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**RESEARCH ARTICLE**

# COMPARATIVE SEISMIC RESPONSE SPECTRUM ANALYSIS (ZONE II) OF A G+10 STEEL FRAMED STRUCTURE

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## ABSTRACT

Seismic Response Spectrum Analysis (SRSA) plays a vital role in evaluating the seismic performance of structures, particularly in earthquake-prone areas. This project report provides an in-depth analysis of a G+10 steel-framed structure using the widely recognized ETABS software. The primary aim of this study is to assess the structural response under seismic loading and gain insights into the building's dynamic behaviour. The methodology section details the systematic approach taken to perform the seismic response spectrum analysis for Earthquake Zone II using ETABS. This includes generating seismic response spectrum curves, selecting suitable ground motion records, modelling the G+10 steel-framed structure, assigning material properties, and applying seismic loads in accordance with relevant building codes and standards. The modelling and analysis processes are meticulously documented, with finite element models developed to accurately reflect the structural system. Realistic material properties and load combinations are used to ensure that the analysis results are both relevant and applicable to real-world situations.



## INTRODUCTION

An earthquake is characterized by sudden and intense ground shaking, resulting from the rapid release of energy within the Earth's crust. These seismic events can range from mild tremors to catastrophic occurrences, posing significant risks to high-rise buildings due to their height and inherent flexibility. During an earthquake, tall structures are particularly vulnerable to considerable swaying, which can jeopardize their structural stability.

To withstand such forces, high-rise steel-framed buildings are designed with a steel framework, which is valued for its strength and lightweight properties. These structures consist of vertical columns and horizontal beams, connected by bolts or rivets. The columns bear the building's load, while the beams help distribute it. The steel framework may either be rigid, capable of resisting bending moments, or braced, incorporating diagonal braces to enhance lateral stability. Steel-framed structures are commonly employed in the development of high-rise buildings, including office towers, residential complexes, hotels, hospitals, and certain industrial facilities.

Response Spectrum Analysis

Response Spectrum Analysis (RSA) is a method for estimating a structure's peak response to transient dynamic events, such as earthquakes or shocks. This technique uses a linear-dynamic statistical approach to evaluate how each natural mode of vibration contributes to the maximum seismic response of a structure assumed to be elastic.

RSA involves plotting the maximum response of a single degree of freedom (SDOF) system to specific ground motions, based on the system's natural frequency and damping ratio. The response spectrum can be created for acceleration, velocity, or displacement and can represent either a single ground motion or multiple motions.

The process begins with determining the structure's natural frequencies and damping ratios through modal analysis. The response spectrum for the given ground motion is then used to estimate the peak response for each vibration mode. These individual peak responses are combined to estimate the structure's overall peak response.

RSA is a widely adopted and effective technique in the design of buildings and other structures to ensure they can withstand earthquakes and other dynamic forces.

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## OBJECTIVES

The goals of the learning can be listed following:

- Analyse the effects of earthquakes on structural systems by evaluating critical parameters such as Maximum Story Displacement and Maximum Story Drift.
- Compare the performance of two structures: Structure-01, which employs different steel grades for different floors and Structure-02, which uses the same grade of steel throughout.

## METHODOLOGY

A detailed model of the G+10 steel-framed structure is first created in ETABS, incorporating key design parameters such as the number of stories, bay spacing, story height, and material properties. Structural elements, including section sizes and material strengths, are specified and integrated into the model. Seismic loads are applied in accordance with IS 1893:2016, and relevant load combinations are considered. The structure is analyzed under Seismic Zone II conditions, with a focus on critical response parameters such as maximum story displacement and story drifts. These parameters are then compared between Structure-01, which uses different steel grades for different floors, and Structure-02, which employs the same grade of steel throughout.

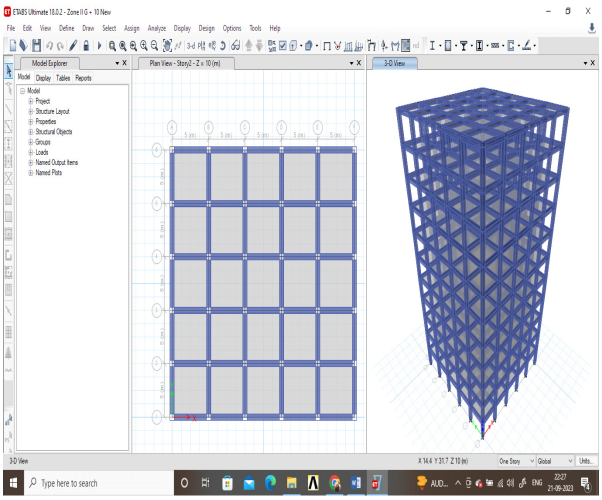

**Figure 1** Floor Plan

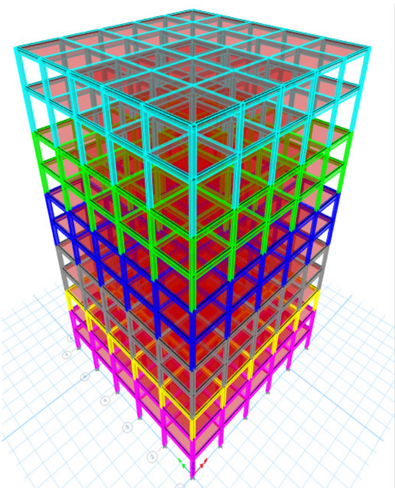

**Figure 2** 3D Elevation of the Structure – 01

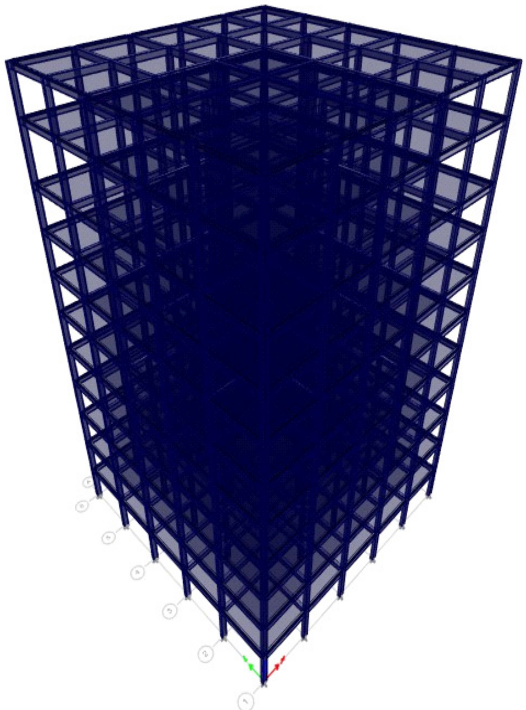

**Figure 3** 3D Elevation of the Structure – 02

**Table 1** Structural Details

| Sl. No | Item | Specifications |
|---|---|---|
| 01 | Material | Structural Steel |
| 02 | No. of Stories | G + 10 |
| 03 | No. of Bay in X – Direction | 05 |
| 04 | No. of Bay in Y – Direction | 05 |
| 05 | Bay spacing in X – Direction | 5000mm |
| 06 | Bay spacing in Y – Direction | 5000mm |
| 07 | Floor Height | 3500mm |
| 08 | Depth of Slab | 150mm |
| 09 | Size of Column | 600mm X 600mm |
| 10 | Size of Beam | 600mm X 600mm |
| 11 | Slab Section | Fe 400 |

**Table 2** Structural Configurations

| Grade of Steel for different floors | | | |
|---|---|---|---|
| Sl. No. | Structure Number | Grade of Steel | Floor Number |
| 01 | Structure – 01 | Fe 500 | For Ground Floor |
| | | Fe 450 | For 1st & 2nd Floor |
| | | Fe 400 | For 3rd & 4th Floor |
| | | Fe 350 | For 5th & 6th Floor |
| | | Fe 300 | For 7th & 8th Floor |
| | | Fe 250 | For 9th & 10th Floor |
| | | Fe 400 | Slab Section |
| 02 | Structure – 02 | Fe 400 | For all floors |
| | | Fe 400 | Slab Section |

The results presented in this analysis are based on the response spectrum analysis performed for the G+10 steel-framed structure located in Seismic Zone II, with the structural and loading details provided in Table 1 and Table 2.

**Response spectrum analysis**

In this section, the results of story displacements and story drifts were presented for Steel Framed Structure. The building was analysed for seismic zone II. As per clause 6.4.3 of IS 1893-2016.

**Maximum Story Displacement:**

The results for the Maximum Story Displacement (mm) across the two structures reveal key differences in seismic performance. Structure - 01, which uses different grades of steel for different floors, exhibits lower story displacements compared to Structure - 02, where the same grade of steel is used for all floors.

For example, at the top story (Story 11), Structure - 01 shows a maximum displacement of 39.945 mm, whereas Structure - 02 shows a higher displacement of 60.129 mm. This trend is consistent across all floors, indicating that the variation in steel grades in Structure - 01 results in better control over displacement under seismic loading.

According to IS 1893:2016, controlling story displacement is crucial to ensure that inter-story drifts remain within acceptable limits to prevent structural damage and maintain building integrity during an earthquake. The findings indicate that Structure - 01 is likely to perform better in minimizing seismic-induced displacements, thereby enhancing overall stability and reducing the risk of damage.

**Table 3** Maximum Story Displacement

| Maximum Story Displacement (mm) | | | |
|---|---|---|---|
| Story No. | Elevation | | |
| (m) | Structure - 01 | Structure - 02 | |
| Base | 0.000 | 0.0000 | 0.0000 |
| Story1 | 3.500 | 2.9140 | 4.7140 |
| Story2 | 7.000 | 7.1120 | 10.966 |
| Story3 | 10.50 | 11.481 | 17.405 |
| Story4 | 14.00 | 15.854 | 23.863 |
| Story5 | 17.50 | 20.147 | 30.225 |
| Story6 | 21.00 | 24.276 | 36.363 |
| Story7 | 24.50 | 28.140 | 42.128 |
| Story8 | 28.00 | 31.629 | 47.354 |
| Story9 | 31.50 | 34.682 | 51.934 |
| Story10 | 36.00 | 38.374 | 57.713 |
| Story11 | 39.50 | 39.945 | 60.129 |

**Maximum Story Drifts**

The Maximum Story Drift results for the two structures indicate key differences in their seismic performance. Structure-01, which utilizes different grades of steel for different floors, shows consistently lower story drifts across all stories compared to Structure-02, where the same grade of steel is used throughout.

This suggests that optimizing the grade of steel as per the specific demands of each floor can effectively reduce story drift, thereby enhancing the overall seismic resilience of the structure.

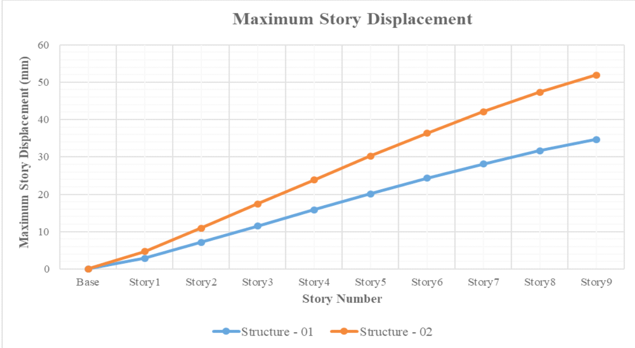


**Figure 4** Maximum Story Displacement

According to IS 1893:2016, controlling story drift is crucial to prevent excessive deformation, which can lead to non-structural damage and even compromise structural integrity. The results imply that Structure-01's approach to varying steel grades is more effective in maintaining lower story drifts, especially in the upper stories where seismic effects are typically more pronounced. This makes it a potentially more resilient option in seismic zones.

**Table 4** Maximum Story Drift

| Maximum Story Drift (mm) | | | |
|---|---|---|---|
| Story No. | Elevation | | |
| (m) | Structure - 01 | Structure - 02 | |
| Base | 0.000 | 0.000000 | 0.000000 |
| Story1 | 3.500 | 0.000833 | 0.001347 |
| Story2 | 7.000 | 0.001199 | 0.001786 |
| Story3 | 10.50 | 0.001248 | 0.001840 |
| Story4 | 14.00 | 0.001249 | 0.001845 |
| Story5 | 17.50 | 0.001227 | 0.001818 |
| Story6 | 21.00 | 0.001180 | 0.001754 |
| Story7 | 24.50 | 0.001104 | 0.001647 |
| Story8 | 28.00 | 0.000997 | 0.001493 |
| Story9 | 31.50 | 0.000872 | 0.001309 |
| Story10 | 36.00 | 0.000820 | 0.001284 |
| Story11 | 39.50 | 0.000449 | 0.000690 |

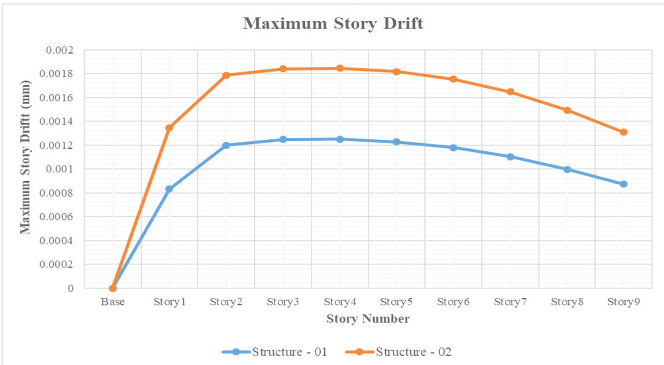


**Figure 5** Maximum Story Drifts

## CONCLUSIONS

Drawing from the sectional details outlined in Table 1 and Table 2, and considering the structure's location in Earthquake Zone II as per IS 1893:2016, the following conclusions can be drawn:

The analysis reveals significant improvements in seismic performance when using different grades of steel for different floors (Structure - 01) compared to using the same grade of steel throughout the structure (Structure - 02). Specifically, Structure - 01 exhibits a reduction in maximum story displacement by up to 38.18%, and a reduction in maximum story drifts by 38.15%. These findings suggest that customizing the grade of steel to the specific requirements of each floor can enhance the overall stability and resilience of the structure in response to seismic loading.

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