Effect of Moment Capacity Ratio at Beam-Column Joint of RC Framed building: A Review

R. C. Hajare [1], H. S. Jadhav[2]

[1]P.G. Student, Dept. of Civil Engineering, Rajarambapu Institute of Technology, Islampur, Maharashtra, India.
[2]Professor, Dept. of Civil Engineering, Rajarambapu Institute of Technology, Islampur, Maharashtra, India.

---***---

Abstract - *The "strong-column-weak-beam" design concept necessitates good ductility and a more desirable collapse mechanism in the structure. The entire response of a structure can only be controlled by the longitudinal beams' flexural strength when RC beam-column connections exhibit ductile behavior. The future mode in which the beams act as hinges is typically regarded as the most advantageous mode for ensuring good global energy dissipation without substantial degrading of capacity at the connections. There are considerable variations among these standards, even though several international codes prescribe that the moment capacity ratio at the beam-column joint be more than one. In this paper, a brief review of the effect of Moment Capacity Ratio at various Beam-Column Joint is discussed.*

Key Words: Moment capacity ratio, Strong-column-weak-beam, Ductility, Beam-Column Joint, Hinges, etc.

1. INTRODUCTION

There are earthquakes throughout the world. It is not cost-effective to create a structure that can flexibly respond to an earthquake without suffering damage. It has been found that beam-column joints are important parts of RC-framed buildings. The performance of reinforced concrete frame constructions is influenced by the integrity of the beam, column, and beam-column junction. Most often, during earthquake conditions, the joints of RC framed structures are subjected to the most severe loading. The structural response of the beam-to-column junction is significantly influenced by the strength and stiffness of the column. Due to subpar beam-column joint performance during recent earthquakes, many RC-framed buildings in India have collapsed. The ductility and strength of an RC framed structure that is needed to sustain significant deformation and reversal forces during an earthquake depend on the design and detailing of the beam-column joints. Therefore, at a junction, the column strength must be increased to be greater than the strength of the beams that frame it. Mathematically, it can be determined as Mc > Mb. A strong column weak beam design philosophy must be established, and this depends on the column to beam moment capacity ratio.

2. LITERATURE REVIEW

Dooley, Kara, et al. [1] uses probabilistic measurements to analytically assess the seismic performance of frame buildings with different strength ratios. Two research structures, three and six stories, with varying strength ratios (from 0.8 to 2.4) were evaluated. Investigated was also the impact of altering the column-to-beam stiffness ratio. Based on the results, it is recommended that a minimum strength ratio of 2.0 be used to avoid the creation of a story mechanism under design seismic loads. Additionally, increasing the strength ratio on its own is more efficient than concurrently raising the stiffness and strength ratios.

Bindhu, K. R, et al. [2] compared the behavior of external beam-column joint sub assemblages with transverse reinforcements described in accordance with IS 456 and IS 13920. One of the exterior beam-column joints at an intermediate storey of a six-story RC building in zone III is analyzed and designed. The most recent revisions of IS 1893 and IS 13920 are taken into account when performing the seismic analysis and design. Under a reverse cyclic loading, four one-third scaled specimens, two specified in accordance with IS 456 and SP 34 and the other two in accordance with IS 13920 were tested. To assess the impact of axial load on the behavior of the joints, two different axial loads were applied. The test findings show that the most recent changes to joint design guarantee that the beam failure will occur before the joint failure. Improvements in the performance of the IS 13920-described beam-column joints during the reversal of loading were also noted.

Birely, Anna C., et al. [3] have worked to create a realistic, accurate nonlinear model for reinforced concrete frames. The model is compliant with the ASCE/SEI Standard 41-06 nonlinear static technique and is suitable for forecasting the earthquake response of planar frames for which the nonlinearity is controlled by the non-ductile response of joints and/or yielding of beams non-ductile response of joints. The model was created to make it easier to implement in the widely used commercial software for this kind of nonlinear analysis. By adding a dual-hinge lumped-plasticity beam element to mimic the beams framing the joint, the nonlinearity is replicated. The dual hinge consists of two rotatable springs arranged in series, one of which simulates joint reaction and the other beam flexural response. . Using information from 45 planar frame sub-assemblage tests, hinge parameters were calculated. The model's use to simulate the reaction of various sub-assemblages demonstrates that it can accurately replicate stiffness, strength, drift capacity, and response mechanism for frames with a variety of design parameters.

Choi, Se Woon, et al. [4] studies, the best column-to-beam strength ratios necessary for securing the beam-hinge mechanism using the multi-objective seismic design method based on nonlinear static analysis. In this formulation, minimizing the two objective functions of structural weight and column-to-beam strength ratio while meeting the limitations is the best course of action. The relationship between the structural weights and appropriate strength ratios is shown based on numerous Pareto-optimal solutions using beam-hinge systems. Instead of proposing a particular single number as a limit for the column-beam flexural strength ratio, a common tendency is discovered through examining the correlations between ideal strength ratios and structural weights using the well-known two-moment resisting example structures.

Kusuhara, F., and H. Shiohara. [5] proposed an expanded version of the nine-parameter model (NPM), a kinematic model that can forecast the moment capacities and moment at the balanced failure of reinforced concrete beam-column joints. The hypothesis differs from others in that the behavior of joints can only be explained by shear deformation, and joint failure is thought to result from the shear failure of joint panels. The NPM assumes that the translations and rotations of four stiff plates at the beam and column ends represent the two-dimensional deformation of a beam-column joint. For each section that is divided by diagonal cracks in the joint, the equilibrium equations are taken into account in the model. The model can be used to explain the joint behavior and the moment capacity by including the constitutive relationships of the materials in the beam-column joints. While symmetry in geometry and loading is assumed in the original expression in order to simplify the equations, the extension allows for different sectional dimensions, reinforcement of the beam and column, and three different loadings on the beams and columns by deriving algebraic expressions of moment capacity without the assumption of symmetry. It lessens the challenge of applying theory to a broad range of beam-column junctions in practice. The projected strengths from the extended model are contrasted with the findings of the authors' experiments on 20 inner joint specimens. The study's findings demonstrate that the model produces reliable predictions.

Patil, S. L., and S. A. Rasal. [6] studies the behavior of reinforced concrete moment-resistant frame structures during the most recent earthquakes has brought to light the negative effects of a weak beam-column joint. The characteristic that is currently in demand in practice is "strong column weak beam" behavior, which causes ductile failure. The current review aims to assess whether the beam-to-column ratio in a building subject to cyclic loads is adequate. The ratio of the beam to the column is gradually increasing, and column failure has been seen. Also reviewed is the variety in horizontal and vertical irregularity.

Parasa, P. K. [7] examines the impact of raising the moment capacity ratio at beam column joints on the structure's overall ductility and lateral strength. The analysis is conducted using SAP 2000. A probabilistic technique is used to examine the impact of ground motion intensity on the likelihood of exceeding any specified damage state for buildings designed with variable moment capacity ratios (MCR) at the connections in order to account for uncertainty in material qualities. For this purpose, pushover curves generated from the nonlinear static analysis are taken into consideration when developing fragility curves. As MCR rises, the structure becomes more ductile. Additionally, structures built with lower MCR values are found to be more fragile than those with greater MCR.

Uma, S. R., and A. Meher Prasad. [8] works on, the essential area in a reinforced concrete moment-resisting frame is the connection between the beam and column. It experiences strong forces during violent ground shaking, and its behavior significantly affects how the structure reacts. When a joint is assumed to be rigid, the consequences of strong shear forces that arise inside the joint are not taken into account. Especially in seismic situations, the shear failure is invariably brittle in nature, which is not an acceptable structural performance. The suggested hypotheses relating to the behavior of joints are reviewed in this work. It is crucial to comprehend joint behavior in order to make appropriate decisions on joint design. The article addresses the effects of earthquakes on various types of joints and underlines the crucial factors that influence them.

Yadav, Abhay, Abhishek Kumar, et al. [9] studies that the moment capacity ratio of the beam-column joint is a crucial factor to take into account for framed buildings, according to this paper. This study explains how the moment capacity ratio impacts building fragility and how the ductility of structures grows as the ratio increases. The purpose of this work is to investigate the impacts of the moment capacity ratio on the ductility, strength, and failure likelihood of multi-story buildings.

Bhandari, Sujan, and Hari Darshan Shrestha. [10] studies that the Gorkha earthquake on April 25, 2015, left behind devastation that serves as a constant reminder of how fragile our cities, like Kathmandu Valley, are. The primary cause of the majority of the RCC building's collapse was the column sway 4 mechanism. The intermediate RC frames of three-, five-, and eight-story typical buildings are chosen for research. The three sets of structures are constructed so that each set has five families of structures with varying column-to-beam moment capacities (CBMCR). For each structure, a nonlinear static pushover analysis is performed in SAP2000 to assess the impact of CBMCR on the structure's lateral strength and displacement capacity. It has been found that increasing CBMCR improves a structure's lateral strength and displacement capacity. Using the N-S component of the accelerogram from the Gorkha earthquake, SAP2000 performs a linear time history analysis. . It has been observed that structures with lower CBMCR values have a higher likelihood of surviving a particular damage condition than those with higher values at the same PGA. Another finding is that these fragility curves can aid in the design process by helping to select an appropriate CBMCR value for structural joints.

Athira, P., and Remya Raju. [11] presents that during an earthquake, the performance of beam-column connectors is not sufficient. Numerous studies have been conducted in an effort to comprehend the intricate mechanics and satisfactory behavior of beam-column connections. The beam-column connection would be the most crucial area in moment-resisting reinforced concrete frames. In order to get a greater performance and material capacity for the connection, new types of shear reinforcements are developed in this study. The first example is created using a traditional design process. The second specimen contrasts a continued conventional shear resistance system with a conventional shear resistance system that has been discontinued. The third variant is made up of longitudinal GFRP (Glass Fiber Reinforced Polymer) bars and ten spiral reinforcements. Hybridization of GFRP will be carried out in order to better the characteristics of GFRP reinforced beam-column joints and investigate the model with GFRP bars. There were two different forms of hybridization, GFRP crust with steel core and steel crust with GFRP core. Higher ductility and less deformation were evaluated on the hybridized bar specimen. ANSYS finite element software was used to model and analyze the corner beam-column junction in this scenario.

Sargar, Ram Arjun, and Jyoti Pushan Bhusari. [12] studies that the design of the beam column joint is essential in RC framed structures. The moment capacity ratio, which is typically greater than one, controls how a beam column joint behaves. This value varies greatly across different codes. The moment capacity ratio at the joint must be taken into account, according to the IS: 13920. A frame's moment capacity ratio (MCR), which increases with increasing column size and reinforcements to provide a strong column-weak beam, is subjected to pushover analysis. Its impact on the creation of hinges, base shear, storey drift, ductility, and lateral displacement is investigated, and the ideal moment capacity ratio is computed. The MCR should not be less than 1.4 in order to improve ductility and achieve plastic hinges at the end of beams rather than in the column. In order to do this, increasing the column's reinforcement appears to be more successful than expanding the column's dimensions.

Ajay Kumar Bhosale, H. S. Jadhav, [13] studies, the effect of a nonlinear static analysis on the overall ductility and lateral strength of the structure is examined. SAP 2000 is used to increase the moment capacity ratio at beam column joints. MCR rating for that construction should be evaluated from the perspective of ductility. From the pushover curve, it can be seen that, up to a certain point, the MCR increases the ductility and strength of the structure.

Kumar, Jawala, et al. [14] examined the fragility and reliability analyses of RC frames with five, seven, and ten stories that were built utilizing different MCR values between 1.0 and 3.2. For all seismic zones, RC frames are constructed in accordance with IS 1893 (2002). The National Disaster Management Authority, Government of India, has chosen the risk curves needed for different seismic locations in India (such as zone II, III, IV, and V). All proposed buildings undergo a seismic risk assessment, and a suggested minimum value of Moment Capacity Ratio (MCR) is determined based on the obtained Reliability Index and the Target Reliability Index

Chavan, Kshitij S., and D. R. T. Meena. [15] examined the RC Frame's beam-column joints are fragile in terms of earthquake resistance. When the load is greater during earthquakes, the joints are badly damaged because the material has a limited load carrying capacity. Repairing broken joints is challenging and should be avoided. Beam and Column are the horizontal and vertical elements of a multistory RC Framed construction. This mostly impacts the brittle Column Beam joints that occur during earthquakes. Therefore, a collapsed column causes the entire building to collapse. The moment capacity Ratio (MCR) provided by IS is therefore one of the key factors in preventing damages (13920, 2016) However, the IS code offered the same value for all building shapes and seismic zones. According to the study, it varies depending on the shape and scale of the building as well as the seismic zones. The MCR value indicates the structure's lateral strength, stiffness, and ductility when it must endure stresses. Therefore, this study was conducted for two different irregularly shaped RC framed buildings. Software from SAP 2000 is employed in this investigation.

Zhang, Wang-Xi, et al. [16] studies, the seismic performance of the RC-framed structure is examined using nonlinear static and nonlinear dynamic techniques. The impact of the moment capacity ratio at the beam-column joint on the lateral strength and ductility of RC-framed buildings in various seismic zones True whether or not there are slabs acting under the column's moment amplification factor. To calculate the structure's seismic performance, plastic hinges distributed with unidirectional and bidirectional pushover are employed. For the time being, the theoretical formula source provides a precise estimate of the structural response caused by diagonal seismic action. It may be inferred from the analysis and comparison of two types of established models that the framed structure with slabs is more damaging than the structure without slabs when the moment magnifying factors of the column vary. However, as the column's moment magnifying factors increase, the RC structure switches from having a "column hinge mechanism" to a "beam hinge mechanism."

Wongpakdee, Nattapat, and Sutat Leelataviwat. [17] displays an analysis of the strong-column weak-beam (SCWB) moment frame's inelastic behavior and demand for the beam to column joint along with several plastic flexural strength distributions. The response and deformation of the frames were assessed for this using a pushover and non-linear dynamic analysis. A series of 44 far-field ground motions were used in a dynamic analysis to examine the response of the frames in a wide range of levels of intensity of ground motion up to the collapse level. The pushover analyses of the first mode were used to evaluate the response of the RC frames with various work ratio values. Finally, it was determined that the demand for the beam-column joint had surpassed code requirements. A set value of the demand for the beam-column joint is also impractical and could not be sufficient to ensure the desired SCWB mechanism.

T. S. M. N. Arun Kumar, [18] demonstrates the instability of RC structures with various MCR values at the beam-column joint in both regular and irregular structures with and without infill walls. The pushover curves obtained from the non-linear static analysis are taken into account when developing fragility curves for this purpose, and probabilistic analysis is used to evaluate the damage statistics and separate the buildings based on their varying seismic performance. The fragility curves indicate that the RC construction with a lower MCR value, i.e. MCR 1.12, has substantially larger damage possibilities. Regardless of the number of stories and damage levels, the incorporation of greater MCR values lowers the likelihood of damage.

Zaghi, Arash E., et al. [19] enhanced knowledge of how the column-beam strength ratio affects different seismic performance assessments. For this, three post-Northridge steel moment-resisting frames of three, nine, and twenty stories are subjected to a total of 540 nonlinear time-history studies. Changing the column dimension or the yield stress of the column and beam materials will alter the CBSR values in every single model. . Furthermore, the influence of the beam-to-column stiffness ratio along with its strength ratio was assessed using only the smallest and biggest CBSR values. In particular, for low-rise frames, it may be determined that the relationship between the flexural strength of the columns and that of the beams does not preclude the columns from performing as per the present requirement of the design regulations. Under strong ground motions, columns can yield even for MCRs greater than two.

Choi, Se Woon, et al. [20] studies that to determine the ratios of ideal strength between columns and beams required to ensure the hinge mechanism, a multi-objective seismic design approach based on non-linear static analysis is constructed and utilized. The ideal approach in this formulation, if the constraints are satisfied, is to minimize the two objective functions of the structural weight as well as the ratio of resistance from column to beam. The correlation between structural weights and ideal strength ratios is presented based on several Pareto optimal solutions with hinged mechanisms. Through the examination of the relationships, a mutual tendency is identified using the well-known example structures of resistance to the two moments as a replacement for or suggestive of a specific unique value as a limit for the bending strength ratio of the column-beam. be Department of Structural Engineering, Civil Engineering 9 The Ductility and Lateral Strength of RC Framed Building in Different Seismic Zones Are Affected by the Moment Capacity Ratio at Beam-Column Joint. between the ideal resistance to structural weight ratios.

3. CONCLUSION

From the study of the above research papers, it can be concluded that different researchers had studied different types of problems related to the Moment Capacity Ratio of the Beam-Column joint. And it is addressed that Moment Capacity Ratio of the Beam-Column joint plays an important role in achieving a strong column weak beam concept. Analysis of software such as ETABS, and SAP 2000 are also combined with manual calculations. Various models are generated and the MCR of the Beam-Column joint are studied. Analytical results show different values of MCR as per the different configurations of structures in different seismic zones. The approach of a single value of MCR is not adequate for better Ductility and Lateral strength of the structure in different seismic zones.

The future scope of studying this type of research is to find the adequate or optimum value of MCR. Effect of MCR at Exterior and Corner Beam Column joint can be studied. The study can be extended by considering irregular building frames. Effects of shear wall and infill wall can also be considered in this analytical model for further study. The effect of the moment capacity ratio on a flat slab can also be evaluated.

REFERENCES

[1] Dooley, Kara L., and Joseph M. Bracci. “Seismic Evaluation of Column-to-Beam Strength Ratios in Reinforced Concrete Frames.” ACI Structural Journal, vol. 98, no. 6, 2001, https://doi.org/10.14359/10751.

[2] Bindhu, K. R., et al. “Performance of Exterior Beam-Column Joints under Seismic Type Loading.” ISET

Journal of Earthquake Technology, vol. 46, no. 02, 2009, pp.47-64,iset.org.in/public/publications/39845_Paper_503.pdf.

[3] Birely, Anna C., et al. "A Model for the Practical Nonlinear Analysis of Reinforced-Concrete Frames Including Joint Flexibility." Engineering Structures, vol. 34, 2012, pp. 455–65., https://doi.org/10.1016/j.engstruct.2011.09.003.

[4] Choi, Se Woon, et al. "Minimum Column-to-Beam Strength Ratios for Beam–Hinge Mechanisms Based on Multi-Objective Seismic Design." Journal of Constructional Steel Research, vol. 88, 2013, pp. 53–62., https://doi.org/10.1016/j.jcsr.2013.05.004.

[5] F. Kusuhara , and H. Shiohara, "Moment capacity of reinforced concrete interior beam-column joints based on a theory of flexural resistance of joints." in Proc., 10th US National Conference on Earthquake Engineering, Earthquake Engineering Research Institute, Alaska, 2014., https://datacenterhub.org/resources/11718/download/10NCEE-000336.pdf

[6] S. L.Patil, and S. A. Rasal. "Behaviour of Beam-Column Joint on Different Shapes RC Framed Structures: A Review." International Journal of Science and Research (IJSR) ISSN (Online): 2319–7064, vol. 6, no. 4, 2017, pp. 351–53, www.ijsr.net/archive/v6i4/ART20172238.pdf.

[7] Parasa, Praveen Kumar. "In a Rectangular RC Framed Building Moment Capacity Ratio at Beam Column Joints." International Journal of Advance Research in Science and Engineering, vol. 4, no. 7, 2015, pp. 84–94, ijarse.com/images/fullpdf/1436858868_10_Research_Paper.pdf.

[8] Uma, S. R., and A. Meher Prasad. "Seismic behavior of beam column joints in reinforced concrete moment resisting frames." Document No.: IITK-GSDMA-EQ32-V1. 0, Final Report: A-Earthquake Codes, IITK-GSDMA Project on Building Codes (2015).

[9] Yadav, Abhay, et al. "Review on Moment Capacity of Beam-Column Joint in Regular RC Framed Building." International Research Journal of Engineering and Technology (IRJET), vol. 3, no. 3, 2016, pp. 251–53., d1wqtxts1xzle7.cloudfront.net.

[10] Bhandari, Sujan, and Hari Darshan Shrestha. "Effect of Column-to-Beam Moment Capacity Ratio on Seismic Performance of Reinforced Concrete Moment Resisting Frames." Proceedings of IOE Graduate Conference, vol. 5, 2017, pp. 39–47, conference.ioe.edu.np/publications/ioegc2017/IOEGC-2017-06.pdf.

[11] Athira, P., and Remya Raju. "Behaviour of Corner Beam Column Joint with Rectangular Spiral Reinforcement and Longitudinal FRP Bars." International Research Journal of Advanced Engineering and Science, vol. 2, no. 2, 2017, pp. 161–65, irjaes.com/wp-content/uploads/2020/10/IRJAES-V2N2P201Y17.pdf.

[12] Sargar, Ram Arjun, and Jyoti Pushan Bhusari. "Effect of moment capacity ratio on RC framed structure." Innovations in Infrastructure. Springer, Singapore, 2019, pp. 275-285, , https://link.springer.com/

[13] Ajaykumar L.Bhosale, and H. S. Jadhav. "Effect of Moment Capacity Ratio at Beam-Column Joint on Ductility and Lateral Strength of RC Framed Building." Int. Journal of Engineering Research and Application,3ISSN : 2248–9622, vol. 9, no. 3, 2019, pp. 12–18, ijera.com/papers/vol9no3/Series-5/C0903051218.pdf.

[14] Kumar, Jawala, and Mr. Varun Kumar Sikka. "Moment Capacity Ratio at Column – Beam Joint in a RC Framed Structure." SMART MOVES JOURNAL IJOSCIENCE, vol. 6, no. 3, 2020, pp. 1–7, https://doi.org/10.24113/ijoscience.v6i3.274.

[15] Chavan, Kshitij S., and DR. T. Meena. "Effect of Moment Capacity Ratio on Ductility of Different Shape RC Framed Building in Various Seismic Zones." International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 5, 2020, pp. 2385–95, www.irjet.net/archives/V7/i5/IRJET-V7I5461.pdf.

[16] Zhang, Wang-Xi, et al. "Multifactor Influence Analysis of Seismic Performance of RC Frame Structure with Cast-in-Site Slabs." Procedia Engineering, vol. 210, 2017, pp. 360–68, https://doi.org/10.1016/j.proeng.2017.11.089.

[17] Wongpakdee, Nattapat, and Sutat Leelataviwat. "Influence of Column Strength and Stiffness on the Inelastic Behavior of Strong-Column-Weak-Beam Frames." Journal of Structural Engineering, vol. 143, no. 9, 2017. https://doi.org/10.1061/(asce)st.1943-541x.0001864.

[18] Kumar N. Arun, and T. H. Sadashiva Murthy. "Probability of Failure of Building with Various MCR Values at Beam-Column Joint in Regular and Irregular Building." International Journal of Research in Engineering & Applied Sciences, vol. 6, no. 6, 2016, pp. 129–141, https://euroasiapub.org/

[19] Zaghi, Arash E., et al. "Impact of Column-to-Beam Strength Ratio on the Seismic Response of Steel MRFs." Bulletin of Earthquake Engineering, vol. 13, no. 2, 2014, pp. 635–52, https://doi.org/10.1007/s10518-014-9634-9.

[20] Choi, Se Woon, et al. "Minimum Column-to-Beam Strength Ratios for Beam–Hinge Mechanisms Based on Multi-Objective Seismic Design." Journal of Constructional Steel Research, vol. 88, 2013, pp. 53–62, https://doi.org/10.1016/j.jcsr.2013.05.004.

[21] Bureau of Indian standards: IS-1893, part 1 (2016), "Criteria for earthquake resistant design of structures: part 1 general provisions and buildings", New Delhi, India.

[22] Bureau of Indian standard, IS-456(2000)," Plain and reinforced concrete code of practice"

[23] Bureau of Indian standards: IS-13920 (2016), "Ductile design and detailing of reinforced concrete structures subjected to seismic forces -code of practice", New Delhi, India.