A Review on Seismic Performance Evaluation of High-Rise RCC Buildings for Different Seismic Zones and Soil Types

AKSHAY PAWAR[1], SANJAY DESHMUKH[2]
[1] *Student, M. Tech. Structural Engineering, Department of Civil Engineering, K. E. Society's, Rajarambapu Institute of Technology, Rajaramnagar (Islampur), Dist., Sangli, MS, India*
[2] *Assistant Professor, Department of Civil Engineering, K. E. Society's, Rajarambapu Institute of Technology, Rajaramnagar (Islampur), Dist. Sangli, MS, India*

Abstract— Structural engineers play a crucial role in designing earthquake-resistant structures, especially for high-rise RCC buildings situated in various seismic zones and built on different soil types. Earthquakes alter the strong ground motion, potentially leading to structural failure, and the impact of these events largely depends on the soil type where the RCC building stands. This paper employs ETABS, STAAD Pro, and SAP2000 software to conduct evaluations using the equivalent static method and response spectrum method. These evaluations aim to examine the effects of different soil types and seismic zones on high-rise RCC buildings. An extensive literature review is undertaken to comprehend the seismic behaviour of high-rise RCC buildings across various soil types and seismic zones. The study identifies the most suitable and cost-effective conditions that ensure the maximum serviceable life of high-rise buildings.

Index Terms- Earthquake-resistant structures, Seismic zones, Soil types, High-rise RCC buildings, Seismic evaluation.

I. INTRODUCTION

Everywhere in the globe, there is enormous demand for new construction due to population growth and urbanization, and high-rise buildings are particularly vulnerable to earthquake damage [18]. A building having a height between 50 to 250 meters is called a high-rise building according to IS:16700-2017 [7]. An assessment of a high-rise reinforced concrete (RCC) building's seismic performance entails determining how effectively it can resist forces caused by earthquakes [11]. This process is very crucial for ensuring the safety and integrity of structures in regions prone to seismic activity. In India, seismic zones are categorized, based on their vulnerability to earthquakes, ranging from Zone II (low seismicity) to Zone V (high seismicity). Additionally, the soil type such as soft, medium, and hard soil at a site importantly influences the building's response to strong ground motion. Four seismic zones have been defined in India based on the probable occurrence of earthquakes [21].

These zones are:
Zone II: This zone is considered to have the least seismic activity and is therefore the least vulnerable to earthquakes. It includes parts of northern and eastern parts of India.
Zone III: This zone is moderately active and includes areas of the central part of India, parts of Gujarat, and some areas along with Himalayan region.
Zone IV: This zone is subjected to a higher level of seismic activity and consists of areas of northeastern India, Himachal Pradesh, Uttarakhand, and Jammu & Kashmir.
Zone V: This is the most seismically active zone and includes areas along the western coast, the Kutch region of Gujarat, and some parts of the Himalayan belt [2].
The details of the three soil types are briefly explained in the following section.
Soft Soil: During an earthquake, soft soils like clay or loose sand tend to magnify greater movements of the ground. This can lead to more severe shaking and potential ground failure, which can be particularly dangerous for any structures that are not designed to withstand such earthquake-resistant construction [3].
Medium Soil: Medium soils, which are typically a mix of sand, silt, and clay, can also affect ground motion but to a lesser extent than soft soils. They provide a

somewhat better foundation for buildings, but it's still important to consider their properties in earthquake-resistant construction [3].

Hard Soil: Hard soils, like rock or dense clay, transmit seismic waves more efficiently. This generally leads to less amplification of ground motion compared to soft and medium soils. Structures on hard soils are generally less susceptible to settlement or liquefaction [10].

The details of storey drift, storey shear, base shear, storey displacement and time period are briefly explained in the following section.

Story Drift: The relative lateral displacement between the floors above and/or below the storey under concern during an earthquake is known to as story drift [13].

Storey Shear: The overall lateral forces produced by design during an earthquake at al levels above the storey are known as storey shear.

Base Shear: Base shear is the total lateral force that a building's foundation experiences during an earthquake or other lateral loads. It is the force that tries to move the structure laterally at its base [15].

Story Displacement: Story displacement refers to the lateral movement or displacement of a particular level (storey) of a building from its original position due to seismic forces or other lateral loads.

Time period: The time period of a building or structure is a measure of how quickly it vibrates back and forth after being subjected to external force, such as an earthquake. It is time taken for one complete cycle vibration [5].

II. LITERATURE REVIEW

Regarding the seismic performance evaluation of RCC buildings for various seismic zones and soil types, a thorough literature analysis is conducted using the research works published in various national and international journals. The results have been thoroughly reviewed and provided in the part that follows.

Kamble and Awchat (2018) authors of this work used STAAD.Pro and ETABS to study the analysis and design of high-rise (G +20 story) structures. The study's conclusions indicate how base shear and story drift are taken into account and provide an effective lateral load-resisting system. It also concludes that the software STAAD-Pro and ETABS produce almost identical results. It is determined that high-rise modeling can be done using both software [14].

Pechorskaya et al. (2021) used ETABS and RSA software to analyze the high-rise structures and evaluated the effects of the results on design from the two software programs. The researchers found 8.75 percent excess axial load for the edge columns by RSA software than the ETABS software. Researchers concluded from the data that the moments and forces provided by RSA had higher results than those generated by the ETABS software. Although RSA software performs better than ETABS software, RSA software has not been thoroughly studied, hence ETABS software is used by researchers for more research [19].

According to the relevant laws and standards, Kumar et al. (2020) provide the design verification G + 8, RCC general commercial building in Hyderabad, Telangana. The authors provided an explanation of the functional requirements of the construction, loads and load combinations, the quality of the materials, and the techniques used for the research and design of the building. The findings of the analysis and design made using software STAAD. Pro & ETABS 2017 have been simplified by the authors. The analysis and design of structural members made using STAAD Pro and ETABS were compared. It was concluded that the results obtained using ETABS and STAAD Pro are almost equivalent. Professional software reduces the amount of time required to perform design and analysis [17].

In their present study, Duppati et al. (2021) used the STAAD Pro program to design a G + 5 residential building utilizing the static equivalent method of analysis. In the X and Z directions, the cumulative displacements in this earthquake region from zone II to zone V are 7.263 mm, 15.174 mm, 16.72 mm, 25.003 mm, and 10.788 mm, 22.973 mm, 25.337 mm, and 38.002 mm. The maximum storey drifts in the X and Z are likewise 2.692 mm, 5.175 mm, 5.331 mm, 7.903 mm, and 3.896 mm, 6.955, 7.912 mm, and 11.848 mm, respectively. The results indicate that storey displacement and drift increased not only from the bottom to the top but also that they rose from zone II to zone V in both directions [9].

For various regular and irregularly shaped G+10 RCC buildings, Haque et al. (2016) executed static and dynamic analysis, which is similar to static analysis, response spectrum analysis, and time history analysis. The author used RCC building frames that were square, rectangular, L-shaped, and W-shaped, among other regular and irregular shapes. SAP and ETABS are used in zone 3 to analysis the 10-storey RCC building frame. Response spectrum analysis results show that there is a greater displacement for irregularly shaped building frames than for regularly constructed buildings. Additionally, the impacts of the earthquake force on static analysis are almost the same for all models, with the exception of model 1, which has a W shape and is the model most prone to earthquake load cases [12].

Dost and Chaudhary (2021) studied the design and analysis of G+15, G+20, and G+25 residential structures that are seismically resistant in zone IV with medium soil type, using ETABS software. The maximum lateral displacement resulting from seismic activity, including shear walls, was observed in the 16^{th} , 21^{st} , and 26^{th} stories, observing 16.032 mm, 18.78 mm, and 29.23 mm. Likewise, the maximum lateral displacement resulting from wind load was observed in the 16^{th} , 21^{st} , and 26^{th} stories, observing 0.6812 mm, 1.1258 mm, and 3.6692 mm, respectively. The result of the study indicates the shape of the building and its height/number of storey have an impact on lateral displacement [8].

Kotwal et al. (2019) have investigated G+12 and G+16 RC ordinary moments resistant framed structures (OMRF) in zones II, III, IV, V, and medium soil. The base share, storey drift, time period, story shear, and storey displacement of the findings were compared. It is discovered that the forces obtained by following IS:1893-2002 codes are much less than the values obtained by following IS:1893-2016. Since the seismic coefficient approach was the only one used to make conclusions, it is advised to do a thorough investigation utilizing the response spectrum and modal analysis method [16].

Vali and Ajitha (2014) have evaluated the performance of the G+35 RCC building, accounting for soft soil and all seismic zones. The several bracing systems—X-brace, V-brace, inverted V, and infills—are shown in these analytical models using SAP 2000 software. It is determined that, of the three bracing systems, one infill system has the least variance in displacement in terms of structural performance. Additionally, since the height of the structure increases, the base shear reduces as a result of the bracings' infilling the increased stiffness of the structure [20].

Bajajet et al. (2013) used SAP 2000 software to study several soil types and compute the associated base shear and lateral displacement, varying the floors as 4th, 5th, and 6th, and the zones as III, IV, and V. It was discovered that when the type of soil changed from hard to medium and from hard to soft, there was an increase in lateral displacement of 53.33% and 60.25%, respectively. Additionally, it shows that the base shear has increased by 43.25% and 26.85%, respectively, when the types of soil change from hard to medium and medium to soft [4].

Deshmukh and Shende (2019) investigated cohesive and non-cohesive soil during the earthquake in G+10-story residential structures. The authors conclude that in cohesive soil, the base shear found for the fixed base condition is 18% larger than in non-cohesive soil. Compared to non-cohesive soil, cohesive soil exhibits an 18% greater level of soil structure interaction. Compared to non-cohesive soil, cohesive soil exhibits more displacement or outcome. They also conducted a parametric study to investigate the influence of soil flexibility on buildings of various slenderness ratios [6].

III. SUMMARY OF LITERATURE AND GAP

The ETAB, STAAD Pro, SAP2000, and RSA software have been utilized by the researchers for building analysis and design. RSA software has not been thoroughly studied, hence ETABS software is used by researchers for more research. In zone IV, the story drift, base shear, and displacement are the parameters used by the researchers to evaluate the structure's seismic performance. The researchers evaluate the seismic performance of a high-rise residential building located in seismic zones III and IV using equivalent static analysis as per IS: 1893 (Part 1) 2002 and considering lateral forces due to wind and seismic loads. The researchers studied high-rise buildings with soft soil types and different seismic zones in India. The researchers studied the seismic behaviour of low-rise buildings on different types of soil, such as soft clay, medium sand, and hard rock, in seismic zones III, IV, and V using nonlinear response history analysis. The literature review reveals that the ample study of the seismic behaviour of RCC high-rise buildings lying in all four seismic zones and for all three types of soil has not been carried out by the researchers, till date. This will be an extensive study that will cover all seismic zones and all types of soils.

CONCLUSION

The following conclusions are determined in view of the literature review investigation:

1. It is concluded that the analysis and design of high-rise buildings could be done by both ETAB and STAAD Pro software.
2. It is found that the forces calculated using the IS 1893(Part 1): 2002 codes are significantly lower than those determined using the IS 1893 (Part 1): 2016 standards.
3. In seismic zones III, IV, and V, the maximum shear forces and maximum bending moments are higher in soft soil strata compared to medium and hard soil strata.
4. In zone IV, lateral deflection decreases as the soil type transitions from soft to medium and then from medium to hard.
5. In zone IV, storey drift and base shear decrease as the soil type changes from soft to medium, and then from medium to hard.

FUTURE SCOPE

1. Expand the study to include different building types with varying designs, materials, dampening systems, and seismic zones in order to evaluate the efficacy and economic viability of alternative earthquake-resistant design approaches.
2. Examine that soil-structure interaction affects multistorey structures' seismic response and take it into account during the design stage.
3. Explore the use of innovative materials and technologies such as base isolation, energy dissipation devices, fibre-reinforced polymers, and shape memory alloys to enhance the seismic resilience of buildings.
4. Develop a comprehensive framework for performance-based seismic design that considers multiple levels of performance objectives, hazard scenarios, and structural and non-structural components.
5. Further studies can be conducted to evaluate the seismic performance of buildings with different heights using other methods, such as pushover analysis, time history analysis, or nonlinear dynamic analysis.
6. Extend the study to other types of buildings with different structural systems, heights, and configurations, and compare their seismic performance on different types of soil.
7. Extend the study of the seismic behaviour of RCC high-rise buildings lying in all four seismic zones and for all three types of soil.

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