A REVIEW ON EFFECT OF LATERAL TIES IN COLUMN UNDER SEISMIC LOADING

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Abstract - Most of studies on the seismic performance of shear-critical, reinforced concrete columns have only considered how they would react to lateral deformations applied parallel to one of the column faces. These columns' effectiveness as measured by their cracking patterns, shear strengths, effective stiffnesses, deteriorating stiffnesses, and inelastic shear deformations was observed. Based on these experimental findings, a new model was created to predict the range of cyclic force-deformation response, which includes peak strength, loss of axial load carrying capacity, and shear force and associated shear deformation at shear cracking. In this model, the force at the start of critical shear cracking corresponds to the concrete's contribution to shear strength for an intermediate short column. The diagonal fracture plane is assumed to be parallel to the neutral surface, and a spatial truss model with idealized longitudinal, transverse, and diagonal truss components is used to evaluate the transverse reinforcement contribution. The suggested model's applicability for application in the seismic assessment and rehabilitation of existing structures was confirmed by test data from this study and a previous investigation.

***Key Words*:** RC Column, Earthquake, Collapse, Lateral Ties, Buckling, Shear Failure.

1.INTRODUCTION

The vertical load bearing components are called columns, and they can be used as gravity members in RC wall frame constructions or as part of the structure's lateral load resisting system, like in a moment-resisting frame. In any case, the RC columns' capacity to avoid collapse is crucial to the overall integrity of an RC wall or frame construction during an earthquake. This is because the loss of vertical load-carrying capacity of one or more columns may result in the vertical forces being transferred to other load-bearing components, which may ultimately lead to the partial or total collapse of the entire building structure. Therefore, it's essential to understand every possible way an RC column can fail.

2. REVIEW OF LITERATURE

Shamim A. Sheikh and Ching-Chung Yeh (1990) examined "Tied Concrete Columns Under Axial Load And Flexure" Similar to concentric compression, the distribution of longitudinal and lateral steel has a significant impact on how columns respond to axial compression, flexure and load. A greater number of longitudinal bars supported laterally increases ductility and flexural strength. Reduced tie spacing for Higher strength and durability would also arise from the same amount of lateral steel. In the testing, flexural capacity owing to confinement was found to be 26%. Despite being successful at containing the concrete at small deformations, unsupported longitudinal bars tend to buckle and drive the ties outward at significant deformations. The outcomes of this study highlighted the necessity for to connect the needed amount of steel, unsupported bars, and a 90° angle which relates to the axial load intensity and anticipated column performance.

M. Rodriguez and R. Park (1992) investigated "Seismic Load Tests on RC columns Strengthened by Jacketing", The study was examined reinforced concrete columns built in New Zealand in the 1950s and designed to early seismic regulations, revealed that these columns have relatively low available ductility. It was discovered

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that these column units had accessible displacement ductility factors of about during quasi-static cyclic lateral loading experiments that mimicked seismic stress. The two as-built column units that had previously been tested and were damaged were modified with reinforced concrete jackets. Before the jackets were installed, the surface of the columns had been mildly roughened by chipping. According to the investigation's findings, typical reinforced concrete columns built in accordance with early seismic regulations have dramatically increased stiffness, strength, and ductility when jacketed with fresh reinforced concrete. But as the inquiry revealed, this retrofitting method requires a lot of labor.

Koji Yoshimura et al (2004) investigated "Experimental Study on the Effects of Height of Column under Lateral Forces, Column Reinforcements, and Wall Reinforcements on Seismic Behavior of Confined Masonry Wall" was researched. The study was conducted to investigate the seismic performance of the confined concrete hollow block masonry walls considering the parameters such as height of inflection point, shear span ratio, tensile reinforcement ratio, horizontal wall reinforcement ratios and vertical axial stress. The following results were reached based on test observations and data analysis. While it is obvious that the wall reinforcements contribute to the final lateral shear strength of the walls, the impact of varied amounts of horizontal wall reinforcement on the ultimate shear stress.

Uma S.R. and Meher Prasad. A (2004) investigated the "Seismic Evaluation of RC Moment Resisting Framed Structures Considering Joint Flexibility" on the insufficient performance of the inadequately planned and detailed structure in seismic conditions. In the modeling of beam column joints, special focus is placed on capturing the shear effects within the panel zone and all other significant factors thought to contribute to non-ductility. IDARCFJ (Inelastic damage analysis for reinforced concrete frame with flexible joints) h, a computer tool for inelastic dynamic analysis. The effective comparison of analytical results with reported experimental behavior serves as an illustration of the joint shear model's validity as well as the formulations that are suggested. Joint failures have a major impact on essential reactions such inter-story drift and total displacements. The potential for joint failures in framed structures that are described and planned in accordance with the code is highlighted, and its impact on the overall responses is demonstrated.

Durgesh C. Rai et al. (2006) investigated "Behavior of Seismic and Non seismic RC Frames under Seismic Loading" that one-third scale models of a one-bay, single-story space frame were subjected to cyclic lateral loading in order to examine the impact of seismic details on the hysteretic behavior of RC frames. No discernible changes in the hysteretic behavior of models with seismic (IS 3920: 1993) and non-seismic (IS 456: 2000) features were found because beams and columns' premature joint failure prevented them from reaching their full flexural capacities. As a result of extensive cracking at the intersections of the column and footing and the beam-column joints, the test frames eventually evolved a side sway collapse mechanism. Lateral ties in seismic frame joints postponed cracking and strength deterioration but were unable to stop joint shear failure. Deep columns and beam stubs are two ways to get the yield mechanisms you want. Despite the unfavorable yield mechanism, both models exhibited consistent hysteretic behavior up until displacements reached a 5 percent drift ratio. severe pinching of the hysteretic loops was observed during large displacement cycles.

Y. L. Mo and S. J. Wang (2007) proposed research on "Seismic Behaviour of RC Columns under Various Tie Configuration. Tests are used to evaluate the new transverse reinforcement configuration's seismic performance. According to the experimental findings, the innovative transverse reinforcement structure with alternate ties offers seismic performance that is on par with or better than that of traditional arrangements often utilized in building. Finally, it is established that the suggested configuration complies with the current ACI criteria for compression lap splices.

Haroon Rasheed Tamboli and Umesh N. Karadi et al. (2012) studied several kinds of reinforced concrete (RC) frame building models, including blank frame, infilled frame, and wide open initial story frame, seismic analysis was carried out using the Equivalent Lateral Force Method. The Equivalent Diagonal Strut method was used to model the brick Infill panels, and the software ETABS was used to evaluate every frame model. The wide open first story frame should not be used in seismic regions since the story drift is much larger than the upper stories and might potentially cause the building to collapse. Instead, filled frames should be used. The infill Wall increases the framework's strength and rigidity. The base shear was underestimated as a result of the seismic study of the RC structure. Different response numbers such as time interval, natural frequency, and story drift were therefore not significant. Underestimating base shear could cause a structure to collapse during an earthquake's shaking.

Shafqat A and Ali A (2012) studied the "Lateral Confinement of Short Column". From the study, the following findings can be taken. In comparison to the other columns, the control column (CSB1) shown less deformability. The concrete core unexpectedly crushed at cl = 1.15% after peak load, with longitudinal bars bowing outward. For a 2mm x 36mm restricting strip with substantial strength Pu = 716.13 kN and ductile behavior cl = 12.4%, a significant improvement has been noted. In comparison to the control column, the axial capacity of the column confined with 2 mm steel strips was roughly 78% higher, whereas the capacity of the column contained with 1.2 mm steel strips was only 15.8% higher. The capacity of CSP2 is lower than that of CSP1 because the 1.2 x 60 mm confining strips employed in CSP2 were unable to resist the bulging of concrete core due to inadequate stiffness. It is greater than CSB1, though. The deformability (toughness) of concrete-tied columns can be increased by substituting steel plates of an equivalent area for the circular tie bars. The configuration and geometry of lateral confinement may have an impact on the peak strength and the corresponding strain of confined concrete.

Selwyn Babu and Mahendran. N (2013) investigated "Design Criteria for Reinforced Concrete Columns Under Seismic Loading". The minimal eccentricity specified in IS 456 - 2000 is exceeded even in the mild seismic Zone (i.e., Zone 2). This is evident from the e/D ratios. When the span is expanded, it is discovered that the e/D ratio falls. Additionally, it is discovered that the e/D ratio rises from the bottom to the top story. Additionally, it is discovered that the e/D ratio rises with the zone number. Equations have been created to determine the internal columns of multistory building frames with the least amount of eccentricity. The design criterion for the seismic design of internal columns in multistory building frames can be this minimum eccentricity**.**

Ahmed M. El-Kholy and Hany A. Dahish (2015) investigated "Improved confinement of reinforced concrete columns". For square short RC columns with slenderness ratios of k = 7.33 and 14, with EMM layer is compared to specimens restricted with only ties, RC column specimens with ties and an EMM layer show higher plastic deformation and more ductile behavior. By warping extra EMM layers and utilizing EMM with better mechanical properties, higher ultimate load capacity, better ductile behavior, greater reduction in the ties volumetric ratio, and larger energy dissipation can be accomplished. To determine the viability of the suggested lateral reinforcement utilizing various mesh types for both short and long RC columns under various types of loads and environmental conditions, an extensive experimental program is needed.

Dogan .G and M. H. Arslan (2016) examined "Failure Modes of RC Columns under Loading". A building completely collapses if an RC column fails. If a column (and structure) lacks adequate transverse steel, any form of failure can happen. According to experimental research, the material quality in a damaged RC column is quite poor and insufficient. A building stock inventory should be created, especially in seismic regions, and both immediate and long-term solutions should be developed for low-quality structures. In seismic region as Turkey, an effective control mechanism should be built at any stage of concrete manufacturing. In conclusion, thousands of RC structures that are already in existence have a non-ductile nature. If these structures are not immediately retrofitted or strengthened, many lives will be lost in a future big earthquake**.**

Zeng et al (2016) developed a finite element model to assess the performance of stirrup-equipped concrete columns. The stress strain relationship generated by the FEM analysis was used to study the confinement effect of stirrups. In addition to simulating the behavior of concrete confined by stirrups, the proposed uniaxial compressive stress-strain relation and the concrete damage model with plasticity could be used to examine the behavior of squarely confined RC members under various types of loads.

Pathan Irfan Khan and N.R.Dhamge (2016) conducted research on "Seismic Analysis of Multi-Story RCC Building due to Mass Irregularities." It displays the seismic analysis of RCC structures with various irregularities, including vertical geometry irregularity, mass irregularity, and stiffness irregularity. Every time a building has a unique irregularity, it is important to analyze the building in various earthquake prone areas. It is evident from numerous earlier studies that shear walls, base isolation, and other measures can be taken to reduce the impact of earthquakes on structures. As the percentage of irregularity increases, the building's lateral displacement decreases. As the amount of vertical irregularity rises, the story drift decreases and continues within the parameters set forth in IS 1893-2002 (Part I), clause no. 7.11.1. It was discovered that foundation shear occurs more frequently in mass uneven building frames.

Bayrak and Sheikh (2018) examined "The Ductile Design of HSRC and UHSRC columns after comparing the seismic performance of HSRC and ultra-high strength RC (UHSRC) columns with NSRC columns". They concluded that when a column with 102 MPa concrete compressive strength was given 70% more confinement reinforcement than the ACI code criteria (ACI 318-95), it behaved ductility. It was advised to include the axial load ratio in the design expressions for confinement reinforcement because as the axial load ratio increased, the column's displacement capacity dramatically decreased and the deterioration of its strength and stiffness was increased.

Sohail Shaikh and Shilpa Kawate (2018) investigated "Behavior of Concrete Encased Columns in Irregular Buildings under Seismic Conditions". The study concludes that employing concrete-encased columns reduces base shear by 10–14%. Because of this, there has been a 43% area decrease in mass irregularity and a 51% area reduction in stiffness irregularity. Additionally, some of the tale displacement responses attained as a result of this sort of column are marginally higher than those attained by standard RC columns, although they are still within acceptable bounds. This is a result of the concrete-encased columns' ductility. Because of the structure's increased flexibility, concrete-encased columns have longer service lives than traditional RC columns. As a result of the findings, it is possible to draw the conclusion that concrete-encased columns are preferable for stiffness irregularity buildings due to their high stiffness property, which allows the building to withstand it more effectively.

Nojavan A et al (2018) investigated "Effect of Lateral Loading Protocols on Seismic Performance of RC Column". According to the study, column specimen SP5 suffered more extensive damage despite having a comparable loading regimen to that of SP2 and being subjected to a higher axial load ratio. In addition, the ultimate monotonic push displacement that was used after several cycle displacement reversals caused the specimens strength to decline quickly and their damage to be more extensive than it would have been in the event of pure cyclic or monotonic displacements. The Park and Ang damage model was the only one that could accurately predict the greater extent of damage in specimen because it can directly account for the effects of biaxial loading under the condition that the calculated energy dissipation takes into account both directions. It also showed the best correlation with observed damage during each test.

Ehsan Noroozieh et.al (2019) investigated "Finite Element Modelling on the combined use of NSM rebars and FRP jackets in strengthening RC columns". A thorough parametric study was conducted to ascertain the influence of axial load, FRP confinement implementation around the base or over the entire height of the column, the number of plies of FRP jacket, the type of jacket fiber, the ratio of NSM reinforcement, and the compressive strength of the concrete on the behavior of the strengthened RC columns after the numerical models had been validated using the available experimental data. The findings demonstrate that by setting the maximum compressive strain in the confined concrete is possible to identify the ideal number of jacket plies for achieving a certain amount of ductility. When NSM reinforcement was increased from 0.16% of the total cross-sectional area to 1%, the lateral strength increased by around 28% and the ductility factor dropped by about 50%.

Saim Raza et al (2020) investigated "Collapse Behavior of Limited Ductile High Strength RC Columns under Multidirectional Earthquake Actions". The findings of the numerical analysis underwent rigorous statistical processing, which revealed that the RC columns' actual displacement route during seismic excitations takes the shape of elliptical loops with various aspect ratios and orientations. Considering this, in 208 the octo-elliptical path, a bidirectional lateral loading protocol, was proposed. This protocol generalized the displacement path of the columns under multidirectional seismic excitations. The experimental work showed that the collapse drift capacity of limited ductile HSRC columns is significantly affected by the axial load ratio. As a result, under unidirectional lateral stress, tripling the axial load ratio to 0.45 lowered the drift capacity by about 75%, while doubling it from 0.15 to 0.3 reduced it by around 35%. This shows that axial load ratio increases under bidirectional lateral loading have a more dramatic impact on diminishing the column's drift capacity than they do under unidirectional lateral loading.

Eyitayo A et al (2021) investigated "Influence of Biaxial Lateral Loading on Seismic Response of Reinforced Concrete Columns". The contribution of biaxial lateral demand on stiffness degradation is not as important as the influence of biaxial lateral demand on strength and deformation capacity, according to the currently available experimental dataset. For columns subjected to biaxial lateral loads, stiffness degradation models created for uniaxial lateral demands may be applied. To further validate this finding, however, further test data are required. The identification of biaxial displacement routes on RC columns as well as the evaluation of analogous coupling factors and trajectory lengths expected in seismic events should be done using 3-D modeling of prototype multi-story RC buildings that have been subjected to a variety of ground motion records.

Mehtab Alam et al (2022) investigated "Critical Analysis and Blast performance of the Columns with Seismic Reinforcements and with new diagonal reinforcements". The findings demonstrate that by minimizing damage and displacement, the introduction of cross-diagonal reinforcements in place of seismic reinforcements greatly improves the blast resistance of the reinforced concrete column. To improve the response of the axially loaded square RC columns subjected to 82 kg-TNT equivalent close-in explosion loading, the present research work considers seismic reinforcement over the confining regions, over the confining regions as well as mid-height, and over the entire length of the column. The addition of seismic confining lateral reinforcements enhances the column's deflection response, but it has little effect on preventing damage (concrete crushing/cracking) caused by severe explosion loads. The seismic reinforcements are replaced with cross-diagonal reinforcements, which considerably improves the column's blast performance. Among the seismic reinforcements in the square column, a cross-diagonal reinforcement with a larger diameter (10 mm) is determined to be the most effective at preventing concrete crushing and cracking.

Tae-Hee Lee et al (2022) investigated "Experimental Seismic Structural Performance Evaluations of RC Columns Strengthened by Stiff-Type Polyurea". The residual defection at the load point of the rectangular and circular PU- and STPU-strengthened specimens fell by 53.7% and 60.1% and 50.7% and 60.5%, respectively, from the pseudo-dynamic test compared to the non-strengthened specimen. Due to the continuous confinement effect caused by the circular cross-sectional shape, the STPU-strengthened circular column showed the optimum strengthening performance as anticipated. Additionally, the test findings demonstrated that under seismic loading, the reinforced specimens had higher rigidity than the non-strengthened specimens. The fact that the PU and STPU-strengthened RC column specimens had less rebar strain than the non-strengthened specimens implies that these materials are efficient strengthening agents.

Govind Rawat and Mohit Kumar Prajapati (2023) investigated "Effect of Lateral Reinforcement on Strength and Ductility of Reinforced Concrete Column". The inferences of the study were proposed that Reinforced concrete column ability to support lateral loads is solely dependent on the longitudinal bars incorporated into the concrete. Transverse reinforcement must be added at vulnerable points, such as joints, where heavy tensile and flexural bending could cause failure.

3. LITERATURE SUMMARY

1. Lateral ties in seismic frame joints postponed cracking and strength deterioration but were unable to stop joint shear failure.

2. Concrete spalling on column faces must be avoided, and the anchorage effectiveness of beam bars for such knee joints must be improved.

3. The vertical axial load has a beneficial impact on the value of the ultimate shear stress of the specimens, regardless of the height of the point of application of lateral forces to the specimens, or whether the inflection point is low or high.

4. Lateral ties in seismic frame joints postponed cracking and strength deterioration but were unable to stop joint shear failure.

5. Because drift rate is crucial for a structure's stability, designers take precautions to minimize the P-effect and

substantial structural system displacement. This phenomenon must be avoided by using an RC Shear wall.

6. Vertical structural element discontinuity are essential because it prevents structural failure or damage.

7. Lack of lateral reinforcements contributes to shear and torsion failure, the most brittle modes of failure for RC columns. Deterioration of the concrete core may result in loss of the column's ability to support axial loads as shear failure progresses.

8. As the column's axial capacity decreases, the gravity loads it supports must be distributed to nearby elements. Rapid axial capacity loss will cause the building frame to dynamically redistribute internal actions, which may eventually cause collapse.

9. It is also noted that certain of the story displacement responses obtained as a result of this sort of column are marginally higher than those of typical RC columns, although they are still within allowable limits. This is a result of the concrete-encased columns' ductility.

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