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ARTICLE

A Comparative Study on Seismic Analysis of Multistorey Buildings in Different Seismic Zones

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ABSTRACT

The multi-story buildings are constructed to accommodate numerous residents in confined spaces due to the growing population and lack of available land. The population growth and industrial revolution caused a migration of people from rural to urban areas resulting in the need for the construction of multi-story buildings for both residential and commercial uses. The tall buildings, which are not adequately constructed to resist lateral stresses, result in the total collapse of the structure. Buildings that can withstand earthquake forces are created by considering different criteria such as the building's inherent frequency, damping factor, kind of base, significance of the building and ductility of the structure. Because they have better moment distribution properties, structures designed for ductility need to be designed for lower lateral loads. To ensure safety against the seismic stresses of multi-story buildings, it is essential to understand seismic analysis in order to develop earthquake-resistant structures. Both a regular moment-resisting frame and a special moment-resisting frame were taken into account for the seismic study. In the present study, a G + 8 storey reinforced concrete (RC) structure in three different seismic zones was compared in terms of percentage longitudinal steel, reinforcement details, and design base shear. The structure was examined for seismic zones III, IV, and V in accordance with the guidelines of IS 1893 (Part 1): 2016. Results showed that base shear increased with the change in the seismic zone from III to V.

Keywords: Multistorey building; ETAB; Base shear; Seismic zone; Reinforcement steel

1. Introduction

Earthquakes occur due to the abrupt movement of one of the planet's several strata, which releases an enormous amount of energy. An earthquake strikes swiftly, violently, and abruptly without warning.

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It could harm improperly constructed or designed structures, putting the residents in danger or perhaps killing them. The term "metal assembly procedure" describes a construction method in which large chunks of fresh concrete or steel deck are connected to the concrete element using the hydraulic compressive connection, allowing the two parts to function as a single, cohesive block [1].

The majority of the structures used for construction in India are low-rise buildings. Due to the ease of construction and economy realized, steel and concrete members are therefore frequently employed for these constructions. However, the alarming rate of population increase and the scarcity of available land has made it necessary for buildings in many cities to expand vertically. Therefore, a lot of medium- to high-rise structures are being built these days to serve the objectives [2]. It has been determined that the usage of composite parts over reinforced concrete beams is more efficient and cost-effective for these high-rise structures. A response spectrum analysis is used for assessing the structural reaction to quick, nondeterministic, transient dynamic events. Earthquakes and shocks/impacts are two examples of these occurrences. It is challenging to carry out a time-dependent analysis because the precise time history for the load is unknown. The short duration of the event prevents it from being categorized as an ergodic ("stationary") process, hence a random response strategy is also not appropriate. A unique kind of mode superposition serves as the foundation for the response spectrum approach [3].

ETABS is used to analyse and design multi-story buildings. The grid-like geometry specific to this form of construction is taken into account via modelling tools and templates, code-based load prescriptions, analysis techniques, and solution approaches. ETABS can be used to analyse simple or complex systems under static or dynamic conditions. Modal and direct-integration time-history analyses may be coupled with P-Delta and Large Displacement effects for a sophisticated evaluation of seismic performance. Under monotonic or hysteretic behaviour, nonlinear linkages and concentrated PMM or fibre hinges may capture material nonlinearity. It is possible to develop applications of any complexity due to its intuitive and integrated features.

Cholekar and Basavalingappa [4] compared the multistorey RCC and composite building in terms of base shear, storey drift and displacement using SAP2000. Results showed that the joint displacement values were small in composite structures than RCC structures. Pallavi and Nagaraja [5] compared the seismic analysis of multistoried building (G + 9) with shear wall and bracing using ETAB 9.7 software. The comparison was made in terms of storey displacement, storey drift and base shear. The addition of shear wall in the building had higher strength than bare model frame and bracing. Base shear for Zone V and Zone IV was increased by 41.2% and 52.4% for placing of shear wall at the corners as compared to bare model frame. Vikram et al. [6] analysed the residential multi-storey building (G + 5 storey) against the seismic load using ETABS software in different seismic zones II, III, IV and V. Zone II provide better stability and Zone V had maximum axial force. Kumar and Needhidasan [7] studied the analysis of multistorey building (G + 8) in different seismic zones (II and IV) using STAAD Pro software in base shear, storey drift and movement of the building. Results showed that base shear, lateral force, storey shear and overturing moment increased in both the direction as seismic zone goes from II to IV. The equivalent static lateral force method had a higher value of moment and force resulting higher cost than response spectrum method. Thapa et al. [3] compared the analysis of reinforced concrete structure with steel framed structure in terms of materials, storey drift, base shear using ETABS 2016. Results showed that reinforced concrete structures required higher amount of raw materials compared to steel structure. The value of base shear and storey displacement was lower and storey stiffness was maximum for steel structure compared to RC structure.

The major objective of this study is to compare the percentage of longitudinal steel, reinforcement details, and design base shear of a single G + 8 story reinforced concrete (RC) structure in three different seismic zones i.e., III, IV and V of India using the ETABS analytical model. In the beginning, this structure was examined in accordance with IS:1893 [8]. Dimensioning and calculations were done to determine the weight of the necessary steel and the volume of the necessary concrete. A comparison was done between the data from the three seismic zones, which are reported in detail for each structural component of the building separately and for the entire building.

2. Methodology

2.1 Building description

The floor plan of the building had dimensions 28 × 20 m, therefore total area of the floor plan was equal to E = 560.00 m^2. The height of the floors was h = 3.60 m, except for the height of the first floor (ground floor) which was h = 4.20 m. Therefore, the total height of the building was h_{tot} = 33 m. Rigid supports are used and the effect of soil is neglected. The description of the building has been given in **Table 1** and the plan view has been shown in **Figure 1**. The flow diagram of the methodology has been shown in **Figure 2**.

Table 1. Building description and parameters.

Sr. No.	Parameter	Value
1	Shape of building	Rectangular
2	Length	28 m
3	Width	20 m
4	Grid spacing	4 × 5 m
5	Number of storey	9 (G + 8 + T)
6	Wall type	Red Brick
7	Support condition	Fixed support at base
8	Depth of footing:	2 m below Plinth Level
9	Height of storey	4.2 m (G to 1st) & 3.6 m typical (1st to Terrace)
10	Total height of building	33 m

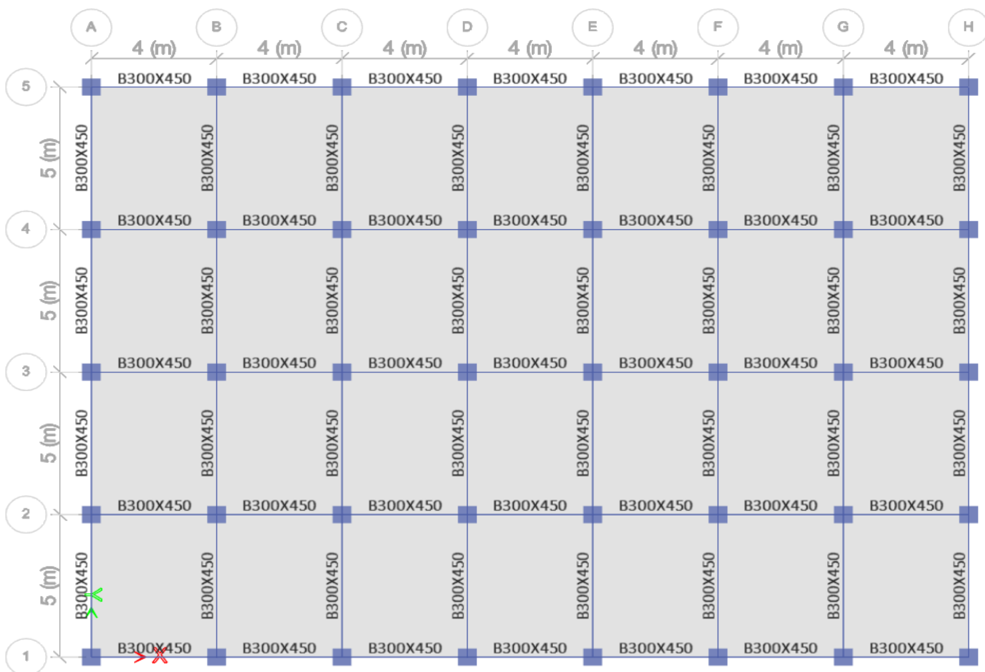

Figure 1. Plan view.

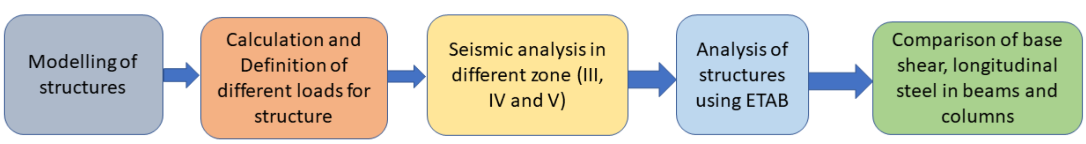

Figure 2. Flow diagram for the methodology.

2.2 Design philosophy of structure

Buildings are designed as RCC framed structure from ground to terrace supported over columns and shear walls as per IS: 1893 [8]. The framing system made of the vertical load supporting system was structural RCC columns. The earthquake forces are transferred with framed action of the structural system. As per IS: 1893 [8], Linear dynamic analysis will be performed for buildings greater than 15 m height category and static analysis for other minor structures. Concrete of specified grades (mentioned in clause 6.2) is used for concrete members like beam, column, retaining wall, foundation system etc. Appropriate measures are being taken for durability and fire requirement up to 2-hour fire rating. Wherever steel surfaces are kept exposed without any fire-rated cladding, in such case intumescent paint is proposed. The paints and colour combinations will be finalized as per architectural intent along with fire and rust-proofing requirement. **Figure 3** shows the 3D render view of the building.

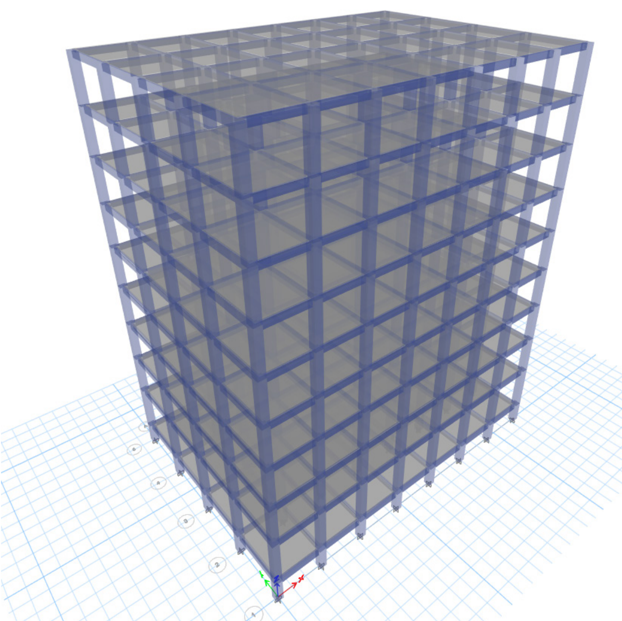

Figure 3. 3D render view.

2.3 Material grade, cover and section sizes

The primary size of the different components has been given below.

Columns	: 300-450 mm wide & 450-750 mm depth
Shear walls	: 200-300 mm thick
Plinth Peripheral beams	: 300 mm wide & 450/600/750 mm deep
Main/secondary Beam	: 300/450 mm wide & 450/600 mm deep
Slab	: 150 to be provided
Retaining Walls	: Not Used

For the Main Hospital Building Minimum Grade of concert proposed is M30, however for other buildings M25 shall be considered as a Min Grade of concrete. The reinforcement to be used in the construction is Fe500D which is corrosion resistant steel, having min yield strength is 500 N/mm^2. For lateral ties in columns and beams, steel strength Fe415 shall be used as per IS: 13920 [9] provisions. Dead load and live load were calculated as per IS: 875 (Part 1 and 2) [10,11] respectively. For Simplifying the analysis, an average value of live load as 2.5 KN/m^2 has been considered. The proposed buildings' following factors shall be considered in design as per IS: 1893 [8] and have been given in the table. The load combinations used for this analysis have been given in **Table 2**. The response spectrum function for different zones i.e. III, IV and V have been shown in **Figures 4 (a), (b) and (c)**, respectively.

Table 2. Design parameters for seismic load analysis.

Sr. No.	Parameters	Value
1	Seismic zone	III, IV & V
2	Zone factor	0.16, 0.24 & 0.36 Respectively
3	Importance factor, I	1
4	Response reduction factor, R	5 (For RC Building with SMRF
5	Damping ratio	5%
6	Soil type	2 (Medium)

3. Analysis of result

3.1 Design base shear

For the various seismic zones, the design base shear of a G + 8 story structure was evaluated and

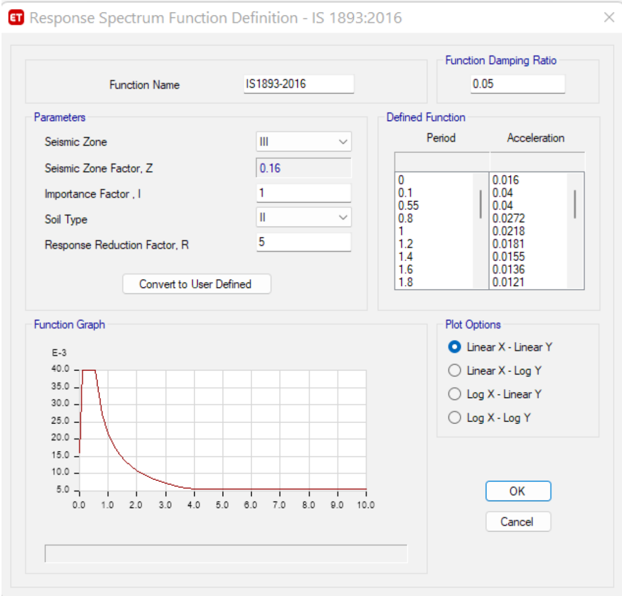

Figure 4(a). Response spectrum function—For Zone III.

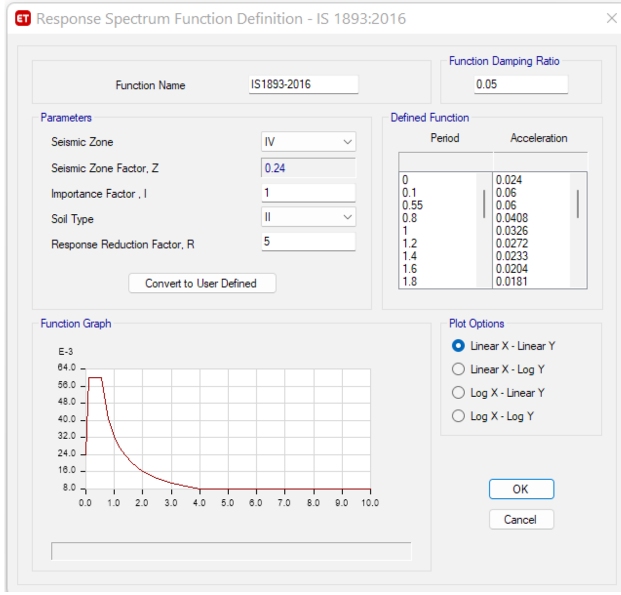

Figure 4(b). Response spectrum function—For Zone IV.

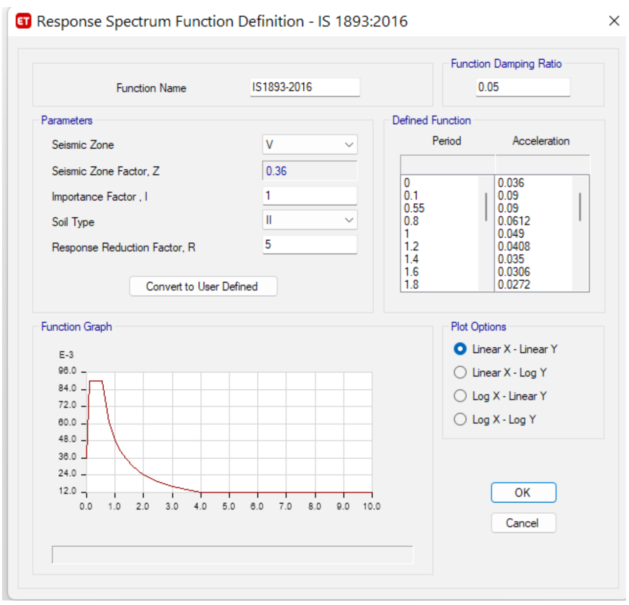

Figure 4(c). Response spectrum function—For Zone IV.

compared. The variation of base shear with the seismic zone has been shown in **Figure 5**. The corresponding static approach was used for this analysis as per IS 1893 [8]. Base shear increased from Zone III to Zone V, indicating that the earthquakes in these regions are becoming stronger.

3.2 Comparison of longitudinal steel in column

The total quantity of steel on the floor was calculated. **Figure 6** illustrates how different seismic zones affect the proportion of longitudinal rebars in the column. The quantity of steel in various levels of columns goes from 0.0% to 3.5% as seismic zone varies from Zone III to Zone V, and the overall amount of steel in all columns changes from 1.1% to 3.1%. **Figure 6** illustrates that the first floor had the highest percentage of longitudinal steel requirement followed by 2nd and 3rd floor. It was evident from **Figure 7** that the demand for steel reinforcement increased as the danger of earthquake increases or moving toward the high seismic zone area.

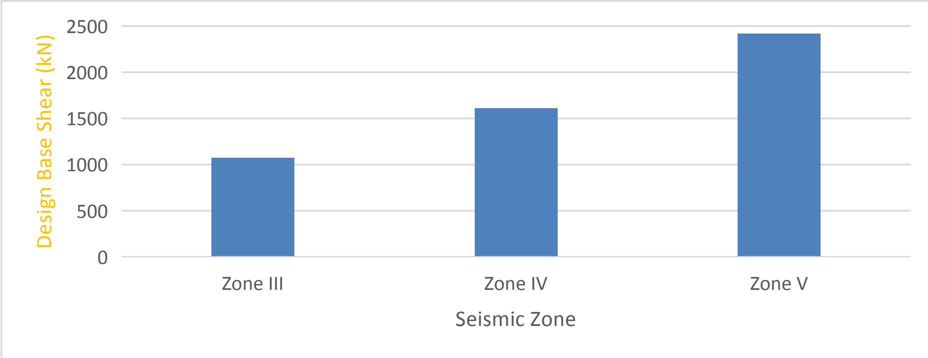

Figure 5. Design base share value for the buildings at different seismic zone.

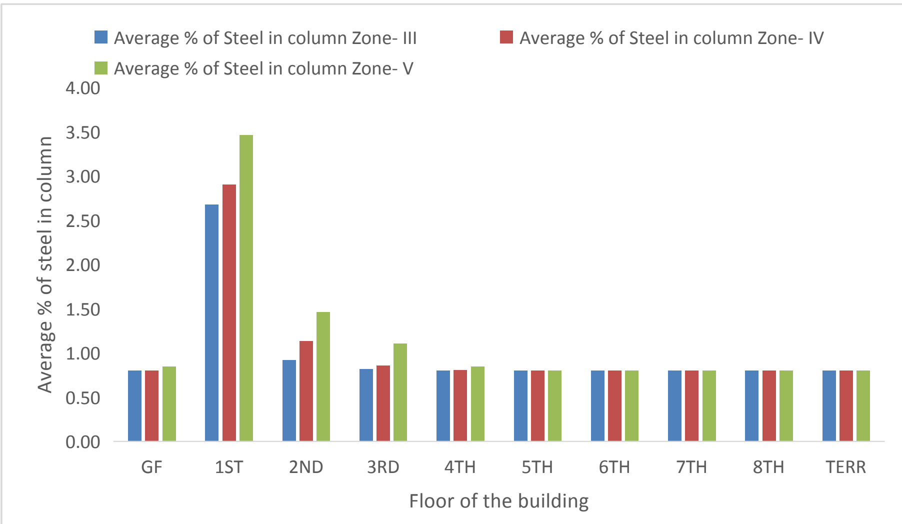

Figure 6. The average percentage of longitudinal steel in different levels of the column in a different seismic zone.

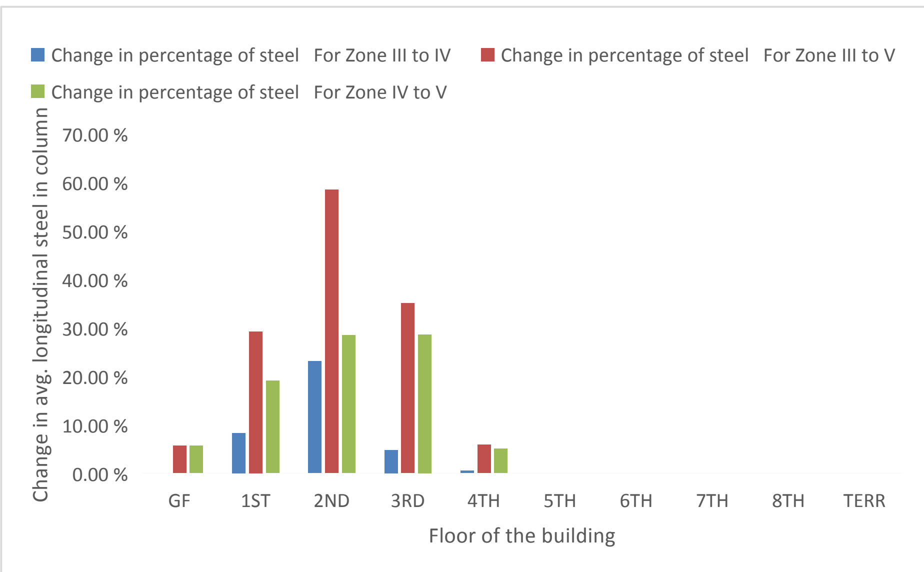

Figure 7. Change in the average percentage of longitudinal steel in different levels of the column in a different seismic zone.

The variation in the average percentage of longitudinal steel in the different levels of a column in seismic zones III, IV and V have been illustrated in **Figure 7**.

3.3 Comparison of longitudinal steel in beam

A structural element is known as a beam support load primarily by bending. A beam bends around its neutral axis as a result of a bending moment that forms inside the beam as a result of external stresses on the beam, its own weight, and external responses. The proportion of longitudinal steel is computed at the supports and midway during the span. The required longitudinal steel in beam at the top and bottom in different seismic zones has been shown in **Figure 8**. The requirement of longitudinal reinforcement for the beam at the top and bottom increased as the seismic zone changed from Zone III to V. The maximum reinforcement was required at Zone V. It is evident from **Figure 8** that the requirement for steel reinforcement increased with the increase in the risk of earthquake forces.

3.4 Comparison of steel detailing in column and beam

Buildings in Zone II are made with ordinary moment resisting frame (OMRF) and are detailed as per IS: 456: 2000, All buildings in Zones III, IV, and V, on the other hand, are made with special moment resisting frame (SMRF) and are detailed according to IS: 13920: 2016. After careful consideration to the results, it was found that the value of base shear increased with the variation of seismic zone from III to V which signify the higher intensity of earthquake. A higher value of base shear indicates the almost twice increase in the amount of steel requirement for beam and column with the change in zone from III to V.

4. Conclusions

In the present study, G + 8 storey building was analysed for base shear, longitudinal steel in beam and column and compared for different seismic zones using ETAB software. The following points were observed from the above study:

1) There was a significant increase in base shear was observed with the change in seismic Zone II to Zone V, which shows that the earthquakes in these areas are getting stronger.

2) The amount of Top longitudinal steel at support sections varies from about 0.23% to 0.46% in beams.

3) The amount of Bottom longitudinal steel at support sections varies from about 0.23% to 0.36% in beams.

4) The amount of bottom midspan reinforcement increased by about 13-35% in beams.

5) The amount of bottom midspan reinforcement

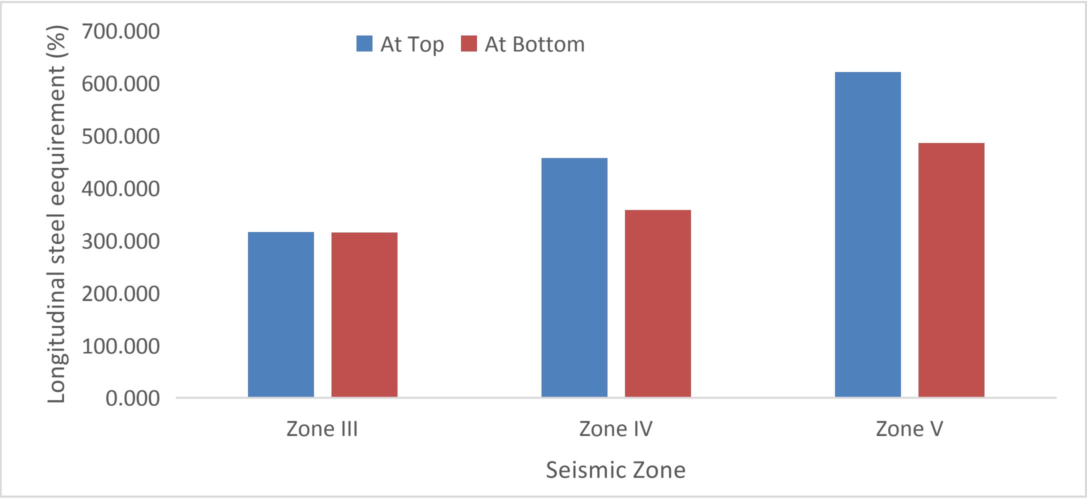

Figure 8. Average required longitudinal steel in the beam at top and bottom in a different seismic zone.

increased by about 44-96% in beams.

6) The overall requirement of steel steadily increased by approx. 35% from seismic Zone III to V.

7) For the column, reinforcement increases in the bottom three levels of building then it goes flat.

Author Contributions

Kiran Devi: supervision, editing, analysis of results, design of article; and Subhankar Petal: concept, analysis of data, draft for the article.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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