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Seismic Analysis of C-Shaped Building with Varying Bay Length: A Review

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Abstract- This study looks at four instances of G+10 story C-shaped buildings. By considering the distinctive irregularities, engineers can design structures that satisfy performance requirements and make efficient use of materials. In order to distinguish the other three structures from the base model, we looked at the same building with varying bay lengths. The base model's bay length is 27 meters, while the second model's bay length is roughly 33 meters, structure III's bay length is 39 meters and 4th models bay length is 45 meters. In this study, an irregularly shaped building model will be analyzed and designed using STAAD.Pro. Shear force, bending moment, and storey drift etc. are just a few of the parameters that will be used to compare the results with simplified analysis methods in order to illustrate the advantages of using STAAD.Pro for irregular building design.

Index Terms- Irregular C-shaped Buildings, Storey Drift, Bending Moment, Shear Force, Earthquake Analysis, STAAD.Pro.

I. INTRODUCTION

The architectural landscape is changing, with buildings eschewing their rectangular exteriors in favor of strong, asymmetrical designs. These unorthodox designs pose a challenge for structural engineers even though they have potential practical benefits and aesthetic appeal. In a typical rectangular building, the load flow is predictable; however, irregular geometries cause this flow to be disrupted, which results in uneven stress distributions throughout the structure. The use of more advanced tools must replace conventional analysis techniques in order to ensure the stability and safety of these non-traditional buildings.

II. LITERATURE REVIEW

B S Shamana et al (2024), This study examines how various structures that have seismic-resistant components perform. This paper presents the incorporation of shear walls and bracings to create a moment-resistant frame for the structure. Using Response Spectrum Analysis's ETABS 2019 software, a comparative seismic analysis of high-rise buildings with and without shear walls and bracings is covered in this discussion. Natural frequency, natural time period, base shear, story stiffness, story displacement, and story drift are the parameters taken into account for the analysis. when building the two.

The story displacement was determined to be minimum in shear walls and maximum in braced and bare frame structures based on the findings of the dynamic analysis. Additionally, because bracing provides stability to the structures, story forces were decreased for those structures. Models with bracing and a shear wall showed less displacement than the bare frame models. When compared to the bare frame model, the models with shear walls and bracing showed a notable improvement in the stiffness of the building. Additionally, it was noted that the application of shear walls and bracing significantly decreased story drift. It was found that shear walls had a greater percentage reduction in story drift. When the structure becomes more stable against the lateral load, the base shear of the structure is found to increase.[1]

Denise Penelope N. Kontoni et al (2024), Using tuned mass damper (TMD) systems, a T-shape in a plan steel HRB subjected to four different earthquakes will be studied in this study in order to determine the most controlling arrangement of TMDs in both the fixed base HRB model and the SSI HRB model. This will help to mitigate vibration and control displacements and base straining actions resulting from earthquakes. The seismic mitigation effect of six different plan arrangements of TMDs applied on the top plan of the fixed HRB model, as well as these TMDs distributions applied on two intermediate plans along the HRB height for the SSI HRB model, was investigated using three-dimensional models of the steel high-rise building (HRB) with a T-shape in the plan subjected to four different earthquakes.

It is observed that the seismic response in the fixed and SSI models is effectively controlled by the TMDs for the T-shape in the plan steel HRB. The TMD distributions on the top plan of the fixed model effectively control the seismic response of

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the steel HRB model, resulting in a reduction of lateral displacements and base straining actions. In the SSI model as opposed to the fixed base model, the TMDs for the T-shape in the plan steel HRB are more effective.[2]

Chao-Qun Yu et al (2023), The L-shaped multi-cellular CFST (LM-CFST) frame, which consists of H-shaped steel beams and LM-CFST columns, was proposed in this paper. First, tests were conducted using a combination of axial compression and cyclic lateral loads on four LM-CFST frames. Both the top and bottom ends of the column showed signs of local buckling, and when the drift ratio was high, steel fractured. The spindle-shaped hysteresis curves had ductility indexes ranging from 2.61 to 3.24. Subsequently, an improved finite element model was created and verified by comparing it with the test outcomes. The impact of the axial compression ratio, web cell length, concrete strength, and steel tube thickness on the seismic performance of LM-CFST frames was investigated using a parametric analysis.

It was discovered that while concrete strength had minimal bearing on the seismic performance of LM-CFST frames, the axial compression ratio could have a considerable impact. Lastly, a comparison was made between the compression-bending capacities acquired through the sectional analysis method outlined in EC4 and those obtained through testing. It was discovered that with reasonable discrepancies, this method could predict the compression-bending capacity of the LM-CFST frame under combined axial compression and cyclic lateral loads.[3]

Sahraoui Ghoul et al (2023), The nonlinear behavior of L-shaped shear walls made of reinforced concrete under seismic loading is the focus of this study. There isn't a lot of numerical modeling available for these walls' seismic performance, despite their widespread use. Furthermore, this kind of shear wall is not mentioned in the Algerian seismic design code RPA99. The accuracy of a finite-element model is verified through experimental testing results, demonstrating a strong correlation between the two. In order to evaluate the dependability and confirm the failure patterns of the damage mechanism, a numerical parametric analysis of the L-shaped reinforced concrete walls constructed in accordance with Algerian seismic design codes was conducted in the second section.

According to the numerical modeling results, the L-shaped shear wall is demonstrated to meet the objective in a practical and reliable manner, especially when it comes to accurately assessing the failure conditions, bearing capacity, and damage as well as predicting the nonlinear behavior of reinforced concrete shear walls. In order to prevent diagonal stresses, radial and diagonal reinforcements are used to reduce shear force and offer stress-reducing support.[4]

Ayush Pathak et al (2021), In this study, a G+16 structure with a variety of plan configurations, including L, T, and I shapes in addition to rectangular shapes, is modeled using Staad.Pro. The seismic performance of the structure is then examined in two different seismic zones III using medium and soft Indian soil. This study compares the story-wise displacement, base reaction, axial and shear force etc of RC multistory building framed structure.

It is clear that as soil conditions improve, less displacement occurs. This is indicated by the minimum displacement in medium soil conditions and the maximum displacement in higher soil conditions. The I shape model yields the minimum displacement, the L shape model yields the average displacement, the T shape yields the maximum displacement, and the rectangular shape model yields the maximum displacement when comparing the displacement by plan configuration overall. This suggests that the earthquake effect is also influenced by the plan configuration of the structures.[5]

is asymmetrically reduced by 35%. For 15-floored structure, average range is 18% lower than that of the standard building, and it is 36% lower asymmetrically. Upon comparing all the cases, In summary, regular buildings show maximum story shear, while asymmetrical buildings have maximum displacement and drift values.[7]

Siva Naveen E et al (2019), This research investigates the seismic behavior of RC structures with varying levels of irregularity. A ten-floored regular structure was modified or retrofitted to create the 34 single ire ,gularity structure and 20 structures with multiple irregularities by introducing irregularities in both plan and elevation. A comparative analysis of the regular frame and these 54 irregular configurations was conducted. To calculate the results of response spectrum, the earthquake loading was applied.

It has been observed that irregularity affects the seismic response significantly. Stiffness irregularity is the type of single irregularity that has the greatest impact on response out of all those that have been studied. Among the configurations with multiple irregularities, the structure exhibiting stiffness, mass, and vertical geometric irregularities demonstrated the most pronounced seismic response. The findings of this study can contribute to the informed design of non-uniform structures without sacrificing their functionality.[8]

Tejas Gorle et al (2018), This study investigates the seismic performance of an eight-story reinforced concrete residential building across seismic zones II to V using STAAD.PRO V8i software. The foremost aim of the research was to determine the deformations and forces resulting from seismic loads. The analysis focuses on key response parameters including story drift, joint displacement, member forces, and support

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reactions. Seismic forces such as base shear, axial load, moments in columns, and shear and bending moments in beams were considered.

All models demonstrate that the displacement values rise with increasing zones and fall with decreasing zones, based on the observations. Compared to the traditional concrete design, the earthquake-resistant design of the G+8 RC framed building used more steel in each zones. More steel was used in the building of the structure from the ground floor to the G+8 level.[9]

Shehata E. Abdel Raheem et al (2018), This study gradually reduces the plan reference of six structural model of L-shaped building models. In order to facilitate comprehension of the structural seismic behavior requirements for the L-shaped strcuture (building) class, this study looks at the effects of plan configurations irregularities of re-entrant corner and lateral-torsion coupling on measured seismic response demands. Story drift, story shear, inter-story drift, overturning moment and torsion moment at building height and base, and irregularity ratio for torsion are a few of the measured responses.

Research indicates that buildings with irregular configurations are more susceptible to stress concentration and lateral torsional coupling compared to their regular counterparts. Additionally, the vertical resisting elements situated at the corners of L-shaped buildings may experience significantly higher lateral shear forces than those observed in symmetric structures.[10]

Chetan P. Agrawal et al (2018), Examining the structural behavior of multi-story buildings with different plan configurations such as rectangular, L-shaped, and C-shaped buildings in accordance with the seismic regulations suggested by IS: 1893-2002 is the aim of this project. ETABS 9.7.1 version is used to model the G+10 storey 11 floor Reinforced concrete framed building using Dynamic (Time History Analysis) a nonlinear analysis method. These analyses are conducted considering the discrete seismic zones IV and V, and the behavior is assessed with medium soil. Following the structure's post-analysis, various responses including lateral force, displacement, overturning moment, drift, share at the base of the structure, and design outcomes are also calculated and compared for every scenario.

It is observed that every story drift in each story stays within reasonable bounds. The least amount of story drift occurs in regular buildings as opposed to those with irregular shapes. Story shear always decreases with increasing story height. The maximum displacement of stories, maximum drift of stories, maximum shear of stories, and maximum overturning moment increase in both directions when the seismic zone for a building with the same frame type shifts from IV to V. Regularly shaped buildings should be chosen because irregularly designed buildings are more prone to deform. The story displacement grows linearly from bottom to top for all structures, with irregular structures experiencing a larger displacement. In every instance, when the story height increases, the story overturning moment decreases.[11]

Ravindra N. Shelke et al (2017), The main objective of the project is to perform RSA of vertically irregular RC buildings. The results of The design and analysis of non-standard structures were compared with regular structures. We considered three different types of irregularities: mass, stiffness, and vertical geometry irregularities. It was discovered that the mass irregular structures' base shear was higher than that of similar regular structures. There are greater inter-story drifts and less base shear in the stiffness irregular structure.

The results showed that, for higher stories, the absolute displacements from the geometry irregular structure's time history analysis at each node were larger than those from the regular structure; on the other hand, as we lowered the stories, Over time, the displacements in the two structures tended to converge. Higher displacements of upper stories are caused by lower stiffness.[12]

Pushkar Rathod (2017), Seismic analysis for all types of structures must be carefully considered when operating in high earthquake-prone areas. The structure can be planned and built to withstand the significant lateral movement of the earth's crust during an earthquake by using seismic analysis. Any type of structure, regardless of complexity or simplicity, can be assessed using ETABS in both static and dynamic scenarios. Because it is a unified and efficient tool for analysis and designs ranging from simple 2D frames to modern high-rises, ETABS is one of the best structural software packages for building systems.

Since asymmetrical plans have been shown to deform more than symmetrical plans, building a new structure in a high seismic zone is likely to require building a symmetric structure in order to improve stability. Storey shear is inversely correlated with the number of storeys. Storey stiffness increases with storey height. But only the sixth floor is resolved in this case. The shear stiffness value is maximum for all shapes. After the sixth floor, though, the stiffness keeps getting less.[13]

Manish A Kewalramani et al (2017), This study aims to comprehensively examine the torsional behavior of both symmetrical and asymmetrical building structures. While accidental eccentricity causing mass and stiffness center misalignment induces torsion in symmetrical buildings, asymmetrical structures inherently exhibit torsion due to irregular mass and stiffness distribution. This inherent torsion

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significantly impacts the seismic vulnerability of asymmetrical buildings.

Because of the insufficient and asymmetric placement of its shear walls, the square-shaped building exhibited the greatest inter-story drift, clearly illustrating the dependence of the structure's stiffness and mass concentration on it. Shear walls in other plan configurations, on the other hand, are both more symmetrical and adequate than those in the square-shaped building. The location of shear walls influences a building's lateral storey drift and displacement during seismic activity. The optimal shear wall location for reducing lateral storey displacement and drift was offered by the L and T plan configurations.[14]

Jereen Ann Thomas et al (2017), This research is based on a asymmetrical Structure (buildings) examines the impact of a diaphragm of a structure on a building's performance while the earthquake will executes. Multi-story buildings are susceptible to lateral loads from wind or earthquakes, which is why seismic studies are necessary. It's crucial to comprehend how structural diaphragms function because there are many different approaches to building design that reduce these lateral loads. The impact of plan configuration on torsional buckling, displacement, base shear, and storey drift has been shown in numerous studies. The maximum displacement of the structure caused by an seismic load depends on the lateral stiffness of the building frame.

It was clear that changes in the structure's plan configurations affect the displacement along with the drift of storey's. The Swastika shape configuration fared well when compare other considered model. It is evident that the diaphragm effect affects the structure's behavior in addition to plan configuration. Semi-rigid diaphragms need to be taken into consideration when evaluating structures with irregular plans.[15]

Sanjay Kumar Sadh et al (2016), This study looks at how two aspect ratios the horizontal or plan aspect ratio (L/B ratio), where L is the building frame's length, B is its base width, and H is its total height affect the seismic analysis of multistory regular R.C.C. buildings. This study has considered 4-Structural models with different vertical aspect ratios of 1, 4, 6, and 8 of varying 4, 16, 24, and 32 storeys, and different horizontal aspect ratios of 1, 4, 6, and 8 of varying lengths from 12 to 96 meters. Their influence on the behavior of the RCC multistory structure is classified with the help of the IS-1893-2002-Part-1 seismic zone-3 design parameters.

The square configuration with a horizontal and vertical aspect ratio of 1 performs among the best seismically, according to the previously mentioned seismic parameters. The square configuration would be the ideal choice for plan configuration as a result of these findings.[16]

Mohaiminul Haque et al (2016), this experiment aims to perform both static and dynamic analysis, that is, equivalent static analysis, response spectrum analysis (RSA), and time history analysis (THA), over a variety of regular and irregularly shaped reinforced building frames. This is based on the seismic parameters mentioned above, the square configuration with an aspect ratio of 1 (horizontal and vertical), and perform in accordance with the Bangladesh National Building Code (BNBC)-2006. In this article, 4, G+9 buildings which are designed as per the specifications of Bangladesh (Zone III) are analyzed using SAP 2000 v14.0.0 and ETABS v9.7.1. A comparative study has been carried out between the dynamic response spectrum and the maximum displacement resulting from static loading in different shaped buildings.

The findings stated that, for all models in the analysis of static loads, the effects of the earthquake or seismic force were almost the same, except 1st model (W-shaped). The W-shape is the form most vulnerable to an earthquake load case. Building frames with irregular shapes have larger displacements than building frames with regular shapes, according to the response spectrum analysis. Overall, it is discovered that regular structures outperform irregular ones.[17]

Anirudh Gottala et al (2015), this observation discusses the impact of earthquakes, one of the most important dynamic loads, and how it should be considered when analyzing a structure. For the study, a structural model of G+ 9 (10-storied) structure is modeled and designed. This model is subjected earthquake or seismic analysis and static (Seismic Coefficient Method) approaches, in accordance with IS-1893-2002-Part-1. Nodal Displacements, Bending moment, and Mode shapes are used to observe, compare, and summarize the results for Beams, Columns, and the Structure as a whole during the static and dynamic analysis.

The results show that the Moments values for the Static and Dynamic analyses are 35–45% higher, respectively. There is no discernible difference between the values of the axial forces found by the static and dynamic analyses of the RCC Structure. The column torsion values are positive for dynamic analysis and negative for static analysis.[18]

Arvindreddy et al (2015), This paper carries out an analytical investigation to find out how different regular and irregular structures located in severe earthquake zone V respond. A fifteen-story building has been subjected to both dynamic and static analysis using ETABS 2013 and IS code 1893-2002 (part 1). comparable in terms of lines Static analysis applies to regular buildings up to 90 meters in height in zones I and II; dynamic analysis will be applied to irregular and regular buildings in zones IV and V. Two types of dynamic analysis

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are the linear Response Spectrum Analysis and the dynamic Time History Analysis.

The results of the static analysis method show lower storey displacement values than those of the response spectrum analysis. The nonlinear force distribution could be the cause of this variation. Both the static and RSA methods showed that storey displacement and storey drift were less in diaphragm irregularity than in regular structures. Unlike all other structures, stiffness irregularity exhibits nonlinear behavior early on, as demonstrated by the pushover curve. Because of this, earthquakes accentuate the structure's stiffness and irregularity.[19]

Dileshwar Rana et al (2015), this research is related to seismic effect and performace of reinforced framed, comparing regular and vertically irregular configurations. Five building geometries were analyzed, including one regular frame and four irregular variations. Using Staad.Pro V8i software, the structures were modeled and assessed for the seismic effect for shear, bending, and drift. Adhering to IS 1893:2002 for seismic zone IV and medium soil conditions, the study revealed variations in seismic response across different building heights.

It is determined that as setback increases, so does the critical shear force. Compared to irregular setback frames, regular building frames have a much lower shear force. For all building heights, the critical bending moment of irregular frames is greater than that of regular frames. This is because, the fact that setbacks have made building frames less rigid. For irregular frames, therefore, extra reinforcement is needed.[20]

Mr. S.Mahesh et al (2014), this research investigated the seismic and wind load performance of both regular as well as irregular eleven-story residential buildings. By employing STAAD PRO V8i and ETABS software and assuming linear material behavior, the study analyzes the structural response under combined seismic and wind loads. To assess the influence of soil conditions, all three types of soil were considered across various seismic zones. The analysis includes plotting key response parameters such as drift, base shear, bending, and displacement for different soil and seismic zone combinations.

Compared to the irregular configuration, the regular configuration has a higher story drift value. because the structure is more substantial. Ultimately, the software STAAD PROV8i is worth more than the other. 5–10% of the area is made up of steel. Story 12's asymmetrical arrangement has a higher story drift value. Story 13 has a greater story drift value in the standard configuration.[21]

Rucha S. Banginwar et al (2012), Since RSM's analysis of the plan configurations provides important information for real-world application, more emphasis is given to it in this paper. This proposed work's study looks at how various geometrical arrangements affect how the previously constructed building in the same location behaves structurally during earthquakes. The results showed that only building number three had torsion, as that building had the highest degree of irregularity. The structure is symmetrical about ONE axis, despite having an oblique block orientation. Building No. 1 displayed the least displacement, while Building No. 3 displayed the largest. It suggests that severely irregularly constructed buildings exhibit the maximum displacement and storey drift. The planning of a structure has an impact on the displacement, story drift, and story shear that occur during an earthquake.[22]

III. CONCLUSION

In this paper we reviewed several authors who have conducted researches regarding irregular shaped buildings

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