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Effect of Moment Capacity Ratio at Exterior and Corner Beam-Column Joint of Irregular RC.

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Abstract *: The "strong-column-weak-beam" design principle demands that the structure have good ductility and a more acceptable collapse mechanism. When RC beam-column joints behave ductile, the longitudinal beams' flexural strength is the single factor that can regulate a structure's complete reaction. The most favorable mode for maintaining good global energy dissipation without significantly reducing capacity at the connections is often considered to be the future mode in which the beams operate as hinges. Although some international codes require that the moment capacity ratio at the beam-column joint be greater than one, there are still significant differences between these standards. In this present work non-linear static analysis is being done using commercial software for increasing the moment capacity ratio at beam-column joints and its effect on the displacement ductility and lateral strength of the structure is studied. The value of MCR w.r.t. Ductility and Lateral strength is optimized in different seismic zone. From the study, it is observed that ductility of the structure increases with the increase of MCR and Lateral Strength of the structure decreases with the increase of MCR.*

Key Words: moment capacity ratio, ductility, beam column joint, seismic zone.

1. INTRODUCTION

Earthquakes occur randomly across the globe, generating ground motions in both horizontal and vertical directions. These motions induce vibrations in structures and create inertia forces, which significantly impact their stability and performance. During past seismic events, the analysis of damages to RC (reinforced concrete) framed structures has shown that failures often occur due to the inability of concrete to sustain required pressure, soft story mechanisms, inadequate reinforcements, poor anchorage, and column collapses—all contributing to structural instability.

Among the most vulnerable components of an RC structure under seismic loading are the beam-column joints. Studies indicate that these joints are frequently the weakest links, and their failure can compromise the integrity of the entire structure. The complex stress conditions at beam-column junctions—caused by sudden changes in geometry—make them particularly susceptible to cracking and failure. Research has identified that cross-sectional detailing, the amount and placement of reinforcement, the type of concrete, and the loading conditions all critically influence joint behavior.

In earthquake-resistant design, the goal is not to avoid all damage, but to allow controlled damage in selected components. Designing a structure to remain fully elastic under strong earthquake forces would be economically unfeasible. Therefore, modern seismic design allows for inelastic behavior in specific areas, provided the structure remains stable overall. One of the key aspects of seismic resistance is ductility—the structure's ability to undergo large deformations beyond the elastic range without sudden failure. Increased ductility helps reduce the effective earthquake forces acting on the structure.

The capacity design concept promotes a strength hierarchy: it ensures that columns remain stronger than the adjoining beams.

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LITERATURE REVIEW

Kumar, Jawala, and Mr Varun Kumar Sikka [1] A study was conducted to examine the fragility and reliability analyses of reinforced concrete (RC) frames with five, seven, and ten stories, designed using various Moment Capacity Ratio (MCR) values ranging from 1.0 to 3.2. These frames were designed in compliance with the provisions of IS 1893 (2002) for all seismic zones. The National Disaster Management Authority (NDMA), Government of India, provided the seismic risk curves corresponding to different seismic zones across the country (Zones II, III, IV, and V). Each proposed building underwent a comprehensive seismic risk assessment. Based on the results, the Reliability Index was calculated and compared against the Target Reliability Index to evaluate the safety performance of the structures. From this analysis, a recommended minimum MCR value was proposed to ensure that RC frames meet the desired reliability criteria across various seismic zones. **Parasa, P. K. [2]** The study examines the effect of increasing the Moment Capacity Ratio (MCR) at beam-column joints on the overall ductility and lateral strength of reinforced concrete structures. The analysis is performed using SAP2000, incorporating a probabilistic approach to account for uncertainties in material properties and to evaluate the influence of ground motion intensity on the likelihood of exceeding predefined damage states.

To achieve this, pushover curves generated through nonlinear static analysis are utilized in the development of fragility curves. These curves help assess the seismic vulnerability of structures designed with varying MCR values. The results indicate that as the MCR increases, the structure demonstrates enhanced ductility. Conversely, buildings constructed with lower MCR values are observed to be more fragile and susceptible to higher damage under seismic loads compared to those with higher MCRs.

Yadav, Abhay, Abhishek Kumar, and Mohd Afaque Khan [3] The study highlights that the moment capacity ratio (MCR) at beam-column joints is a critical parameter in the seismic performance of framed buildings. It emphasizes the significant influence of MCR on the fragility of structures and demonstrates that increasing the MCR enhances the ductility of buildings. The primary objective of this research is to investigate the impact of varying MCR values on the ductility, lateral strength, and probability of failure in multi-story reinforced concrete buildings. The findings underscore the importance of appropriately selecting MCR to improve structural resilience against seismic loads.

Patil, S. L., and S. A. Rasal [4] Recent studies on the behavior of reinforced concrete moment-resisting frame structures during major earthquakes have highlighted the adverse effects of weak beam-column joints. The preferred design philosophy in practice is the “strong-column-weak-beam” (SCWB) approach, which promotes ductile failure mechanisms and enhances seismic resilience. This review focuses on evaluating the adequacy of the beam-to-column moment capacity ratio in buildings subjected to cyclic loading. It has been observed that as this ratio increases, the likelihood of column failure also rises. Additionally, the review examines the impacts of horizontal and vertical irregularities on the structural performance under seismic forces.

Sargar, Ram Arjun, and Jyoti Pushan Bhusari [5] The design of beam-column joints is a critical aspect of reinforced concrete (RC) framed structures. The moment capacity ratio (MCR) at these joints, typically required to be greater than one, governs their seismic behavior. However, the specified MCR values vary significantly across different design codes. According to IS: 13920, the MCR at beam-column joints must be carefully considered to ensure proper seismic performance.

In this study, frames with varying MCR values—achieved primarily by increasing column size and reinforcement to enforce a strong-column-weak-beam behavior—are analyzed using pushover analysis. The effects of MCR on the formation of plastic hinges, base shear, storey drift, ductility, and lateral displacement are investigated, leading to the determination of an optimal MCR. It is found that the MCR should be at least 1.4 to enhance ductility and promote plastic hinge formation at beam ends rather than in columns. Furthermore, increasing the column’s reinforcement is more effective than merely enlarging its dimensions in achieving the desired moment capacity ratio.

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Bindhu, K. R., P. M. Sukumar, and K. P. Jaya [6] The behavior of exterior beam-column joint subassemblies with transverse reinforcements designed according to IS 456 and IS 13920 was compared in this study. An exterior beam-column joint located at an intermediate storey of a six-story RC building in seismic zone III was analyzed and designed, incorporating the latest revisions of IS 1893 and IS 13920 for seismic analysis and design.

Under reverse cyclic loading, four one-third scale specimens were tested: two designed per IS 456 and SP 34, and two designed according to IS 13920. To evaluate the influence of axial load on joint behavior, tests were conducted under two different axial load levels. The results demonstrate that the recent updates in joint design ensure beam failure precedes joint failure, enhancing the overall seismic performance. Furthermore, beam-column joints designed per IS 13920 showed improved performance during cyclic loading reversals.

Choi, Se Woon, et al.[7], The study investigated the optimal column-to-beam strength ratios required to ensure a beam-hinge mechanism using a multi-objective seismic design approach based on nonlinear static analysis. The design process involved minimizing two objective functions—structural weight and column-to-beam strength ratio—while satisfying prescribed constraints. Through numerous Pareto-optimal solutions derived from beam-hinge systems, the study revealed the relationship between structural weight and appropriate strength ratios. Rather than recommending a fixed single value as the limit for the column-to-beam flexural strength ratio, the analysis identified a general trend by examining correlations between ideal strength ratios and structural weights, demonstrated using well-known two-moment resisting frame examples.

Uma, S. R., and A. Meher Prasad [8] worked 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.

Birely, Anna C., Laura N. Lowes, and Dawn E. Lehman [9] Had 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

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Bhandari, Sujan, and Hari Darshan Shrestha [10] studied 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] presented 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. 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.

Ajay Kumar Bhosale, H. S. Jadhav [13] Studied, 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.

Dooley, Kara L., and Joseph M. Bracci [14] Used 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

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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

OBJECTIVE

- To perform preliminary inspection of the building.
- To inspect the existing RCC structure based on NDT.
- To analyze& model the RCC structure in ETABS considering present conditions of building.
- To find actual strength of the building.
- To determine remedial measures for increasing service life of building.

METHODLOGY

Using commercial software ETABS, analytical models of a five-story irregular RC framed structure (plan type) were developed for seismic Zones V, IV, III, and II, in accordance with relevant IS codes. The final flexural capacity of beams was determined based on design specifications. To achieve varying Moment Capacity Ratio (MCR) values at the points of maximum moment and design axial load, the column reinforcement in each model was progressively increased.
Additionally, a separate model of the same RC structure was created in ETABS, incorporating the behavior of both beams and the overall structure beyond the elastic limit. This model was subjected to non-linear static analysis, which offers a more insightful and performance-oriented approach compared to traditional linear methods. The non-linear analysis was carried out individually for each seismic zone (V, IV, III, and II).

The results of the analysis were presented in terms of lateral strength, reinforcement ratio, and global ductility as functions of the MCR. Based on these outcomes, optimal MCR values were identified for each seismic zone to ensure enhanced performance and structural resilience

CONCLUSION

1. To conclude the perform preliminary inspection of the building.
2. Inspect the existing RCC structure based on NDT.
3. Analyze & model the RCC structure in ETABS considering present conditions of building.
4. Find actual strength of the building.

5. Determine remedial measures for increasing service life of building

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