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Study of Reinforced Concrete Beam-Column Joint

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Abstract:The beam column joint is the crucial zone in a reinforced concrete moment resisting frame. It is subjected to large forces during severe ground shaking and its behaviour has a significant influence on the response of the structure. The assumption of rigid joint fails to consider the effects of high shear forces developed within the joint. The shear failure is always brittle in nature which is not an acceptable structural performance especially in seismic conditions. This paper presents a review of the postulated theories associated with the behaviour of joints. Understanding the joint behaviour 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.

Keywords:Beam column joint , moment resisting frame ,rigid joint ,shear failure ,seismic actions ,shear transfer.

1.Introduction

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 Sudden change in geometry and complexity of stress distribution at joint are the reasons for their critical behaviour. In early days, the design of joints in reinforced concrete structures was generally limited to satisfying anchorage requirements .In succeeding years, the behaviour of joints was found to be dependent on a number of factors related with their geometry; amount and detailing of reinforcement, concrete strength and loading pattern. A heavy damage in a beam-column joint should beam voided during an earthquake because

(a)the gravity load is sustained by the joint,
(b) a large ductility and energy dissipation is hard to achieve in the joint,
(c) a joint is difficult to repair after an earthquake.

However, an excessive complication of reinforcement detailing should be equally avoided to insure good workmanship and construction. Therefore, joint shear failure and a significant beam bar slippage within a joint should be prevented up to an expected structural deformation.

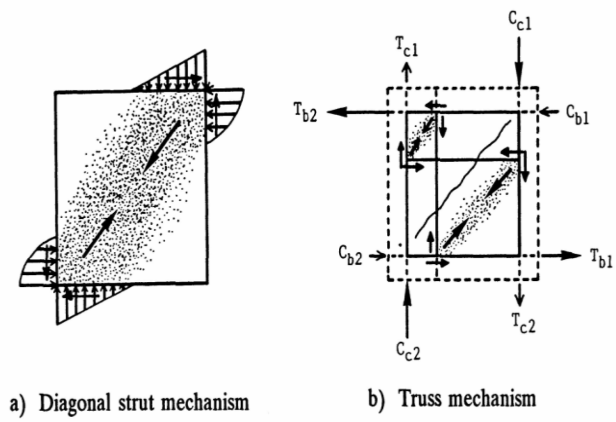
1.1 SHEAR RESISTING MECHANISMS OF BEAM-COLUMN JOINT

1.1.1 Diagonal Strut Mechanism

The diagonal compression strut is formed along the main diagonal of a joint panel by the resultant of the horizontal and vertical Compression stresses and shear stresses acting on the concrete at the beam and column critical sections.

1.1.2 **Truss Mechanism**

The truss mechanism is formed with uniformly distributed diagonal compression stresses, tensile stresses in the vertical and horizontal reinforcement and the bond stresses acting along the beam and column exterior bars.



. **Fig.1 Shear transfer mechanism in joint**

(Source:Kazuhiro Kitayama, Shunsuke Otani and Hiroyuki Aoyama,2010)

1.1 Types of joints :

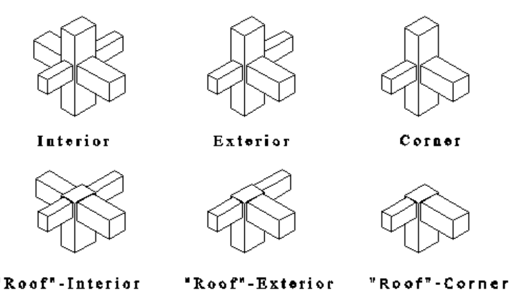


Fig.2 Typical Beam Column Connections

(***Source: Joint ACI-ASCE Committee 352, 2002***)

1.3 Performance Criteria

The requirements Criteria for the desirable performance of joints can be summed up as:
(i)The strength of the joint should not be less than the maximum demand corresponding to development of the structural plastic hinge mechanism for the frame. This will eliminate the need for repair in a relatively inaccessible region and for energy dissipation by joint mechanisms, which, as will be seen subsequently, undergo serious stiffness and strength degradation when subjected to cyclic actions in the inelastic range.
(ii) The capacity of the column should not be jeopardized by possible strength degradation within the joint. The joint should also be considered as an integral part of the column.
(iii)The joint reinforcement necessary to ensure satisfactory performance should not cause undue construction difficulties.

2.Literature Review

Laura N. Lowes and Arash Altoontash,2003, developed a model to represent the response of reinforced-concrete beam-column joints under reversed-cyclic loading. The proposed model provides a simple representation of the primary inelastic mechanisms that determine joint behavior: Failure of the joint core under shear loading and anchorage failure of beam and column longitudinal reinforcement embedded in the joint. The model is implemented as a four-node 12-degree-of-freedom element that is appropriate for use with typical hysteretic beam-column line elements in two-dimensional nonlinear analysis of reinforced concrete structures. Constitutive relationships are developed to define the load formation response of the joint model on the basis of material, geometric, and design parameters. Comparison of simulated and observed response for a series of joint sub assemblages with different design details indicates that the proposed model is appropriate for use in simulating response under earthquake loading.

Sudhir K. Jain,2006, presented critical review of recommendations of well established codes regarding design and detailing aspects of beam column joints. The codes of practice considered are ACI 318M-02, NZS 3101: Part 1:1995 and the Eurocode 8 of EN 1998-1:2003. All three codes aim to satisfy the bond and shear requirements within the joint. It is observed that ACI 318M-02 requires smaller column depth as compared to the other two codes based on the anchorage conditions. NZS 3101:1995 and EN 1998-1:2003 consider the shear stress level to obtain the required stirrup reinforcement whereas ACI 318M-02 provides stirrup reinforcement to retain the axial load capacity of column by confinement. Significant factors influencing the design of beam-column joints are identified and the effect of their variations on design parameters is compared. The variation in the requirements of shear reinforcement is substantial among the three codes.

Nilanjan Mitra,2007, developed performance-based design methods that enable the design of a structure to achieve specific performance objectives, typically in excess of 'lifesafety', under a given level of earthquake loading. Accomplishing performance-based design requires accurate prediction of component load and deformation demands, and typically nonlinear analysis is employed to determine these demands. He focused on developing a series of analysis and design tools to support the performance-based design of one particular structural component: reinforced-concrete beam-column joints. This particular component is chosen for investigation because, despite the fact that laboratory and post-earthquake reconnaissance suggest that joint stiffness and strength loss can have a significant impact on structural response, the inelastic response of these components is rarely considered in analysis or design. Data from previous experimental investigations of joints, spanning a wide range of geometric, material and design parameters, were assembled. Using these data, a series of models were developed and applied to advance understanding of the seismic behaviour, simulation and design of reinforced concrete beam-column joints. These include a 1) discrete choice probabilistic failure initiation model, 2) continuum model for joints, 3) strut-and-tie models for joint and 4) a component-based super-element model for the joint region.

P.Rajaram and G.S.Thirugnanam,2008, a two bay five storey reinforcement cement concrete moment resisting frame for a general building has been analysed and designed in STAAD Pro as per IS 1893 2002 code procedures and detailed as IS 13920 1993 recommendations. A beam column joint has been modeled to a scale of 1/5 th from the prototype and the model has been subjected to cyclic loading to find its behaviour during earthquake. Non linear analysis is carried out in ANSYS software.

Dr.S.R.Uma,2009, presented critical review of recommendations of well established codes regarding design and detailing aspects of beam column joints. The codes of practice considered are ACI 318M-02, NZS 3101: Part 1:1995 and the Eurocode 8 of EN 1998-1:2003. All three codes aim to satisfy the bond and shear requirements within the joint. It is observed that ACI 318M-02 requires smaller column depth as compared to the other two codes based on the anchorage conditions. NZS 3101:1995 and EN 1998-1:2003 consider the shear stress level to obtain the required stirrup reinforcement whereas ACI 318M-02 provides stirrup reinforcement to retain the axial load capacity of column by confinement. Significant factors influencing the design of beam-column joints are identified and the effect of their variations on design parameters is compared. The variation in the requirements of shear reinforcement is substantial among the three codes.

.**Kazuhiro Kitayama, Shunsuke Otani and Hiroyuki Aoyama,2010** summarized earthquake resistant design criteria for reinforced concrete interior beam-column joints. The design criteria emphasize the protection of the joint to an acceptable deformation level of a frame structure during an intense earthquake. For the design against shear, shear resisting mechanism by truss and concrete compression strut, the role of joint lateral reinforcement, and the effect of transverse beams and slabs were studied experimentally. The requirement for beam bar bond was discussed on the basis of nonlinear earthquake response analysis.

Gregoria Kotsovou and Harris Mouzakis ,2012, proposed a method for the seismic design of external beam–column joints by considering the load transferred from the linear elements to the joint is predominantly resisted by a diagonal strut mechanism. The work presented is intended not only to verify the validity of the proposed method, but also to identify means for its implementation that will maximize its effectiveness. The effect of the above characteristics on structural behaviour is established by testing full-size beam–column joint specimens under cyclic loading; the results obtained show that the proposed method produces design solutions that fully satisfy the code performance requirements and are found consistent with already published experimental information.

N. Subramanian and D.S. Prakash Rao,2012, discussed the behaviour and design of two-, three- and four-member beam — column joints in framed structures are; obtuse and acute angle joints are included. Detailing of the joints based on experimental investigations is also explained. The specifications of American, New Zealand and Indian codes of practice are appraised. An equation for calculating the area of joint transverse reinforcement has been proposed for the Indian code, based on recent research.

S. S. Patil and S.S.Manekari,2013, studied various parameters for monotonically loaded exterior and corner reinforced concrete beam column joint. The corner as well as exterior beam-column joint is analyzed with varying stiffness of beam-column joint. The behavior of exterior and corner beam-column joint subjected to monotonic loading is different. Various graphs like load vs. displacement (deformations), Maximum stress, Stiffness variations i.e. joint ratios of beam-column joints are plotted.

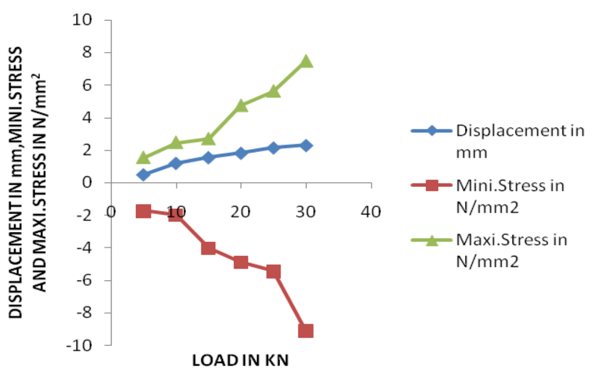


Fig.3 Load Vs Maximum Deformation, Minimum Stress, Maximum Stress Graph

(Source: S. S. Patil and S.S.Manekari,2013)

Mehmet Unal and Burcu Burak,2013, studied the inelastic behaviour of beam column joint, the factors influencing the seismic behaviour of beam-to-column connections . He believed that the key parameters affecting the connection performance are column- to-beam moment strength ratio, confinement provided by the lateral reinforcement and beams framing into the connection region, anchorage of the beam longitudinal reinforcement and shear stress level in the joint. In addition, material properties, section dimensions, eccentricity between the centre lines of beam and column, axial load acting on the column and presence of wide beams or slab also affect the connection behaviour .

A.K.Kaliluthin,Dr.S.Kothandaraman,2014, focused on the general behaviour with specific structural properties of common types of joints in reinforced concrete moment resisting frames to be aware of the fundamental theory of the joint for better efficiency. A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three direction .The behaviour of joints was found to be dependent on a number of factors related with their geometry; amount and detailing of reinforcement, concrete strength and loading pattern.

3.Summary and Conclusion

Structural joints in a rigid frame should be capable of sustaining forces higher than those of the connecting members.However, while beams and columns are designed and detailed with considerable care, the same cannot be said about the joints in RC rigid frames. The structural behaviour 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-storeyed 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

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