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# Seismic Analysis of Multi-Story RCC Framed Buildings with Symmetric and Asymmetric Design

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**ABSTRACT-** A disruptive disturbance known as an earthquake occurs when subterranean movement along a fault line causes the earth's surface to tremble. An earthquake is a natural disaster that has claimed millions of lives throughout history. Due to fatalities and destruction, every earthquake leaves a path of suffering. The bhuj earthquake was the first time when multi-story reinforced concrete buildings in India experienced a significant ground motion shaking. The main causes of failure have been determined to be soft stories, floating columns, irregular masses, subpar building materials and bad construction techniques, uneven earthquake response, soil and foundation, and the impact of pounding on nearby structures.

The main purpose of structural analysis is to ascertain how a structure will respond to loads, which can be either dynamic (such as the weight of people, furniture, etc.) Or static (such as wind, explosions, and earthquakes). Movement beneath the earth's surface causes earthquakes, which create varying degrees of ground shaking that can lead to building damage and collapse. The lateral loads brought on by earthquakes must be taken into account in tall constructions. Seismic design techniques ensure that the building is useful by ensuring that it can sustain moderate and frequent shaking without suffering damage.

Two buildings (g+4) that are thought to be located in seismic zone iv are the subject of the current study's load analysis. The etabs 16 software is used for both the response spectrum approach and the equivalent static analysis method. Parameters such as storey displacements, storey drift, storey stiffness, support reaction, axial force, bending moment, and shear force in columns, as well as bending moment and shear forces in beams, are determined for comparative study based on the analysis results. Because the response spectrum analysis approach is more cost-effective than the static analysis method, it should be considered for high-rise buildings, according to the results.

**KEYWORDS-** Seismic Analysis, RCC Framed Buildings, Symmetric Design, Asymmetric Design

## I. INTRODUCTION

A shortage of arable land is currently causing problems for people all around the world. People moved from rural to urban areas as a result of the population growth and the start of the industrial revolution, making the construction of multi-story buildings for both residential and public purposes inevitable. There is no design optimisation for the lateral force resistance of these high-rise buildings. There is a chance that this will cause the structures to completely collapse. When designing earthquake-resistant structures, a few important factors are taken into account. It is determined by a number of factors, including the structure's ductility, kind of foundation, damping factor, natural frequency, and building significance. Buildings constructed for ductility must incorporate less lateral load capacity in their designs due to its superior moment distribution features. Depending on the type of structure, the response reduction factor R compensates for this component and itself in a different way. The structure was designed as an SMRF due to its high-performance requirements. Only forces lower than those for which it is designed as an OMRF may be used in its construction.

The structures that comprise civil engineering are typically constructed to support static loads. The majority of the time, dynamic loads acting on the structure are not taken into account. This propensity to overlook dynamic forces can occasionally be the primary cause of a catastrophe, especially during an earthquake. Ductility is necessary in case seismic forces are applied. One of the defining features of a structure that must respond to strong ground vibrations should be ductility. If the ductility of the structure is great, it can deform plasticity without collapsing. and the resulting energy dissipation will also be high. As a result, the overall effective force of the earthquake decreases.

The seismic response of the building systems is significantly influenced by the type of analytical technique that is employed. Due to its relative ease of use, the static technique was the only analytical methodology available in previous years. These methods can be too cautious even when they resulted in a secure design. Through the use of techniques that fall under the category of "dynamic analysis," which was made possible by the development of sophisticated computers and analysis programs, the researchers were able to simulate the actual effect of earthquakes on building models in order to obtain the realistic seismic response. This allowed them to proceed towards a more logical. Since it describes and forecasts the instances of structural movement brought on by the influence of dynamic loads, dynamic analysis is considered one of the foundational disciplines in structural mechanics. This discipline of study uses logical analysis and the solution of challenging mathematical equations in addition to observation and experience as its foundation.

Whether or whether the applied action has enough acceleration in respect to the inherent frequency of the structure is the basis for the distinction between dynamic and static analysis. The dynamic analysis is different from the static analysis in this way. The inertia forces can be ignored if a load is delivered slowly enough, making the analysis simpler to do as a static analysis. This is made possible by Newton's second law of motion. As a result, structural dynamics is a type of structural analysis that takes into account how structures behave under dynamic (highly accelerated) loading. Structural dynamics is the term for this kind of structural analysis. Dynamic loads include things like people, wind, waves, traffic, earthquakes, and explosions. It is possible to apply dynamic loading to any kind of structure. Dynamic analysis can be used for modal analysis, time history tracking, and dynamic displacement determination. Structures created by civil engineers are typically designed to support static loads. The impact that dynamic loads have on the structure is frequently disregarded. Disasters can occasionally be caused by a failure to take dynamic forces into account, particularly when an earthquake occurs. Ductility is necessary in case seismic forces are applied. Ductility will be more important than anything else for a construction that must respond to strong ground vibrations. The quantity of ductility and potential energy dissipation is directly proportional to the structure's capacity to bend plasticity without collapsing. As a result, the real forces of the earthquake are less powerful.

A school building's load is taken into account in this work. Two different approaches—the equivalent static analysis method and the response spectrum method—are used to assess two buildings, G+4, which are assumed to be in seismic zone IV. Both analyses are carried out using ETABS 16 software. Storey displacements, storey drift, storey stiffness, support response, axial force, bending moment, and shear force in columns, and bending moment and shear force in beams are among the characteristics that are derived for comparative study based on the analysis results. The results allow for the conclusion that response spectrum analysis is a technique that should be considered for high- rise structures since it is more cost-effective than static analysis.

### *A. Objectives of the study*

This study's main goal is to analyse multi-story R.C. School building models utilising the response spectrum method and the corresponding static methodology. A list of the objectives this study seeks to achieve is as follows:

- The equivalent methodology and the response spectrum method will be used to model the G+4 building.
- Must make significant deductions from the study's findings (drifts, displacements, storey shears, storey stiffness, and reinforcements) in order to gain a thorough grasp of how earthquake stresses affect the behaviour of structures with and without shear walls.
- This report's objective is to provide a summary of the results and make the required deductions.

### *B. Scope & Limitation of the Study*

The following are the scope of the study of this paper:

- ETABS makes it simple to model and assess both symmetrical and asymmetrical building plans.
- This paper's scope is restricted to examining how structures behave in seismic zoning factors of 0.4.
- Throughout the investigation, the size of the columns and beams remains unchanged.
- Both columns' cross-sectional areas are measured identically. The impact of earth pressure is disregarded in earthquake analysis.

## II. LITERATURE REVIEW

The seismic performance of reinforced cement concrete (RCC) framed buildings has been a central topic of structural engineering research, especially in seismically active regions. Over the years, various studies have focused on the influence of building configuration, symmetry, and structural irregularities on seismic response.

M. Haque et al. [1], examined the behavior of multi-storey RCC buildings under seismic loads using linear and nonlinear static analyses. They concluded that symmetry in plan and elevation significantly enhances the structural performance, reducing torsional effects. Similarly, the comparative analysis by Rutenberg et al. [2] demonstrated that symmetric structures exhibit better lateral load resistance due to uniform distribution of stiffness and mass, whereas asymmetric buildings are more susceptible to torsional irregularities.

A detailed parametric study was conducted in M. M. Ahmed et al. [3] to investigate the impact of vertical and plan irregularities. The results showed that plan asymmetry caused uneven lateral displacement and increased base shear, especially under higher modes of vibration. The effect of stiffness irregularity on seismic response was further explored by D' Ambrisi et al. [4], where the authors found that sudden changes in stiffness, especially at lower floors, led to soft-storey mechanisms and amplified inter-story drifts.

Dynamic analysis techniques such as response spectrum and time-history analysis have been employed in several studies to understand the detailed behavior of framed buildings. K. Sharma and D. Patel [5], spectrum analysis of a ten-storey structure revealed that torsional response increases with eccentricity in mass and stiffness distribution. Time-history analysis, as discussed by S. Patil et al. [6], highlighted those asymmetric buildings experience larger lateral displacements and base shears due to coupled translational and rotational modes.

Recent advancements have explored the use of base isolation and dampers to mitigate seismic effects in irregular buildings [7]. However, in conventional RCC buildings, careful consideration of symmetry and structural configuration remains a key factor in seismic design. The work in [8] also emphasized the role of seismic codes in mitigating the adverse effects of asymmetry and proposed design recommendations to reduce torsional vulnerability.

In conclusion, existing literature indicates that asymmetric RCC buildings are more vulnerable to seismic forces due to torsional behavior, uneven displacement, and concentration of stresses. Thus, a comprehensive understanding of seismic responses in both symmetric and asymmetric structures is essential for ensuring structural safety and performance.

## III. METHODOLOGY

This study investigates the seismic behavior of multi-story Reinforced Cement Concrete (RCC) framed buildings with symmetric and asymmetric configurations using structural modeling and analysis techniques. The methodology adopted for this research is outlined as follows:

### A. Model Description

Two five-story RCC framed building models were developed and analyzed using ETABS 2016 software. Both models share identical plan dimensions of 22.5 meters × 13.5 meters, and a footing depth of 1.7 meters. The buildings consist of five stories (including the ground floor), and structural elements such as beams and columns are assumed to have uniform cross-sections across all stories.

The two models analyzed in this study are:

- Model 1: Symmetric building analyzed using the Response Spectrum Method.
- Model 2: Asymmetric building analyzed using the Equivalent Static Method.

### B. Structural Elements and Material Properties

The following material and geometric properties are used uniformly across both models:

• Based on standard practice unless otherwise stated)

### C. Loading Conditions

The following types of loads are considered in the seismic analysis:

- Dead Load: Self-weight of structural components including slab, beams, columns, and walls.
- Lateral Load: Seismic loads as per IS 1893 (Part 1): 2002.

Seismic zone parameters and load combinations are defined according to IS 1893:2002. Lateral forces at each floor level are computed using:

- Equivalent Static Method (for Model 2)
- Response Spectrum Method (for Model 1), where natural frequencies and mode shapes are derived through modal analysis within ETABS.

### D. Analysis Approach

The analysis is carried out in ETABS 2016 using the following approach:

- Definition of structural geometry and section properties.
- Assignment of materials, loads, and boundary conditions.
- Modal analysis to determine mode shapes and natural time periods.
- Application of seismic loads based on the respective method (response spectrum or static).
- Evaluation and comparison of response parameters such as story displacement, base shear, and time period.

### E. Compliance with Standards

The modeling and analysis adhere to the following Indian Standards:

- IS 456:2000 – Code of Practice for Plain and Reinforced Concrete
- IS 875:1987 – Code of Practice for Design Loads (Other than Earthquake)
- IS 1893 (Part 1):2002 – Criteria for Earthquake Resistant Design of Structures.

## IV. RESULT AND DISCUSSION

This section presents and interprets the results obtained from the seismic analysis of G+4 RCC framed buildings with symmetric and asymmetric configurations. The analysis was carried out using the Response Spectrum Method as per IS 1893:2002. Various structural parameters were evaluated, including story displacement, drift, story shear, overturning moment, stiffness, and base shear. Results are compared in both longitudinal and transverse directions and are supported by tables and graphical representations.

### A. Story Displacement

The maximum lateral displacements were obtained at the top stories and were observed to vary significantly between symmetric and asymmetric models. Table 1 illustrates the diversity in the amount of displacement experienced by various narratives across all of the models when the response spectrum is presented in the longitudinal direction in figure 1.

Table 1: Values of displacement for different stories for all the models

| Displacement in mm | | |
|---|---|---|
| Storey Level | Model 1 | Model 2 |
| 5 | 35.097 | 6.511 |
| 4 | 31.396 | 5.675 |
| 3 | 25.031 | 4.366 |
| 2 | 16.446 | 2.767 |
| 1 | 6.834 | 1.118 |
| 0 | 0 | 0 |

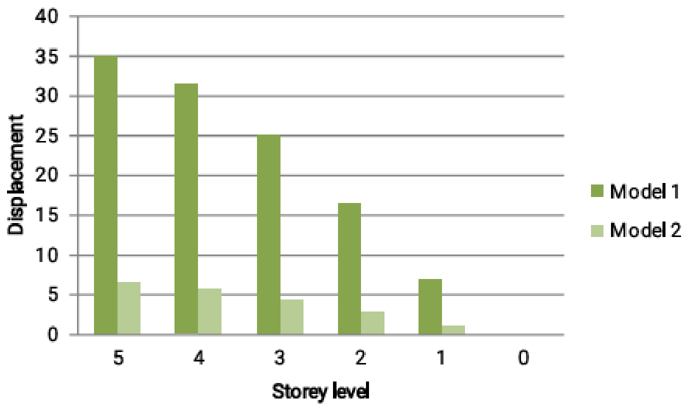


Figure 1: Displacement along longitudinal direction

Asymmetric structures exhibited slightly higher lateral displacements than symmetric ones, particularly in the transverse direction, indicating greater vulnerability to seismic excitations due to irregular mass and stiffness distribution.

### *B. Story Drift*

Story drift is a critical parameter for assessing inter-story deformation. It was found to increase with story height and was within permissible limits as per IS 1893:2002. Table 2 shows the drift values for each of the models in the transverse direction for each of the distinct storylines and figure 2 is showing the chart of drift along transverse direction

Table 2: Drift values for each of the models in the transverse direction

| Drift | | |
|---|---|---|
| **Storey Level** | **Model 1** | **Model 2** |
| 5 | 0.001466 | 0.000318 |
| 4 | 0.002403 | 0.000486 |
| 3 | 0.003151 | 0.000585 |
| 2 | 0.00347 | 0.000598 |
| 1 | 0.002384 | 0.000393 |
| 0 | 0 | 0 |

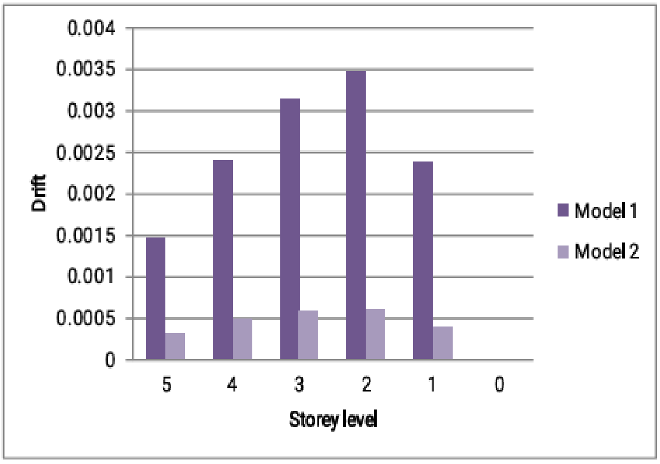


Figure 2: Drift along transverse direction

Asymmetric buildings recorded higher drift values, especially at mid-height levels, where torsional effects are more pronounced. Symmetric models showed a more uniform drift distribution.

### C. Story Shear

The story shear values indicate the seismic force distribution across the building height.

Shear forces were maximum at the base and decreased toward the top. Asymmetric models experienced higher shear in the lower stories due to uneven stiffness distribution. Table 2 presents the values of the storey shear for each of the models along the longitudinal direction for the various storeys and figure 2 displays the values of storey shear for all models when the response spectrum is in the longitudinal direction. These values are specific to each story in the building.

| Storey Shear kN | | |
|---|---|---|
| Storey Level | Model 1 | Model 2 |
| 5 | -2198.6444 | 9583.6535 |
| 4 | -3721.1069 | 18092.4275 |
| 3 | -4577.4921 | 24761.201 |
| 2 | -4958.1077 | 29330.6517 |
| 1 | -5053.2616 | 31453.0192 |
| 0 | 0 | 0 |

Table 2: Values of the storey shear

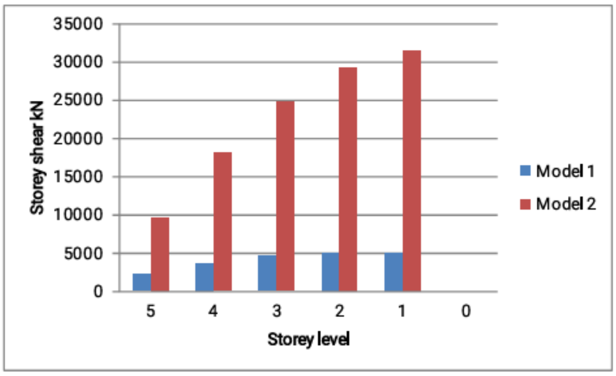


Figure 2.Storey Shear along longitudinal direction

### D. Overturning Moment

Overturning moments were analyzed to assess the stability of the structure under seismic loading. Overturning moments were higher in the asymmetric model due to eccentricity and lateral displacement. This highlights the importance of torsional stability in irregular structures.

The values for the overturning moment of different narratives for each model when the response spectrum is along the longitudinal direction are shown in figure 3. and table 3 is showing the values of overturning moment for different stories for all the models along longitudinal direction.

| Over turning moment kN-m | | |
|---|---|---|
| Storey Level | Model 1 | Model 2 |
| 5 | 0 | 0 |
| 4 | 28750.9606 | 6595.9332 |
| 3 | 82626.9068 | 17759.254 |
| 2 | 155995.0301 | 31491.7303 |
| 1 | 242593.0184 | 46366.0535 |
| 0 | 335440.8708 | 61525.8384 |

Table 3: Values of overturning moment for different stories

### E. Story Stiffness

Story stiffness plays a vital role in resisting lateral loads. It was calculated for both directions. When the response spectrum is orientated longitudinally, the storey stiffness values for each model are shown in table 4 and figures 4 apply to a wide range of storeys.

Table 4: Values of stiffness for different stories for all the models in longitudinal direction

| Stiffness in kN/m | | |
|---|---|---|
| Storey Level | Model 1 | Model 2 |
| 5 | 2528471.713 | 2651950.944 |
| 4 | 2800727.145 | 2847005.214 |
| 3 | 2871341.602 | 2867341.851 |
| 2 | 3043306.616 | 3000354.398 |
| 1 | 4628826.963 | 4543922.179 |
| 0 | 0 | 0 |

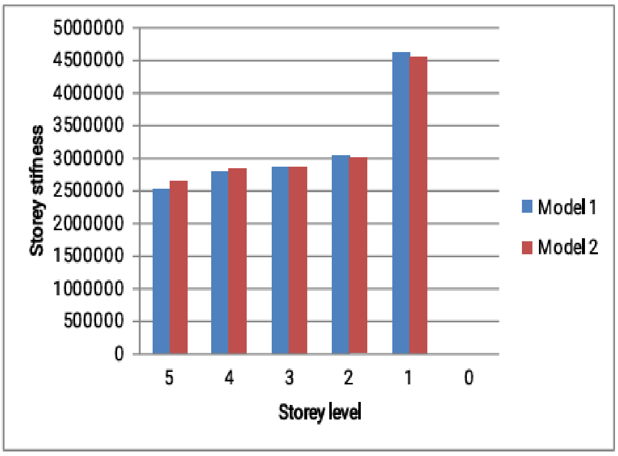


Figure 4: Storey Stiffness along longitudinal direction

The symmetric model exhibited consistent stiffness distribution, while the asymmetric structure had lower stiffness in specific stories, indicating zones more susceptible to lateral deformation.

### *F. Base Shear*

Base shear is a cumulative measure of lateral force at the base due to seismic activity. Table 5 is showing comparison of base shear for each model and figure 5 is showing base shear of models.

Table 5: Comparison of base shear for each model

| Models | Base shear in kN | |
|---|---|---|
| | EQX | EQY |
| Model 1 | -5053.2616 | -5053.2616 |
| Model 2 | 31453.0192 | 31453.0192 |

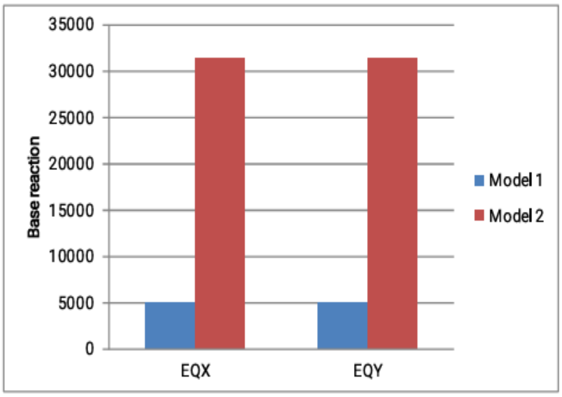


Figure 5: Base shear of models

The symmetric model recorded slightly higher base shear due to balanced mass and stiffness, resulting in greater overall response. Asymmetric models showed reduced base shear but higher localized effects, such as increased drift and torsion.

### *G. Summary of Findings*

Symmetric structures demonstrate better seismic performance with uniform distribution of forces and deformations.
Asymmetric models are more vulnerable to lateral displacement, drift, and torsional effects.
The response spectrum method efficiently captures modal effects and provides a reliable basis for comparing different configurations.
Critical design attention is required for stiffness irregularities and displacement control in asymmetric buildings.

## V. CONCLUSION

Two distinct models of a five-story building are analysed using the ETABS program, employing the response spectrum approach and the associated static method. The parameters that will be used for comparison study are determined by the analysis's results. Storey displacements, storey drift, storey stiffness, time period, base shear, and overturning moment are some of these variables. The following findings can be drawn from the conducted investigation:
A five-story building's displacement determined by the response spectrum approach is found to be greater than that determined by the matching static method.
A five-story building's displacement determined using the response spectrum approach is 43.62 percentage points greater in the longitudinal direction and 62.1 percentage points greater in the transverse direction than that determined by the equivalent static method.
For a five-story building, the response spectrum approach yielded a drift that was 53.62% higher in the longitudinal direction than the corresponding static method, and 72.18% higher in the transverse direction.
The overturning moment of a five-story building examined using the response spectrum approach is 33.73% higher in the longitudinal direction and 52.83% higher in the transverse direction than that determined using the equivalent static method.
The response spectrum methodology yielded a 5-story structure's storey stiffness that is higher than that of the similar static method in both longitudinal and transverse directions.
The base reaction of a five-story building as determined by the response spectrum technique is larger than that as determined by the same static method in both the longitudinal and transverse dimensions.
Buildings built with symmetrical plans have better seismic performance than those built with asymmetrical layouts, according to the results shown above. Furthermore, an asymmetrical building layout greatly increases floor displacement, storey shear, axial loads, and torsion in columns, all of which make it more appropriate for usage in earthquake-prone areas.

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