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ABSTRACT: Seismic analysis of reinforced concrete multi-storied buildings is decisive to ensure their structural integrity and safety during earthquakes. This study focuses on the seismic analysis of a reinforced concrete multi-storied building using the Indian Standard Code of Practice, specifically IS 1893 (Part 1):2016, which provides guidelines for earthquake-resistant design. The equivalent static load method, a simplified procedure for seismic analysis, is employed to determine the lateral forces acting on the structure due to seismic activity. Using structural analysis software, the building model is created with material properties, dimensions, and load conditions. The building s analysed for the seismic zones and various subsoil conditions. The results of the analysis include displacement, and story drift, which are evaluated to ensure compliance with the code's safety criteria. This method, while less complex than dynamic analysis, provides a practical approach for preliminary seismic design of buildings, ensuring adequate resistance to seismic forces in regions with varying seismicity levels.

KEYWORDS: Seismic Zones, Seismic Analysis, Equivalent Static Load, Design Base Shear, Storey Drift, Subsoil

Introduction

In view of fast urbanization and development of smart cities, lands in the cities are becoming expensive day – by – day. Therefore, vertical growth of a city is inevitable, which is achieved through the construction of high – rise buildings for residential as well as commercial use.

All developing smart cities are witnessing the transformation into a hub of high – rise buildings. Subsoil condition is one of the criteria while selecting a site for high – rise buildings. Due to limited availability of land irrespective seismic zones in India, it is inevitable to use the available land of any subsoil condition for the construction of multi – storied buildings. The present study focuses on the seismic analysis of a ground plus five (G+5) storey symmetric building based on IS 1893 Part-1 (2016).

Literature Review

The study compares seismic performance and design methodologies of a G + 22 reinforced concrete (RC) building using four major seismic codes: ASCE-7 (USA), EN1998-1 (Europe), NZS 1170.5 (New Zealand), and IS 1893 (India). It highlights differences in ductility classes, response reduction factors, drift estimation procedures, and reinforcement detailing. The study emphasizes that while modern seismic codes share a common design approach, significant variations exist in their specific provisions, affecting the expected seismic performance. This comparison underlines the need for uniformity in seismic design standards globally [1]. The research paper analyzes the seismic performance of a G+9 multi-storied building using

STAAD-Pro. It evaluates the building's response to seismic forces, focusing on different seismic zones as per Indian Standards (IS) codes. The study employs both static and dynamic analysis methods to assess key structural parameters like base shear, displacement, and drift. It concludes that STAAD-Pro is effective in optimizing structural design for seismic safety, highlighting its reliability in ensuring that multi-storied buildings meet safety standards while remaining cost-effective, especially in earthquake-prone regions [2]. The research paper explores the seismic behavior of a G+10 reinforced concrete building located in seismic zone V. The study focuses on buildings situated on sloping grounds with 0° and 10° inclinations and different types of soil strata (soft, medium, hard). The analysis is conducted using the ETABS software as per IS 1893-2016 standards. Key seismic responses such as horizontal displacement, bending moment, shear force, torsion, and storey drift are evaluated. Additionally, the study includes a cost comparison between buildings on sloping and level grounds, highlighting the structural and economic impacts of building on challenging terrains [3]. The analytical study explores the impact of seismic activity on multistory buildings, particularly in three seismic zones in India: III, IV, and V. The study is motivated by the growing need for vertical expansion in urban areas due to population increase and limited land availability. The research examines a G + 8 reinforced concrete (RC) building using ETABS software to compare base shear, percentage of longitudinal steel, and reinforcement details across the three seismic zones. The study finds that as the seismic zone increases from III to V, the base shear also increases, indicating stronger earthquake forces. Consequently, the demand for steel reinforcement in columns and beams rises, with significant differences in the amount of steel required for higher seismic zones. The findings highlight the importance of designing buildings with appropriate structural elements to withstand seismic forces, ensuring safety and durability in earthquake-prone areas [4]. The research work primarily compares the seismic design guidelines between two versions of the Indian Standard (IS) codes: IS 1893 Part-1(2023) Draft and IS 1893 Part-1(2016). The study's objective is to evaluate how changes in the guidelines impact the structural safety and performance of high-rise buildings during earthquakes. Key aspects explored include the spectral acceleration response, changes in fundamental periods, modal participation factors, and damping ratios. The research uses response spectrum analysis to observe the building's behavior under seismic loads and examines whether the updated provisions in the 2023 draft offer improved resilience compared to the 2016 guidelines. The paper concludes that understanding these differences is crucial for developing more effective earthquake-resistant designs, enhancing the safety and stability of tall buildings in seismic zones. It emphasizes the importance of continuously updating seismic design standards to ensure buildings can withstand future seismic events [5].

The present study focusses on the variation in Storey Drift of a G + 5 multi-storied symmetric building based on the zones and soil type as per IS 1893 Part-1 (2016) using structural analysis software.

Methodology:

In the present work a symmetric G + 5 Reinforced Cement Concrete (RCC) building [7] has been analyzed for seismic forces (refer with Fig. 1a & 1b).

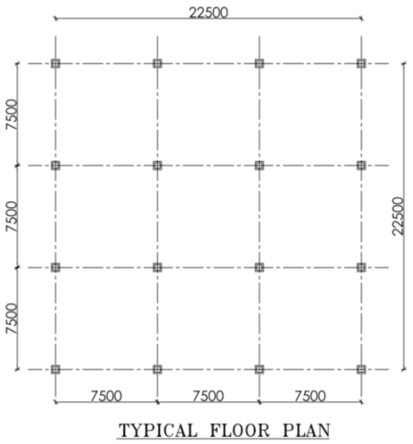

Fig. 1a

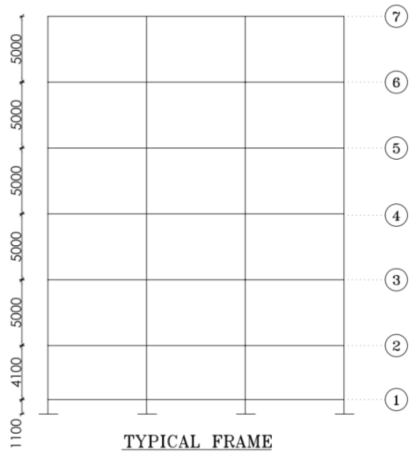

Fig. 1b

The building specifications are as follows:

S.N.	Particulars	Specifications	Remarks
1	Column Size below plinth	600 mm x 600 mm	-
2	Column Size above plinth	500 mm x 500 mm	-
3	Main Beam Size	300 mm x 600 mm	-
4	Secondary Beam Size	200 mm x 600 mm	-
5	Slab Thickness	100 mm	-
6	External Wall Thickness	230 mm	-
7	Grade of Concrete	M25	-
8	Grade of Rebar	Fe415	-

Flow of the study is as mentioned below:

1. Gravity and Imposed load calculations at Terrace, Typical Floor and Ground Levels
2. Storey-wise Seismic Weight calculation
3. Seismic Load calculation for Zones II, III, IV & V for Hard Soil, Medium Stiff Soil and Soft Soil
4. Analysis of the Space Frame for various combination of Zones and Soil Type using software
5. Storey Drift computation in each case of loading and its comparison

A 3 dimensional space frame (without slabs and secondary beams) is modeled in analysis software. The dead loads due to walls, secondary beams & slabs and Imposed load are applied in the form of point loads and uniformly distributed loads on the appropriate main frames. Floor wise seismic weight of the building is computed. Reduction in the Imposed load is considered as per IS 1893 (Part-1): 2016. The seismic analysis is conducted by Equivalent Static Load Method. Depending upon the seismic zone and soil type, base shear is computed and distributed amongst all the storeys. Refer with the table no. 1 for the various cases adopted for the analysis. The building being symmetric, the lateral load analysis presented here is only in one (X) Direction.

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Table 1: Seismic Zone Wise cases based on Soil Type

Case	Seismic Zone	Soil Type	Abbreviation
1	II	Hard Soil	AZ2H
2		Medium Stiff Soil	AZ2M
3		Soft Soil	AZ2S
4	III	Hard Soil	AZ3H
5		Medium Stiff Soil	AZ3M
6		Soft Soil	AZ3S
7	IV	Hard Soil	AZ4H
8		Medium Stiff Soil	AZ4M
9		Soft Soil	AZ4S
10	V	Hard Soil	AZ5H
11		Medium Stiff Soil	AZ5M
12		Soft Soil	AZ5S

Analysis of the Building:

A space frame is modeled which consists of 168 main beams and 16 columns with fixed base (refer with Fig. 2), to represent ground + five storey building. The grade of concrete and steel assigned to the frames are M20 and Fe415 HYSD. The load cases and patterns used are Dead load, Imposed load, and Earthquake load. The combinations of the loads are taken as per IS 1893 (Part-1): 2016. The building being symmetric about both the axes, seismic loads are considered only in one direction for the purpose of the lateral load analysis. The very objective of the study is to understand the effect of change in seismic zones and type of soil on the storey drift for the unaltered specifications of the building elements. Therefore, the seismic weight of the building which is computed as 39515 kN remains constant for all the combinations of seismic zones and type of soil. The base shear computed depends on the seismic zone and type of soil (refer with the table no. 2). The base shear is distributed storey-wise as lateral load over the four frames along the direction of earthquake (refer with table no. 3). In view of symmetry, centre of stiffness and centre of mass coincide over each other. Therefore, static eccentricity is equal to zero and torsion is computed using accidental eccentricity and applied on the model about the vertical axis through the centre of the building.

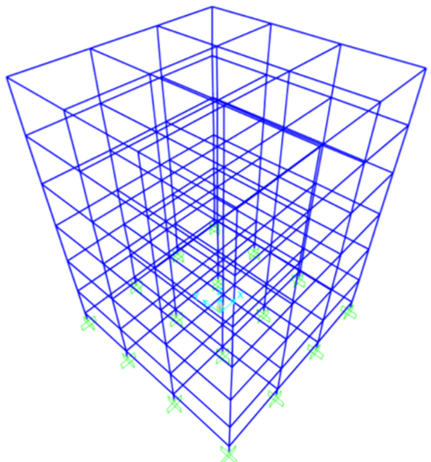

Fig. 2 Analytical Model of the Building

Table 2: Design Base Shear based on Seismic Zone & Soil Type

Case No.	Case	Design Base Shear (kN)
1	AZ2H	613
2	AZ2M	834
3	AZ2S	1024
4	AZ3H	982
5	AZ3M	1335
6	AZ3S	1639
7	AZ4H	1472
8	AZ4M	2002
9	AZ4S	2459
10	AZ5H	2208
11	AZ5M	3004
12	AZ5S	3688

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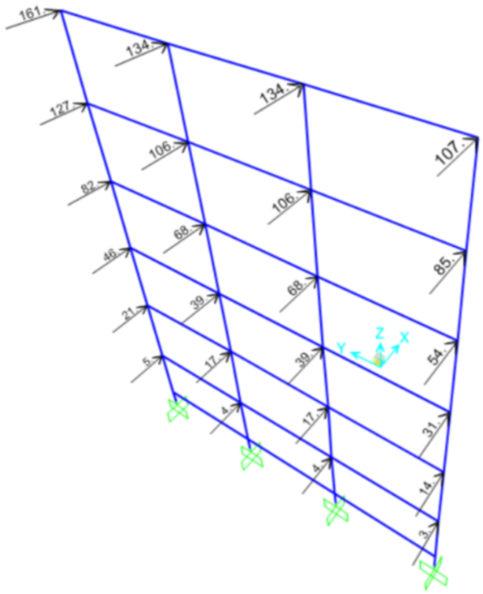

Fig. 3 Case: AZ4H_Seismic Forces (kN) acting Storey-wise in +X direction with positive torsion

Table 3: Distribution of Design Shear for the Case AZ4H

Storey	W_i (kN)	h_i (m)	$W_i.(h_i)^2$	Q_i (kN)	V_i (kN)
7	5646	30	5149537	535	535
6	6420	25	4076941	424	959
5	6420	20	2619607	272	1231
4	6420	15	1483271	154	1385
3	6420	10	667934	69	1455
2	6179	5	167068	17	1472
1	2011	1	2433	0	1472
Total	**39515**	**-**	**14166791**	**1472**	**-**

Referring with the Fig. 3 and table 3, storey shear at the 7th level is 535 kN which is distributed amongst 4 frames at the joints as 161 kN, 134 kN, 134 kN & 107 kN. Similarly at each level, the storey shear is distributed and storey displacements are recorded. Thus, for all the 13 cases computation of design base shear, storey shear, storey displacements and storey drift is executed. The variation of the design base shear with respect to the seismic zones & type of soil are as shown in the Fig. 4a to Fig. 4d.

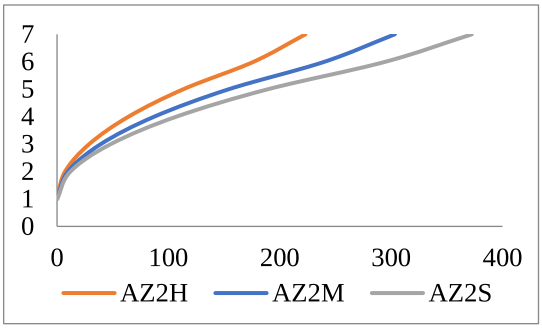

Fig. 4a Storey-Wise Distribution of Design Base Shear (kN) for Zone II

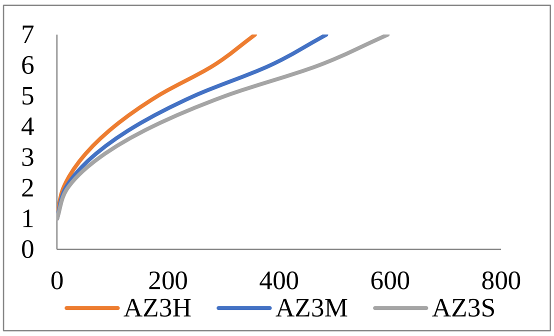

Fig. 4b Storey-Wise Distribution of Design Base Shear (kN) for Zone III

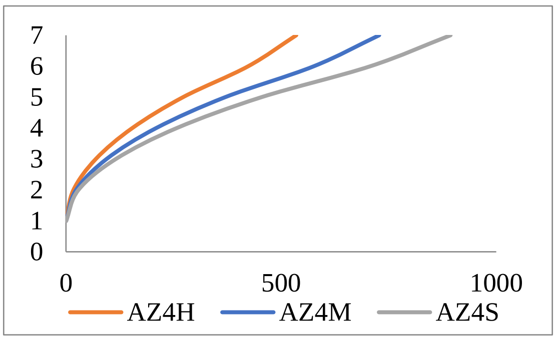

Fig. 4c Storey-Wise Distribution of Design Base Shear (kN) for Zone IV

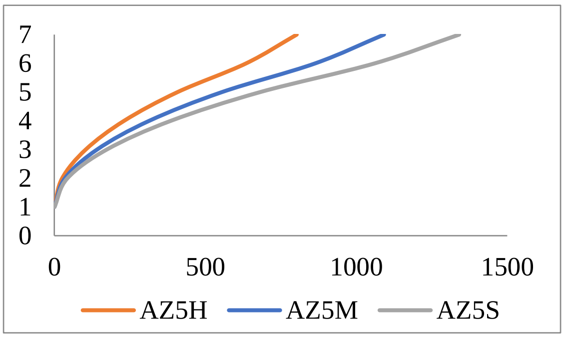

Fig. 4d Storey-Wise Distribution of Design Base Shear (kN) for Zone V

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The maximum permissible storey drift at a particular storey is 0.4% of the storey height[8]. Thus, for the storey height of 5 m, the maximum permissible storey drift is 20 mm and for the storey height of 4 m, the maximum permissible storey drift is 16 mm. The variation of storey drift along the height for various zones and types of soil stratum are as shown in the Fig. 5a to Fig. 5c.

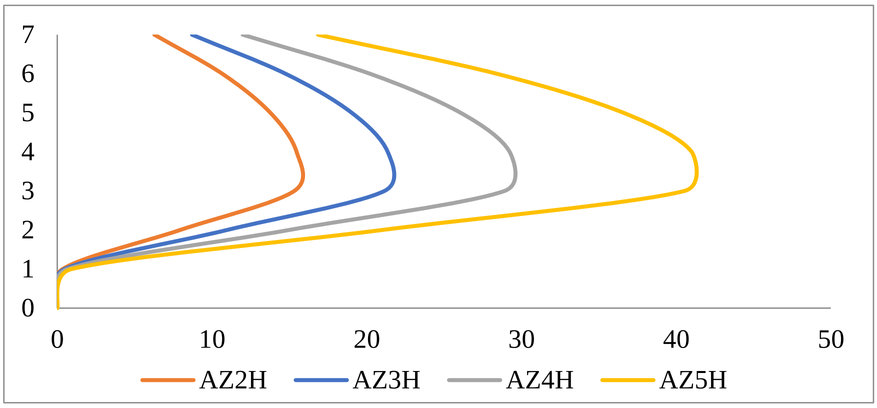

Fig. 5a Zone-Wise Storey Drift (mm) for Hard Soil

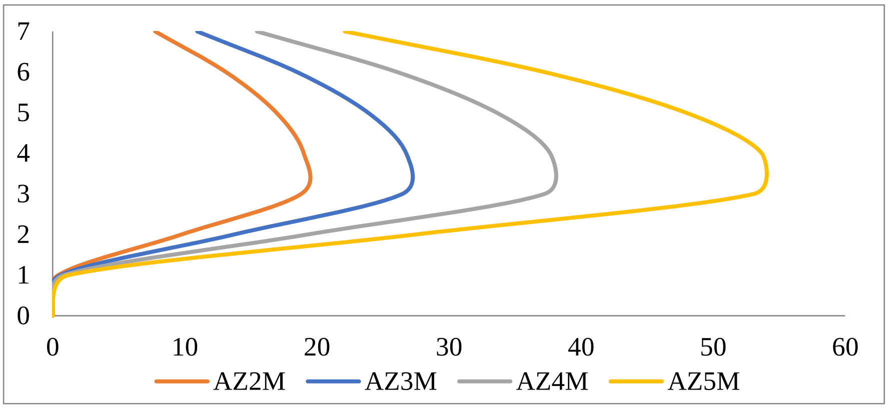

Fig. 5b Zone-Wise Storey Drift (mm) for Medium Soil

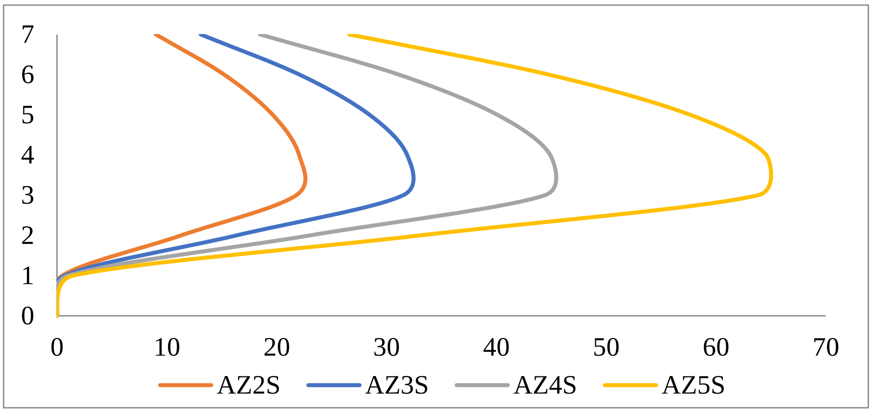

Fig. 5c Zone-Wise Storey Drift (mm) for Soft Soil

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Results & Discussion:

Design Base Shear: The design base shear values are computed for the same building located at seismic zones II to V respectively for Hard, Medium and Soft Soil conditions. Considering the base shear computed for Zone II as the reference value, base shear values for other seismic zones are compared. In case of any of the three types of Foundation Soil conditions, base shear values for seismic zone III, IV and V are respectively observed 1.6 times, 2.4 times and 3.60 times greater than that for the seismic zone II.

Storey Drift: The permissible values of the storey drifts are 20 mm and 16 mm respectively for 5 m and 4 m storey heights. The maximum values of storey drift observed for the seismic zones II to V respectively for the Hard, Medium & Soft Soil Type are as mentioned in the table no. 4

Table 4: Seismic Zone-Wise Maximum Storey Drift (mm) based on subsoil condition

Case No.	Case	Maximum Storey Drift (mm)		Case No.	Case	Maximum Storey Drift (mm)
1	AZ2H	15.47		7	AZ4H	29.24
2	AZ2M	19.01		8	AZ4M	37.67
3	AZ2S	22.05		9	AZ4S	44.92
4	AZ3H	21.36		10	AZ5H	41.01
5	AZ3M	26.77		11	AZ5M	53.69
6	AZ3S	31.89		12	AZ5S	64.60

The maximum storey drift irrespective of seismic zones and soil conditions is observed at 4th storey which is 5 m in height. The permissible maximum storey drift is 20 mm at that storey. It is evident that the building satisfies the maximum storey drift criterion in the seismic zone II only, for hard subsoil and medium soil conditions. Even if the building is located in the seismic zone II, due to soft soil condition, the storey drift has exceeded the maximum permissible value.

Summary:

The seismic analysis carried out for a multi storied building using equivalent static load method for various seismicity zones is summarized as:

(i) The exponential increment of 3.6 times is observed in the base shear values computed for the seismic zone V for all the types of soil conditions when compared with the base shear in seismic zone II in the corresponding type of soils.

(ii) In case of soft subsoil condition, seismic analysis should be carried out even if a multi-storied building is located in the seismic zone II.

(iii) Higher column sizes from the footing top to the 4th storey may reduce the storey drift to the permissible limits as per IS 1893 (Part-1):2016. For the upper storey, the column sizes may be reduced.

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