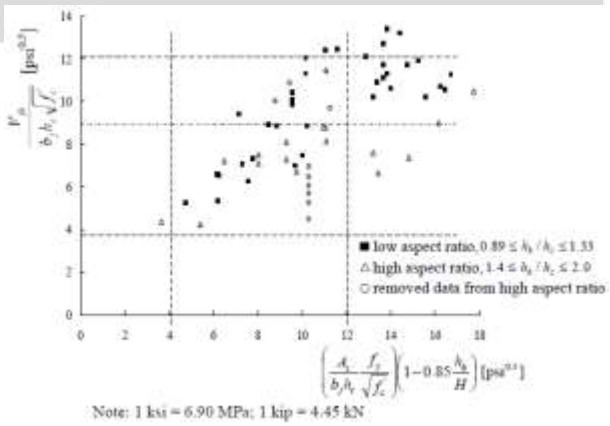

Figure 06: Effect of the beam reinforcement (Adapted from Moehle, 2008)

Influence of transverse reinforcement in a joint panel

Unreinforced joints are considered vulnerable to brittle shear failure under earthquake shaking due to insufficient shear reinforcement in the joint region. Recently, these problems have been highlighted by the damage observed after devastating earthquakes in different countries; moreover, many tests have proven the poor seismic performance of unreinforced joints, especially exterior joints.

The essential functions of the transverse reinforcement inside the joint are to transfer the tension forces and to confine the concrete within a joint. The outcome of multiple studies advocates that increasing the volume of joint transverse reinforcement reduces joint damage and delays the onset of joint failure. Similarly, it was found that an increase in the amount of lateral reinforcement reduces the shear deformation and crack width in the joint panel (Kitayama, 1987). Experimentally, the upper limit of 0.40% stirrups significantly improves both capacities (Kaung & Wong, 2011).

However, recommendations (Kitayama, 1987) on a joint's required minimum lateral reinforcement ratio were 0.30%. Also, they suggested the ratio of column width to the beam bar diameter as a function of the beam bar and concrete strength. Beam-column joints with seismic ties exhibited better seismic performance than joints without ties. The specimens with ties at joints showed adequate sustainability throughout loading cycles (Khan, 2014).

Transverse reinforcement in the joint may significantly influence joint axial capacity under cyclic loading. The requirement for joint transverse reinforcement can thus be formulated by keeping the joint axial capacity no lower than the column axial capacity under strong seismic action.

Influence of beam and column rebar anchorages

Sung et al. in 2007 compared joints with headed bars with joints with hooked bars; they observed that a BCJ with headed bars performs as well as the conventional hooked bars. Thompson et al. in 2002 investigated headed bars usage in exterior joints; they noticed that joints with headed ends showed a good response compared to the hooked bars in terms of strength, deformability, and energy dissipation.

Rajagopal et al. in 2014 discussed innovative joint designs that can reduce reinforcement congestion without compromising strength, ductility, and stiffness. They tested six beam-column joints. The specimens were divided into two groups; one group had standard conventional shear ties and the other group with additional X-type cross bars. They concluded that using T-type mechanical anchorage in combination with X-cross bars improves the performance with an increase in the load carrying capacity, ductility, and stiffness, together with a reduction in reinforcement congestion. This is attributed to the tension in diagonal bars perpendicular to the joint diagonal crack; this helps in limiting the main diagonal crack width.

Ibrahim et al. in 2008 tested five external connections to study the effect of using double-headed studs as shear reinforcement instead of conventional closed stirrups. They concluded that double-headed pins reduce the stress on the joint steel and improve the shear resistance of the joint.

Zouzou et al. 1993 proposed confining stirrups for the diagonal strut in the joint region, as shown in Figure 07 (left). These stirrups resist the splitting stresses formed inside the strut. These stirrups resist the splitting stresses generated inside the strut. The overall ductility of the joint is improved by moving the cracks from the area of the strut to be displaced away from the core of the joint.

In conclusion, the beam-to-column joint with headed bars performs as well (or even better) than the connection with conventional hook bars in terms of bearing capacity and failure mechanisms.

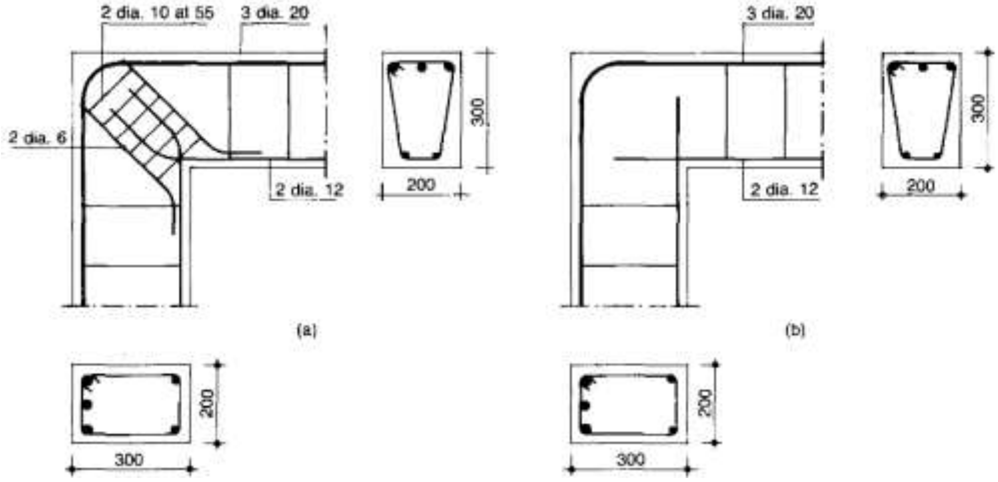

Figure 07: Details for specimens with and without confined strut (Adopted Zouzou et al., 1993).

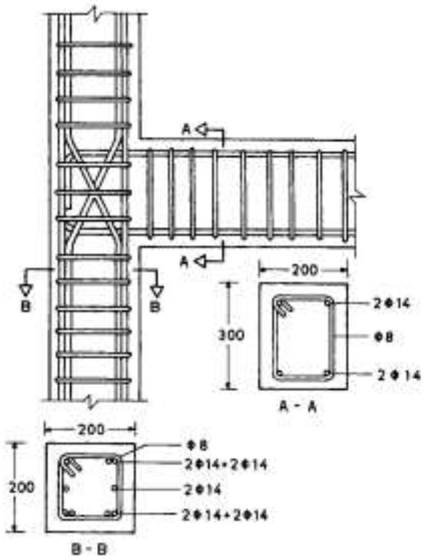

Figure 08: Details for X-type cross bars within the joint (Adopted Rajagopal et al., 2014).

Influence of transverse spandrel beam confinement

Many researchers have reported an improvement in the strength of unconfined exterior BCJs by adding transverse concrete spandrels (parts from perpendicular spandrel beams). Similar conclusions were reported by Megget et al. in 1971. He indicated that the transverse beams confined the joint core concrete and enabled the beam hinging instead of joint shear failure. Topcu (2008) found that spandrel beams increased the joint shear capacity of subassemblies by about 15-20%.

However, they did not affect the bond-slip characteristics of inadequately anchored longitudinal beam bottom bars. ACI 352-02 suggests an exterior reinforced joint with spandrel beams on both sides, a 25%-33% improvement in joint shear strength because of the lateral beam presence. Hassan (2011) supported the opinion of the beneficial nature of lateral beams if they are provided on both opposite joint sides.

Influence of joint eccentricity

The eccentricity of the spandrel beam leads to early deterioration of the joint shear strength and excessive pinching of the load versus displacement hysteresis curves. Burak and Wight (2004) investigated the effect of eccentricity on the seismic behavior of exterior beam-to-column connections through an experimental program. The significant parameters for this investigation are the spandrel beam's eccentricity concerning the column's centroidal axis, column section aspect ratio, and standard beam width. Experimental results on these eccentric beam-column-slab specimens demonstrated that including the floor system with the slab, spandrel, and standard beams adds considerable torsional stiffness to the subassembly and delays the deterioration of the joint shear stiffness and strength. However, the capacity was reached at higher drift levels due to the reduced stiffness of the subassembly resulting from the initial loading in the spandrel beam direction.

Based on the test results, it was concluded that the presence of eccentricity in the joint reduced the joint strength to the extent that none of the specimens could attain their predicted story shear strength. Quintero-Febres and Wight (2001) tested three interior wide beam-column-slab connections under cyclic loading. All of the specimens reached their expected capacities at 2 % drift and kept those capacities till the end of the test without failure or significant strength loss. However, eccentrically connected beams were found to cause the collapse of a four-story school building at Hakodate University, Japan, during the 1968 Tokachi-Oki earthquake. Several damages to beam-column joints were reported during Japan's 1995 Hyogo-ken Nanbu earthquake.both opposite joint sides.

Influence of stiffness reduction in joint

Besides the local impacts derived from the stiffness reduction of the structure joints, changes in the global behavior of the building can be noticed. A modification in the connection stiffness alters the structural behavior under lateral loads. Consequently, it affects the lateral displacements and the second-order effects on the building structure, modifying the design of the structural members.

However, the influence of joint stiffness is not always verified in the structural analysis, neglecting the possible impacts on the behavior of the structure. This can be explained by the lack of more in-depth studies on the stiffness of monolithic reinforced concrete connections and its influence on overall structural behavior. In addition, the usual consideration that the monolithic connections are rigid does not arouse in engineers a concern about the influence of the stiffness of the connection in structural analysis. Therefore, in multi-story structures, the influence of beam-column stiffness can be crucial to global stability (second-order effects).

Influence of stiffness reduction in joint

As we have seen, framing action under earthquake loading can result in relatively high shear and bond stresses in a joint. These stresses lead to local joint deformations that increase the overall flexibility of the structural framing. These deformations are significant in older buildings with weak joints, as a nonlinear response can be concentrated in the joints (Bayhan et al., 2014). Even in buildings with strong joints, joint deformations can appreciably affect overall building response and should be considered in structural analysis models. Joint deformations are usually considered to arise from two effects:

1. Bar slip: The anchorage of the beam and longitudinal column bars in the joint produces high bond stresses. Slip of the reinforcement relative to the joint concrete results in rigid-body rotations of the beams and columns relative to the joint boundaries (Figure 09a).
2. Joint shear: Joints are subjected to large shear stresses. This results in joint shear deformations and beam and column rigid-body rotations of the type illustrated in Figure 09b.

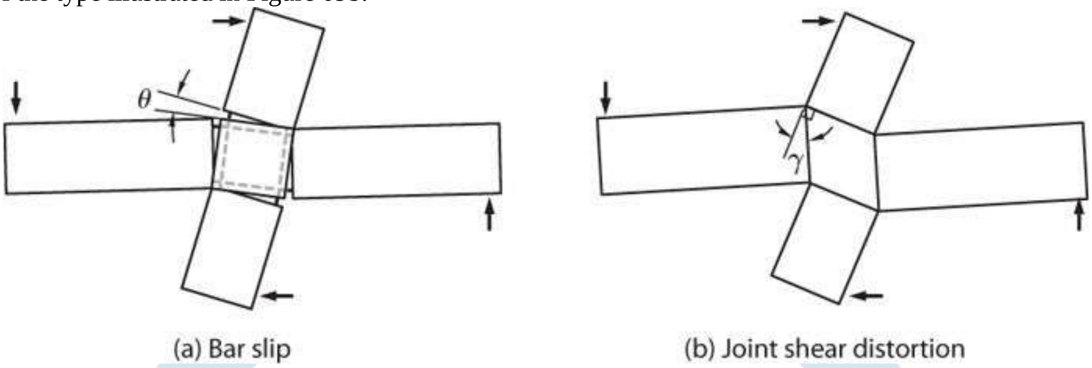

Figure 09: Sources of joint deformation contributing to overall framing flexibility (Adopted Bayhan et al., 2014).

Influence of slab contribution

Cheung et al. in 1991 investigated the improvement in BCJs performance due to slab contribution; they recorded an increase in beam flexure strength and limitation in its strength degradation after peak strength. To utilize these benefits, slab rebars within the effective flange width should be properly anchored.

When a slab is cast monolithically with the beam, the slab acts as a flange, increasing the flexural stiffness and strength of the beam. Developed slab reinforcement within the effective flange width (Figure 10) acts as beam flexural tension reinforcement and contributes to the beam flexural strength. ACI 318 is not explicit on how to account for this T-beam behavior when sizing the beam for required flexural strength. The slab will participate with the beam in resisting flexure, the resulting beam will be flexurally stronger than necessary, leading consequently to higher demands throughout the building if the beam yields under earthquake loading.

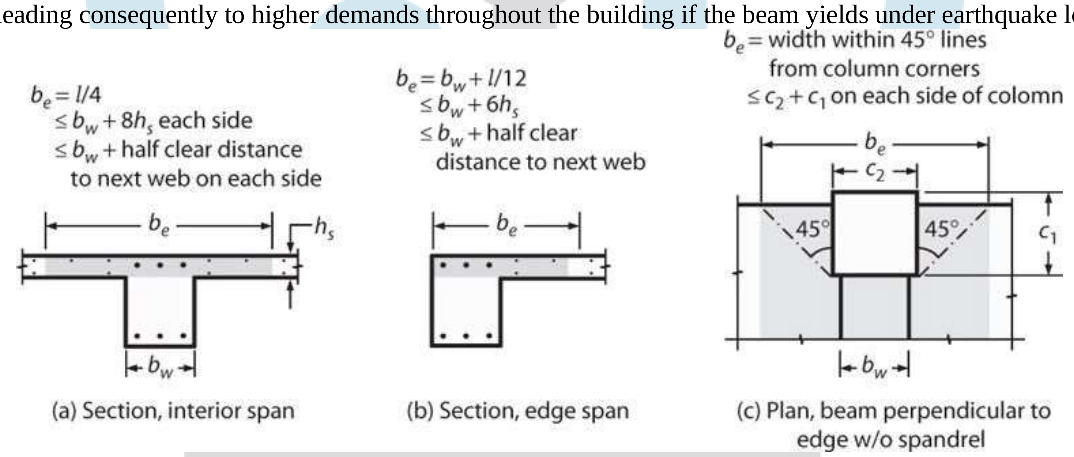

Figure 10: Definition of effective flange width (Adopted Moehle et al., 2014).

VII. RESULT AND DISCUSSION:

From the literature review presented in this paper, various parameters effect on RC beam-column joint behavior is still incomplete and requires further experimental investigations. Quantification of the contribution of reinforcement in joint shear strength requires further investigation. No consensus among researchers has been made on the effect of column axial load on joint behavior. The volume of transverse reinforcement in joints affects joint behavior, but no firm conclusions were made on limiting the percentage. Bond strength is an important parameter and significantly affects joint behavior; nevertheless, more studies are required regarding the placement pattern of reinforcement. The enormous shear forces acting on joint cores must be resisted, primarily through horizontal and vertical shear reinforcement. The diameter of longitudinal column and beam reinforcing bars passing through joint cores must not be excessive to ensure adequate anchorage and to avoid premature bond failure. Practically joint eccentricity is unavoidable due to architectural and other considerations, yet different building codes provide different recommendations.

VIII. CONCLUSION:

In summary, seismic design requirements for RC joints are for the joints and the frames to achieve the required performance during a strong earthquake. When an RC frame is subjected to seismic excitation, the beam-column joint is to help the structure dissipate seismic forces so it can behave in a ductile manner. As beam-column joint cores can be critical regions in the ductile RC moment-resisting frames, good detailing of beam-column joint core regions is essential if reinforced concrete frames subjected to severe seismic motions respond satisfactorily. The performance of beam-column joints was identified as a critical issue in the seismic resistance of RC moment-resisting frames (RC MRF).

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