Seismic Analysis of G+30 High Rise Building

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Abstract- *This paper discusses the seismic analysis of a G+30 storied building with a centrally located core as the lateral load-resisting system. The study focuses on investigating the building's response to seismic loads using the Response Spectrum Method as per Indian Standard (IS) 1893:2016. The building is modeled using three-dimensional finite element analysis, and the seismic loads are applied in different directions to study the building's behavior under different seismic intensities. The results indicate that the centrally located core as LLRs provides significant resistance against lateral forces induced by seismic activity. The study shows that the location of the core plays a vital role in the building's behavior under seismic loads, providing greater stiffness and strength to the building in both the X and Y directions. The study demonstrates that the LLRs system is effective in reducing the seismic forces acting on the structure, providing a safer and more stable building. The maximum displacement, drift, and base shear forces are within permissible limits, indicating that the building can withstand seismic forces as perIS 1893:2016. The analysis shows that the building is most vulnerable in the East-West direction, as expected, given the seismic zone and soil type. This study highlights the importance of designing LLRs systems appropriately and demonstrates the effectiveness of the Response Spectrum Method and three-dimensional finite element analysis in the seismic analysis of high-rise buildings. This research's findings can be used to enhance the seismic design and safety of high-rise buildings in regions prone to seismic activity.*

Keywords- Seismic analysis, LLRS, RSA, Concentric core

I. INTRODUCTION

The seismic analysis of high-rise buildings is a crucial aspect of structural engineering, particularly in areas prone to seismic activity. High-rise buildings are typically designed with lateral load-resisting systems (LLRS) to resist the forces induced by seismic activity. One commonly used LLRS is the central core shear wall system, which consists of a vertical central core and shear walls distributed around the perimeter of the building. This paper focuses on the seismic analysis of a G+30 storied building with a centrally located core as the LLRS. The aim is to investigate the response of the building under seismic loads and to evaluate the effectiveness of the LLRS. The analysis is carried out using both static and dynamic methods. The static analysis is conducted using the equivalent static analysis method, while the dynamic analysis is performed using the response spectrum analysis method. The design loads are calculated based on the seismic zone factor, soil type factor, importance factor, and response reduction factor specified in the Indian Standard (IS) code 1893:2016. The response spectrum is obtained for the given design parameters, and the time history analysis is carried out using the software ETABS. The building is modeled using three-dimensional finite element analysis, and the seismic loads are applied in different directions to study the behavior of the building under different seismic intensities. The results of the analysis indicate that thecentrally located core as LLRS provides significant resistance against lateral forces induced by seismicactivity. The study highlights the importance of designing LLRS systems appropriately and demonstrates the effectiveness of the Response Spectrum Method and three-dimensional finite element analysis in the seismic analysis of high-rise buildings. Overall, this study provides valuable insights into the behavior of high-rise buildings under seismic loads and highlights the importance of implementing appropriate LLRS systems to ensure the safety and stability of these structures.

II. MODELLING OF BUILDING

Modelling of a G+30 storied building in ETABS software is a crucial step in the analysis and design process of high-rise structures. ETABS is a widely used software tool that facilitates the creation of a detailed and accurate 3D model of a building. The modelling process involves defining the geometric parameters of the building, such as the floor plans, column sizes, and beam dimensions. Once the basic geometry of the building is defined, the software allows for the specification of materials and structural elements, such as concrete, steel, and shear walls.The structure being evaluated for seismic activity is a commercial project with plan dimensions of 45m x 43.5m and a floor-to-floor height of 4.2m. The specifics of the building are outlined in Table 3.1, while its corresponding plan can be viewed in Figure

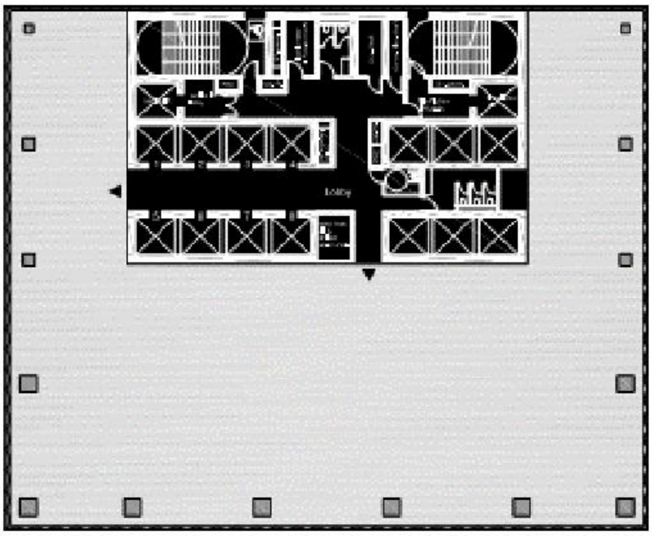


Fig 1.Plan of a building to be analysed

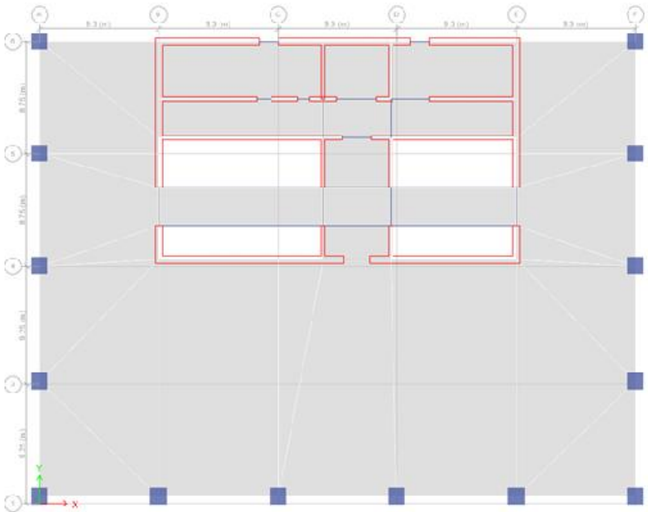


Fig 2.Centre line plan in ETABS

In the seismic analysis of a high-rise building, the properties of the beam and column are crucial factors that affect the overall performance of the structure under seismic loads. In this regard, the length to depth ratios specified in IS456-2000 are considered while determining the properties of the beam and column. In addition, the clauses given in IS13920-2016 are taken into consideration, which specifies the minimum sizes of members required for seismic-resistant design. These clauses are particularly important in regions that are prone to seismic activity, as they ensure that the members are strong enough to resist the lateral forces induced by seismic waves.

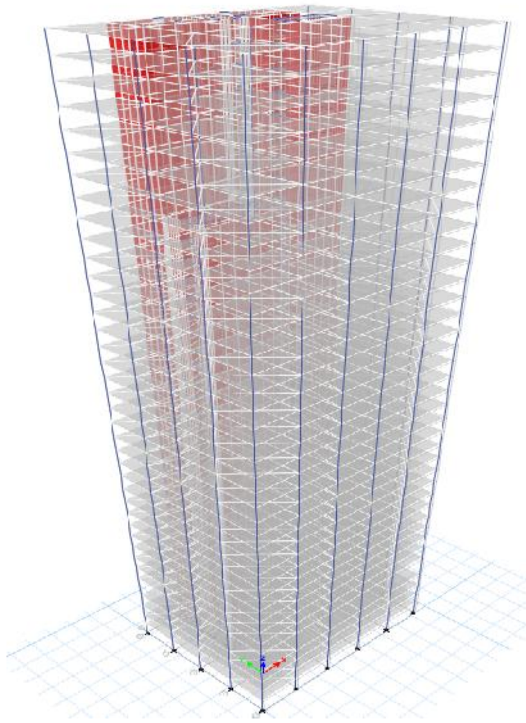


Fig 3. 3D skeleton view of building.

III. LOADING CALCULATIONS

The types of loads shown below is the loads which are considered for the analysis.

A. Dead Load

Dead load refers to the weight of the structure itself and any fixed, non-moving elements such as walls, floors, roofs, and permanent equipment. It ensures the safety and stability of a structure; engineers must calculate the expected dead load accurately and include it in their design calculations. Dead load can be estimated based on the weight of various building materials, such as concrete, steel, wood, and masonry, and the size and configuration of the building elements.Self-weight of the building will automatically calculate by the software after assigning the command of self-weight. Other dead load like wall load (WL), parapet load (PL), slab load (SL), and floor finish (FF) calculated as per the volume and density.

B. Live Load

The live loads that a building is likely to encounter are taken into account using IS 875- part 2 [4]. The code specifies the live loads based on the building's purpose. To account for the worst-case scenario, the building is assumed to be a commercial building, and a live load of 4kN/m2 is used.

The software distributes the assigned gravity loads to the beams after they have been assigned.

C. Seismic Load

As per the Indian standards even though we are going ahead with dynamic analysis, it's required to do static analysis as well so that later we can match the base shear.

The factors shown in table are the factors we need to use while going for the seismic analysis of the structure. The various factors are depending on the specific conditions. Zone factor depends on the location of the structure as it is located in zone III. Importance factor depends on the importance of building. Response reduction factors are depended on the type of lateral resisting system we are going to use in the analysis.

Table 3.5 Standard factors (IS 1893 part 1: 2016)

Factors	**Zone factor (Z)**	**Importance factor (I)**	**Response reduction factor (R)**	**Fundamental periods**	
				Tx	***Tz***
Values	0.16	1	4	2.597	0.2.973

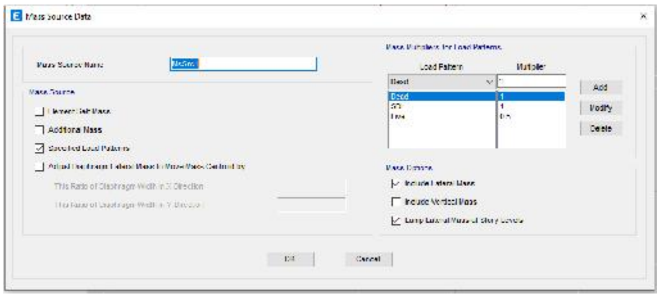


Fig 4. Mass Source 0.5LL+DL

IV. LOADING COMBINATIONS & MODIFIERS

In order to account for additional uncertainties, it is necessary to incorporate certain factors. This requires the consideration of specific load combinations outlined in IS 1893 part 1: 2016 when conducting seismic analysis. The applicable load combinations utilized in this particular structure are presented in the accompanying table.

Load combinations for seismic analysis (IS 1893 part 1: 2016)

Sr.No.	**Load Combination**
1	1.2 [DL + IL ±EL_X
2	1.2 [DL +IL ±EL_Y
3	1.5 [DL ±(EL_X)
4	1.5 [DL ±(EL_Y)
5	0.9 DL ±1.5 (EL_Y)
6	0.9 DL ±1.5 (EL_X)

C. Modifiers

The ETABS software is used as the primary tool to model the conceptual structural system, taking into account wind and seismic loads. The compliance of drift limits and strength are the main factors considered, but dynamic characteristics are also taken into account to avoid excessive accelerations. Expensive passive and/or active dampers are avoided to rectify this issue. Two detailed models are developed for each option considered to assess structural behavior at the serviceability and ultimate limit states. Assumptions made for ETABS modelling include 100% gross section properties for vertical elements inthe SLS models and 70% for ULS models. For link beams and perimeter spandrel beams, flexural stiffness corresponds to 50% for SLS and 35% for ULS.

V. ANALYSIS RESULTS

Once the analysis is completed; the analysis results are been reviewed to be on the line with the permissible limits given in Indian standards clauses.

A. Modal Shapes

Mode shapes are essential to check after obtaining the results of a structural analysis. The reason for this is that the mode shapes provide information about the vibration characteristics of the structure. If the first mode shape shows a rotation, this means that the center of gravity and center of rigidity are far away from each other. This eccentricity leads to rotation instead of translation, which is not desirable in a building.To rectify this, the orientation of columns needs to be changed, and the properties of the section need to be altered so that the center of gravity and center of rigidity come closer. It is important to note that the period and frequency of specific modes are also important to consider in the analysis, as they affect the response of the structure to seismic forces. These values can be determined using software tools and can be presented in a graph or figure for better visualization.

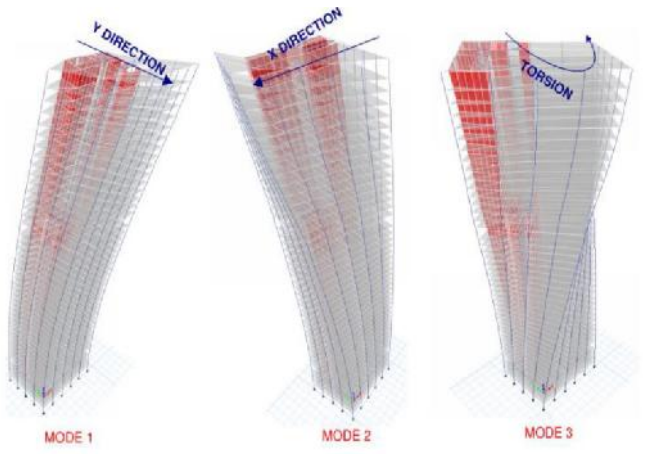


Fig 5. Mode Shape

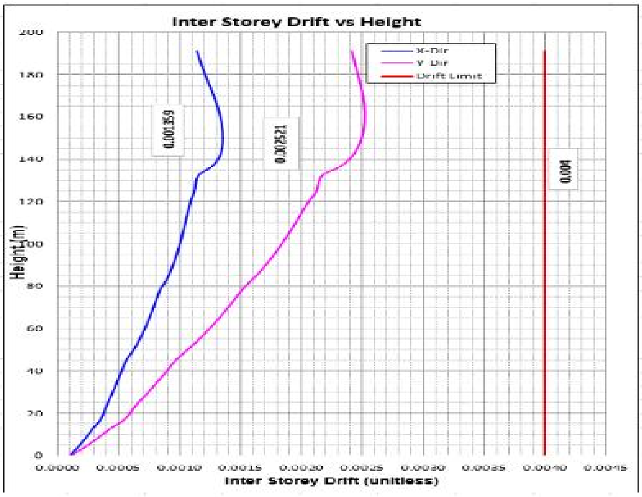
To enhance the building's resistance, the first two modes should exhibit translation, as depicted in the figure. The participation factor, along with the period and frequency of the respective mode, is presented in the table for the first mode of the building

Case	Mode	Period (sec)	UX	UY	RZ
Modal	1	6.46	0%	60%	0%
Modal	2	4.56	53%	0%	10%
Modal	3	2.62	7%	0%	59%

Fig 6. Participation factor for 1^{st} mode

B. Storey Drift

Storey drift refers to the relative horizontal displacement between two adjacent floors of a building caused by lateral loads, such as wind or earthquake. It is an important parameter to be considered in the design of buildings as excessive storey drift can lead to structural damage, reduced functionality, and even collapse during extreme events.As per the Indian standard IS 1893:2016, the maximum permissible limit of storey drift for regular buildings is 0.004 times the height of the storey or 10 mm, whichever is less. For irregular buildings, additional checks and provisions may be required. It is important to ensure that the storey drift limit is not exceeded at any point during the design life of the building. Structural engineers and designers use various techniques and strategies to reduce storey drift, such as proper selection of lateral systems, optimized structural layouts, and proper detailing of connections.



C. Torsional Irregularity

Torsional irregularityis one of the most critical issues in the seismic design of buildings. It occurs when a building's floor plan is asymmetric or when the distribution of mass or stiffness is uneven across the building's plan. This results in the building experiencing torsional forces during an earthquake, which can cause significant damage. To avoid such damage, IS 1893:2016, the Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings, specifies permissible limits for torsional irregularity. The code outlines the acceptable limits for the torsionally irregular buildings and recommends measures to mitigate the torsional effects. Compliance with these limits helps ensure the safety of the building and its occupants during a seismic event.

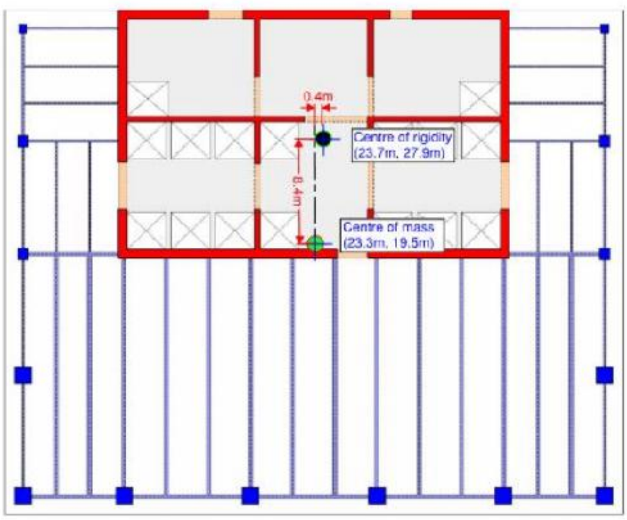


Fig 7. COR and COM on the Floor

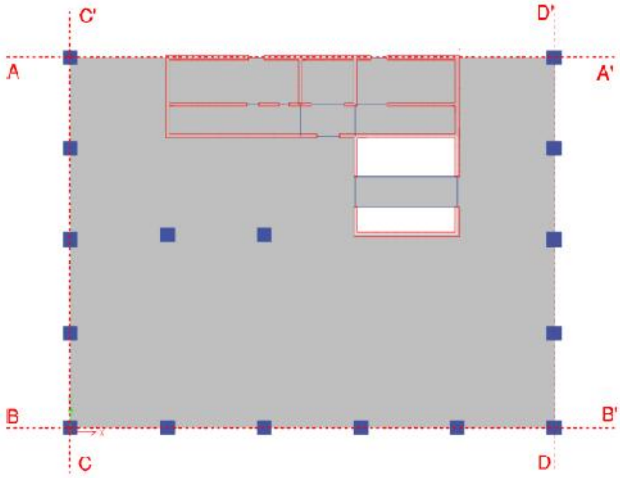


Fig 8. Typical Floor Plan Indicating Grid Location for Torsion Irregularity Check

Grid	Max Displacement	Displacement at another end	Ratio
Along C-C'	147	91	1.61
Along D-D'	147	91	1.61
Along A-A'	237	222	1.05
Along B-B'	237	222	1.05

Torsional Irregularity Check

C. Core Wall Stresses

The figure depicts the stresses for various load cases, while another figure highlights the vertical steel rebar percentage in some of the critical walls. These stress and rebar values are specified for the walls present between the foundation and B3 level (referred to as the base level) and between L23 to L24 level (referred to as the transition level). Under total dead load, the compressive stress is around 6 to 13 MPa at the base level and 2 to 7 MPa at the transition level. Live load results in compressive stress of 0.75 to 3 MPa at the base level and 0.25 to 2.5 MPa at the transition level. Seismic forces generate compressive and tensile stresses approximately of 2.75 to 4 MPa and 1.25 to 2.5 MPa at the base and transition levels, respectively.Based on these stress values, it is evident that some walls are subjected to high stresses. Consequently, a few of the critical walls necessitate 2 to 2.5% vertical rebar, while some of the walls are less stressed and can be optimized in subsequent design stages while ensuring that link beam stresses and drift ratios remain within the acceptable limit.

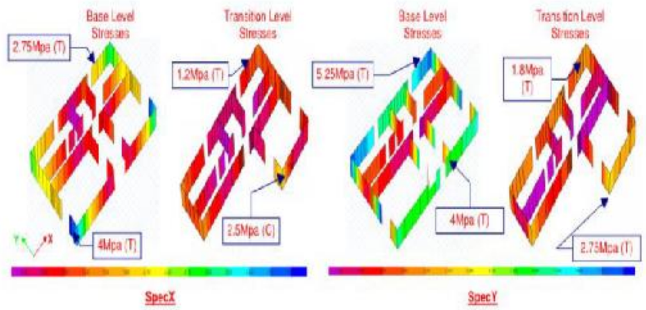


Fig 9. Core Wall Stresses in Etabs (1)

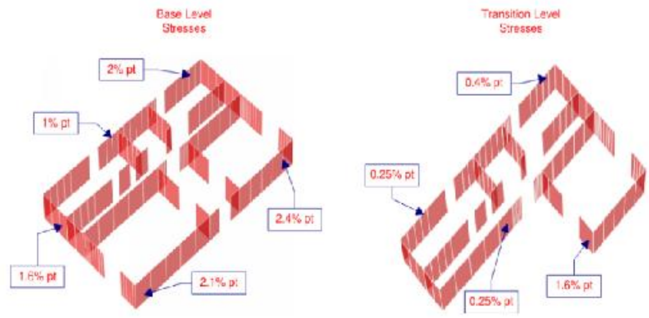


Fig 10. Core Wall Stresses in Etabs (2)

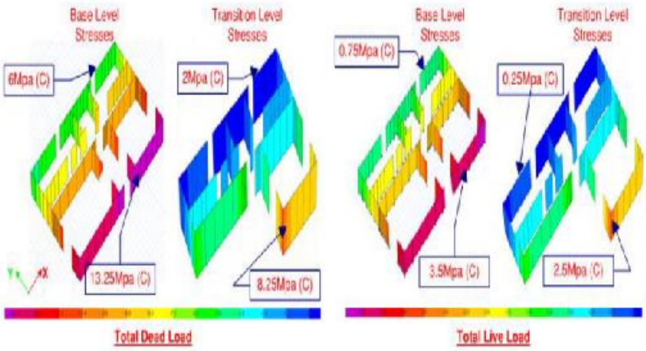


Fig 11. Percentage of Steel

VI. CONCLUSION

1) The building has been analyzed for various seismic loads using ETABS software. The mode shapes have been studied to identify the eccentricities and if any rotation exists in the first mode.
2) The permissible limit of storey drifts and deflections as per IS 1893:2016 has been checked for all the load cases and found to be within the limit.
3) The torsional irregularity check has been performed and the maximum to minimum displacement ratio has been calculated. Though the ratio exceeds the permissible limit of 1.5, since there is no pure torsion in the first two modes, the building configuration need not be altered.

4) The stresses and percentage of vertical steel rebar required for the governing walls have been identified based on the stress values obtained for individual load cases.
5) Based on the stress analysis, some of the governing walls require 2 to 2.5% vertical rebar, while some walls are lightly stressed and can potentially be optimized in the next design stages.
6) The modal analysis shows that the building is safe from resonance for all the load cases.
7) The building has been found to be safe for seismic forces, and the design is within the permissible limits for storey drifts, deflections, modal shapes, and torsional irregularities.

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