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A Study To Evaluate The Performance Of Multi-Storeyed Buildings Reinforced Concrete Structures Under Seismic Loading

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Both symmetric and asymmetrical building types are prevalent in both urban and rural regions these days. This is because of the growing population, the skyrocketing cost of land, and the issue of land shortage. Many constructions cannot be symmetrical or regular in size, form, rigidity, etc. for a variety of reasons, including but not limited to: site circumstances, barriers, operating demands, and countless more. In order to fulfill all of the codal requirements, a building with an asymmetrical or otherwise irregular layout might be planned or built. In contrast to regular and symmetrical layouts, asymmetrical constructions will behave and perform poorly. Although it is generally recommended that designers and contractors steer clear of asymmetrical and irregular designs, there are a number of reasons why design and structural component irregularities may be impossible to eradicate. The purpose of this article is twofold: first, to compare the seismic performance of regular and irregular buildings in plan, and second, to provide a way to mitigate the effects of seismic load on asymmetrical structures. In order to conduct analyses, Etabs software takes into account square, L-shaped, and T-shaped G+10-story building models.

Keywords: Seismic, Symmetric, Buildings, Reinforced concrete, Storey displacement

I. INTRODUCTION

A multi-story structure is a realistic answer to the problems of housing, commerce, and industry brought about by the fast expansion of cities and the resulting increase in population density. For these types of buildings, reinforced concrete (RC) constructions are now the go-to because of their adaptability, longevity, and affordability. It is nevertheless very important to ensure that these buildings can withstand seismic activity without compromising their safety or function. Structures are subject to dynamic loads during earthquakes, which may cause significant damage or even collapse if these forces are not properly accounted for during design and construction. Earthquakes are defined by the abrupt release of energy that causes ground shaking. Achieving a balance between strength, flexibility, and energy dissipation is the goal of seismic resistance design for RC structures, which requires combining concepts of structural dynamics, material science, and engineering mechanics. Seismic loads, in contrast to static ones, are dynamic and can change in period, frequency, and intensity. Vibrations, torsional effects, and resonance are some of the complicated reactions that result from the interplay between the inertia forces induced by these loads and the mass and stiffness of the building. Because of their height, mass distribution, and structural stiffness across floors, multi-story structures are especially vulnerable to seismic forces. Many elements, such as the design, materials, details, and interaction between soil and structure, determine how well these structures hold up during seismic loads.

The design philosophy of RC structures has changed considerably throughout the years, and this has a major impact on how these structures behave during seismic events. Structures are constructed to satisfy specified performance targets under varying degrees of seismic intensity, according to modern building regulations and standards that stress performance-based design. Among these goals is the assurance of quick occupation following small earthquakes, the mitigation of damage in moderate earthquakes, and the prevention of collapse in severe earthquakes. Accomplishing these objectives calls for expert knowledge of seismic risks, structural behavior, and state-of-the-art computational and analytical resources. Making sure the RC structure is ductile is one of the first things to do while constructing it to withstand seismic forces. A structure is considered ductile if it can sustain large deformations without weakening or breaking. It lessens the possibility of catastrophic failure by absorbing and dissipating seismic energy. Ductility in reinforced concrete structures is attained by correctly specifying the reinforcement, which includes using closely spaced stirrups in key areas, having enough anchoring length, and avoiding brittle failure mechanisms. Because of the enormous shear and bending forces experienced by beams, columns, and beam-column joints during earthquakes, ductile detailing plays a crucial role in these structural components.

A multi-story building's seismic performance is greatly affected by its architecture and design. Soft stories, vertical discontinuities, and mass eccentricities are examples of architectural imperfections that can lead to stress concentrations and an amplified seismic response. For example, a soft story, which is typical in buildings with open ground floors for parking, has much lower rigidity than the higher floors, which can cause uneven deformation and even collapse. In a similar vein, structures with non-normal distributions of mass or stiffness are unstable due to torsional vibrations; hence, engineers and architects need to work closely together to find the sweet spot between seismic safety and practicality. Modern methods for improving RC buildings' seismic performance include base isolation and energy dissipation devices. Placing isolators, such elastomeric bearings or friction pendulum systems, at the foundation level allows for base isolation, which decouples the building from ground motion. By reducing the transmission of seismic pressures to the building, these isolators lessen the likelihood of damage. Structures may absorb seismic energy and lessen vibrations by installing energy dissipation devices like dampers. Both methods have been successful in reducing the likelihood of seismic damage to important structures, such as government buildings, hospitals, and bridges.

II. REVIEW OF LITERATURE

Abd-Alghany, Mariem et al., (2021) A building with a soft floor is a kind of high-rise that has an open floor plan on the ground level. The building's seismic performance is greatly impacted by this level. The reason for this is because such a story causes sudden variations in the strength and stiffness on the sides. Here, we use the finite element approach to look assess how RC structures with soft storeys do during seismic events. The position of the soft storey in relation to the building's height, the irregularity of the building's plan dimensions, and the soft storey's height are the criteria taken into account in this study. This study aims to determine, by means of the building's height, the best spot for the soft story in order to lessen its impact. Furthermore, without drastically altering the building's design or use, the effects of using basic strengthening procedures to increase structural safety are studied. The results include the results of the modal response spectrum (MRS) and the equivalent static load approach for stiffness, displacement, and storey drifts, as well as the impacts of the elements that were analyzed. Included in the research are the cracked stiffness ratio and the P-Delta effect. The results show that several architectural parameters, including the ratio of length to breadth and the height of the soft story, considerably impact the resistance and rigidity. The findings also show that shear walls are efficient in decreasing displacements and enhancing stiffness. In addition, the behavior of these structures may be improved by installing a bracing system during the retrofitting process.

Garg, Ankit et al., (2020) Steel bracing systems are the best option for improving the resistance of reinforced cement concrete (RCC) frames to lateral stress. When compared to alternative engineering solutions, steel bracing offers many advantages, including increased strength and stiffness, lower cost, smaller footprint, and much less overall weight. Different types of bracing—X type, X type tension alone, Eccentric-K type, and Inverted-V type—were examined in this seismic analysis of RCC frame buildings. A six-story (G+5) structure in seismic zone IV on medium-density soil was proposed for this objective. Then, using Resist, we conducted similar static analysis on the building models in accordance with IS code 1893:2002. Stability coefficient, P-delta, lateral displacement, storey drift, and inter-storey drift ratio were the primary metrics used to compare the structures' seismic performance. Research has shown that X-type steel bracing is superior to conventional bracing methods in reducing inter-storey drift and greatly increasing structural stiffness in reinforced concrete buildings.

Sardiwal, Devendra et al., (2019) This research updates a previous literature review on the topic of employing Soft Storey for performance-based seismic analysis of non-linear multi-story structures. A method for elastic design known as performance-based seismic design, "performance based plastic design" is another description. Each part of a structure has a strength and deformation capacity that contribute to its total capacity. One definition of a soft storey is a story in a building that is not strong enough to withstand an earthquake. Another name for this is a weak storey. A soft story is one with plenty of natural light and air. Building on undeveloped land may be very risky if not planned and executed correctly.

Hosseini, Mahmood et al., (2017) Buildings are required to meet the Life Safety (LS)

Performance Level (PL) according to most seismic design rules. This is happening at the same time that several structures have failed to meet expectations and have even fallen in recent earthquakes, especially those that were close to their points of origin. Based on this, it seems that there is still room for improvement in the code provisions to inspire enough trust among engineers. Finding out how well the LS PL provisions in the ACI 318-2014 code and the Reinforced Concrete Multi-Story Regular Building Code of 2009 work with the unique moment frame lateral load bearing system was the main goal of this study. In the heart of Tehran's most seismically vulnerable neighborhood, a string of sixteen-story buildings conforming to building codes were intended to do this. Next, a collection of code-compliant near-source three-component accelerograms were used, and each building underwent a battery of nonlinear time history studies. In order to assess the seismic performances, we computed the acceleration and displacement of the roof as well as the base shear pressures. We also looked at the distribution and development trend of plastic hinges in the constructions. The results demonstrate that during some earthquakes, the performance of the structures surpasses the LS PL and, in extreme circumstances, reaches the collapse level.

Haque, Mohaiminul et al., (2016) While Bangladesh is one of the most earthquake-prone countries in South Asia, Sylhet is particularly vulnerable. This study intends to conduct static and dynamic analyses, such as equivalent static analysis, response spectrum analysis (RSA), and time history analysis (THA), on a range of RCC building frames with equal span, considering both regular and irregular shapes, in compliance with the Bangladesh National Building Code (BNBC)-2006. This research evaluates four different ten-story RCC building frames in Bangladesh's seismic zone 3 (Sylhet) using ETABS v9.7.1 and SAP 2000 v14.0.0: W-shape, L-shape, rectangle, and square. Scientists have examined the dynamic response spectrum and the maximum displacement that different building designs can endure under static loads. The effects of seismic force on static load analysis are practically same for all models, with the exception of model-1 (the W-shape), according to the results. When it comes to seismic stresses, the W-shape is the most vulnerable. Also, structures having non-standard shapes in their frames are subject to greater displacements, according to the response spectrum analysis. In terms of overall performance, regular structures are superior to their irregular counterparts.

Seo, Junwon et al., (2015) A twelve-story reinforced concrete moment-resisting frame structure with shear walls will be evaluated for seismic performance using 3D finite element models. The assessment will be conducted in accordance with seismic design regulations, including those set out by the Federal Emergency Management Agency (FEMA) and seismic building codes. Here we are talking about the LATBSDC code, which stands for Los Angeles Tall Building Structural Design Council. Seismic Zone 4, the most dangerous seismic zone according to the USGS, is where the building is situated. We used widely accessible finite element software to generate the 3D model. Seismic performance assessment made use of two industry-standard methods for seismic analysis of structures: nonlinear time-history analysis and response spectrum analysis. The structure's inter-story drift ratios were calculated using both methods. Seismic fragility curves were generated for each floor based on the ratios derived from the time history research and the FEMA standard in order to evaluate the building's seismic vulnerability. In light of the limitations imposed by FEMA and LATBSDC, we contrasted the two approaches' ratios. The findings demonstrated that floor-level fragility decreased with increasing building height throughout all FEMA performance categories, and that the ratios obtained from the two approaches largely fulfilled the given constraints.

III. RESEARCH METHODOLOGY

Etabs was used to generate a G+10 reinforced concrete structure with a symmetrical plan model. Additionally, L-shaped and T-shaped replicas were made using the identical floor space. Loading the structures according to IS 875: 1987 and analysis according to IS 1893: 2002 were both carried out. We used both the response spectrum approach and the seismic coefficient method to conduct our seismic study. The software's early design dictated the frame's dimensions. The model's characteristics are shown below:

Grade of concrete	M25
Grade of steel	Fe415
Height of each storey	3m
Area of plan	324 m2
Size of columns for G+10 structure	450mmx450mm
Size of beams	300mmx500mm
Thickness of staircase slab and landing	150mm
Depth of foundation for G+10 structure	2.5m

Figure 1: Details of Model

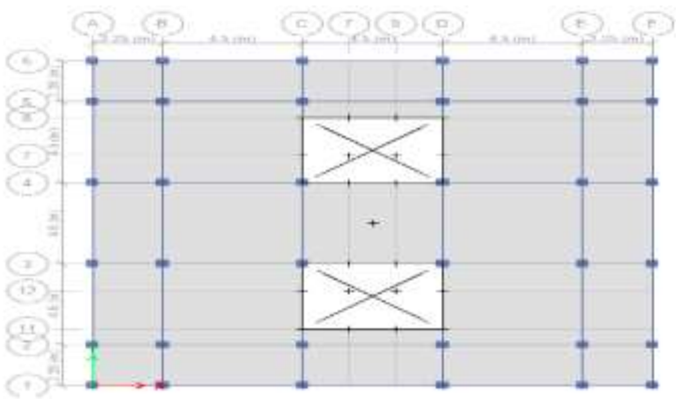

Figure 2: Plan of symmetric structure

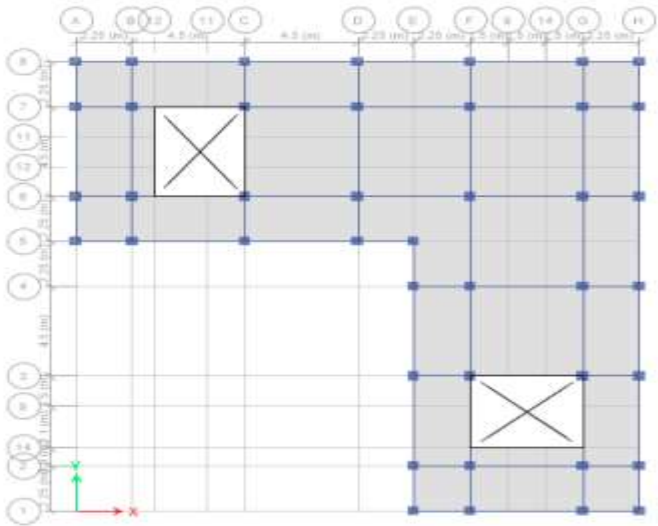

Figure 3: Plan of L shaped structure

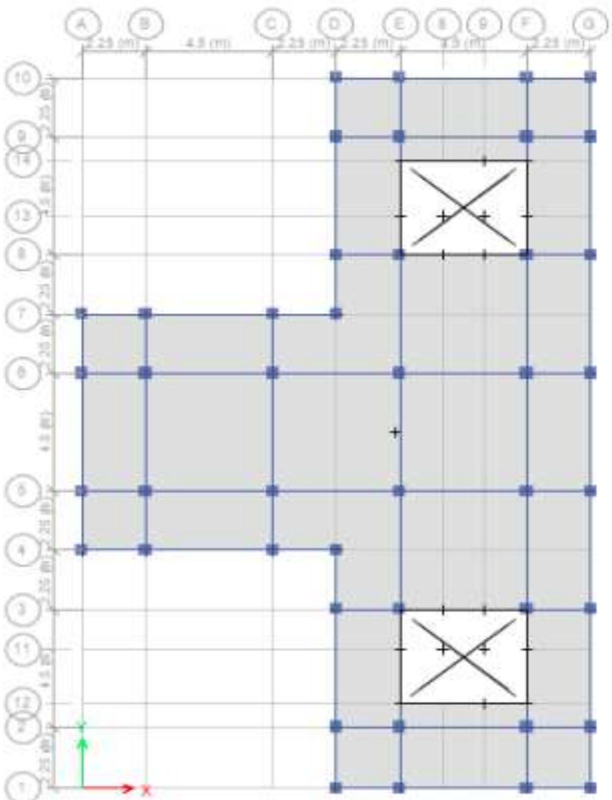

Figure 4: Plan of T shaped structure

The seismic analysis made use of the following parameters.

Type of frame	Special moment resisting frame
Response reduction factor	5
Importance factor	1
Seismic zone	Zone V (very severe)
Zone factor	0.36
Soil type	Medium (Type-2)
Damping	5%
Modal Combination	Complete quadratic combination

Figure 5: Seismic loading parameters

IV. RESULTS AND DISCUSSION

Figure 6 shows the earthquake coefficient method's variation of overturning moment throughout the height of symmetric, L-shaped, and T-shaped G+10 structures, whereas Figure 7 shows the response spectrum method's variation. Using the static technique, the overturning moment is 11.06% more in an L-shaped structure compared to a symmetrical one, and when using the dynamic method, it's 28.39% higher. In a similar vein, a T-shaped building shows an increase of 17.40% when examined using the static approach and 28.7% when assessed using the dynamic method. Additionally, in symmetric, L-shaped, and T-shaped buildings, the overturning moment calculated using the dynamic technique is 20% lower, 8% lower, and 16% lower than that obtained using the static method, respectively.

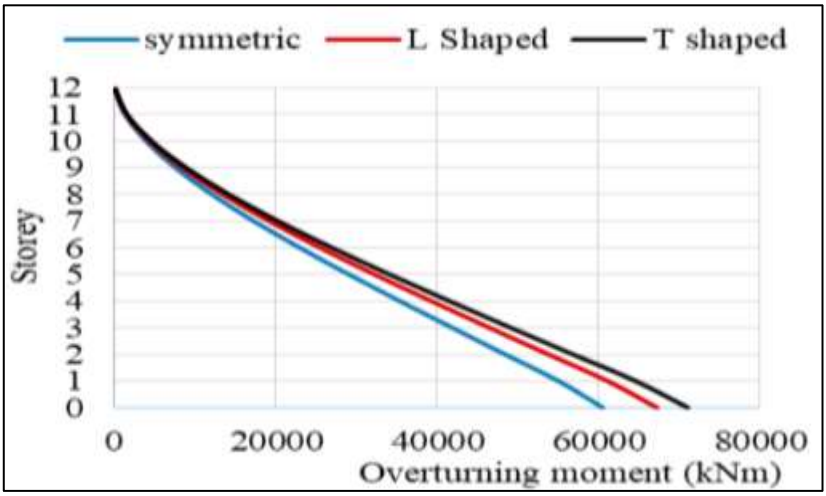

Figure 6: Seismic coefficient technique for G+10 overturning moment

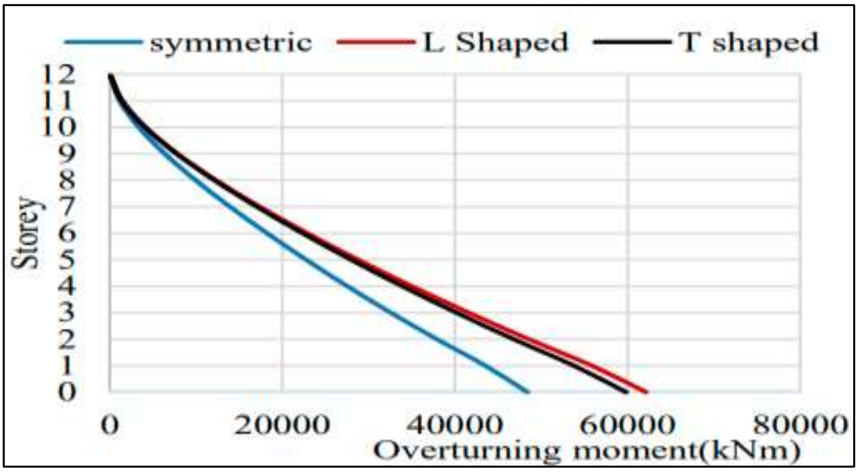

Figure 7: Response spectrum method for G+10 overturning moment

Both Figure 8 and Figure 9 show the variance in storey displacement for the G+10 models. In static analysis, the maximum storey displacements of L- and T-shaped buildings are nearly identical to those of symmetric structures; however, in dynamic analysis, they are 12.62% and 7.55% higher, respectively, than those of symmetric structures. Furthermore, in symmetrical, L-shaped, and T-shaped structures, the maximum storey displacement using the dynamic technique is about 21.3% lower, 10.5% lower, and 15.4% lower than that obtained using the static method, respectively.

Figure 8: Seismic coefficient method for storey displacement of G+10 building

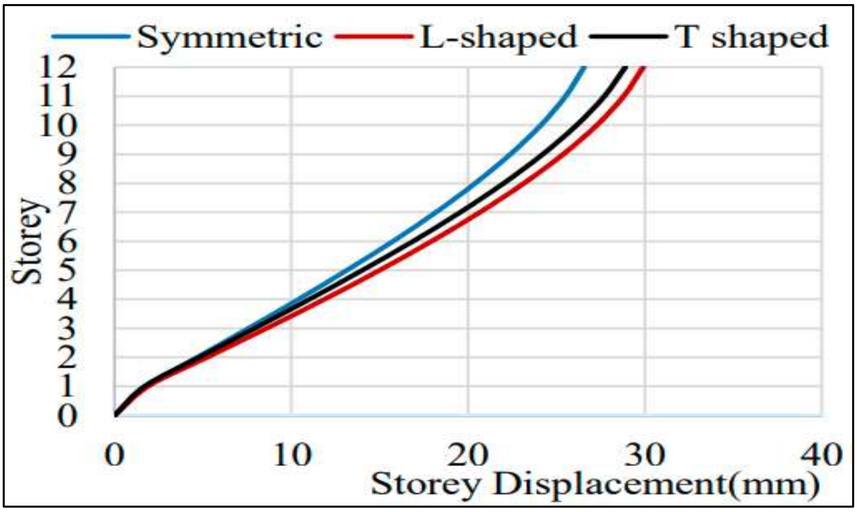

Figure 9: Response spectrum method for storey displacement of G+10 structure

V. CONCLUSION

Variations in seismic response are shown to be considerable when G+10 reinforced concrete buildings with symmetric, L-shaped, and T-shaped plan geometries are analyzed. Using the dynamic response spectrum approach in particular, the research showed that symmetric structures had lower overturning moments and storey displacements than L-shaped and T-shaped buildings. When compared to symmetrical buildings in dynamic analysis, L-shaped and T-shaped structures demonstrated an increase in overturning moments of up to 28.39% and 28.67%, respectively. Additionally, the maximum storey displacements for the former were 12.62% higher, while for the latter they were 7.55% higher. It is important to address dynamic effects for correct seismic design, since dynamic analysis often led to reduced overturning moments and displacements compared to static analysis.

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