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A Review on Comparison Between Seismic and Non-Seismic Analysis of Multi-Storey R.C. Buildings

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***Abstract*: Almost once in every decade, the Indian subcontinent is getting hit by severe to moderate intensity earthquakes. Property in general, and multi-story buildings in particular, are severely damaged by this earthquake. As a result, all structures built in the Indian subcontinent, particularly those in earthquake-prone areas, should be designed to withstand the pressures and stresses caused by earthquakes. We need to ensure safety against the dynamic force, such as an earthquake, which affects structures and influences seismic responses of such structures. The analysis of any structural system to identify the deformations and forces caused by applied loads or ground excitation is an important step in designing an earthquake-resistant construction. Depending on the goal of the analysis in the design process, a variety of approaches are available, ranging from a simple linear analysis to a complex non-linear analysis. According to IS 1893-2002, the seismic response of a residential P (Parking) + 15 storey RC frame building is studied using equivalent static method in SAP2000 software. This paper presents comparison study between analysis of multi-storied buildings for seismic and gravity forces and their effects on structural members.**

***Keywords*: Axial forces, Maximum bending moment, Maximum shear force, SAP2000, Seismic analysis.**

1. Introduction

An earthquake occurs when energy is released suddenly in the earth's crust, causing seismic waves. Seismic loads are extremely powerful, and they can collapse a structure in a matter of seconds, resulting in the loss of lives and property. Dead load, active load, and snow load are the three most frequent loads caused by gravity. Buildings are also vulnerable to lateral loads induced by wind and earthquakes, in addition to these vertical loads. High stresses, sway movement, and vibration can all be caused by lateral loads. Seismometers are used to measure earthquakes. When designing this high rise building structures, IS: 456-2000 and IS: 1893-2002 are also used. The seismic zonation map of India is shown in Figure 1.

The earthquake resistant design code of India [IS 1893 (Part 1) 2002] allocates four categories of seismicity to India in terms of zone factors in the most recent version of the seismic zoning map of India. In other words, the earthquake zoning map of India divides the country into four seismic zones (Zones II, III, IV, and V). In accordance with the current zoning map Zone V is related with the highest level of seismicity, whereas Zone II is associated with the lowest seismicity amount. The Zone factors are shown in Table 1.

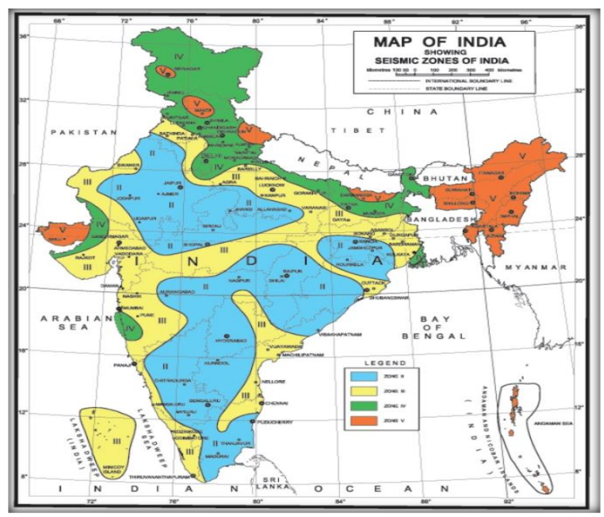

Fig. 1. The seismic zonation map of India

Table 1
Seismic Zone Factor (Z)

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

2. Design Factors

Following are the various factors that affects the design of building structure:

A. Torsion

Objects and constructions have a centre of mass, which is the point at which they can be balanced without rotating. The geometric centre of the floor and the centre of mass may coincide if the mass is equally distributed. Because of the uneven mass distribution, the centre of mass will be outside of

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the geometric centre, causing "torsion" and stress concentrations. In every construction design, a certain degree of torsion is unavoidable. Masses are arranged in a symmetrical pattern.

B. Damping

Buildings, in general, are poor resonators for dynamic shock, because they absorb vibration rather than dissipate it. The rate at which natural vibration is absorbed is referred to as damping.

C. Ductility

The ability of a substance (such as steel) to bend, flex, or move, but only after significant deformation, is known as ductility. Crumbling occurs when non-ductile materials (such as weak reinforced concrete) crumble. With meticulously crafted joints, good ductility can be attained.

D. Stiffness and Strength

A material's strength is its ability to resist applied forces within a safe range. A material's stiffness is its resistance to deflection or drift.

E. Layout of the Building

The size and shape of a building, as well as structural and non-structural aspects, are all defined by this phrase. The way seismic forces are distributed within a structure, their relative magnitude, and significant design problems are all determined by the building configuration.

3. Difference between Linear and Non-Linear Analysis

A. Linear Analysis

The design of structural components or the entire structure should be such that the structure's movement does not exceed its elastic limit even when the maximum design forces are applied. As a result, the structure would always return to its original place with no harm (since it is linear behavior). When the forces are significant, as they are in an earthquake, the dimensions of the structural components or the entire building grow enormously, which is not a cost-effective solution. As a result, non-linear analysis must be considered.

B. Non-Linear Analysis

Non-linear analysis is the process of allowing a structure or structural component to sway beyond the elastic limit and utilizing its non-linearity. In this situation, the structure is designed to withstand lower forces and hence allow for more deflection. As a result, a smaller component can endure the same forces while swaying somewhat more. As a result of non-linear analysis, we may build more cost-effective structures with less damage.

4. Seismic Analysis

Seismic analysis is a subset of structural analysis that involves calculating a building's (or non-building's) earthquake response. In earthquake-prone areas, it is a part of the structural design, earthquake engineering, or structural evaluation and retrofit. The purpose of structural analysis is to determine the structural reaction and behavior when it is subjected to external forces. External forces include live load, wind load, blast, snow, and so on. And it could be in the form of an earthquake, which causes the earth's surface to shake. The inertia force can be ignored if the load is supplied gradually and slowly, and the analysis can be carried out as a static analysis. A static load is one that does not change rapidly. The obligation to design for a lateral force equivalent to a proportion of the building weight was one of the first seismic rules (applied at each floor level). The appendix of the 1927 Uniform Building Code (UBC), which was utilized on the west coast of the United States, adopted this technique. It was eventually discovered that the structure's dynamic qualities influenced the loads created during an earthquake.

The following five types of structural analysis approaches can be classified.

A. Equivalent Static Analysis

This method specifies a set of forces acting on a structure to simulate the influence of earthquake ground motion, which is normally specified by a seismic design response spectrum. It is assumed that the structure responds in its basic mode. The building must be low-rise and not twist considerably as the ground changes for this to be true. Given the natural frequency of the building, the response is read from a design response spectrum (either calculated or defined by the building code). Many building standards enhance the usefulness of this concept by adding components to account for higher buildings with certain higher modes, as well as low degrees of twisting.

B. Response Spectrum Analysis

This method allows for the consideration of a building's many forms of response (in the frequency domain). With the exception of very simple or very complicated structures, many construction rules mandate this. A structure's reaction can be defined as a collection of many different particular forms (modes) that correspond to the "harmonics" in a vibrating string. These modes for a structure can be determined through computer analysis. A response is read from the design spectrum for each mode, based on the modal frequency and modal mass, and then combined to generate an estimate of the structure's total reaction.

C. Linear Dynamic Analysis

When higher mode effects are not considerable, static techniques are appropriate. This is usually the case with short, regular structures. As a result, a dynamic approach is necessary for tall buildings, buildings with torsional anomalies, or non-orthogonal systems. The building is treated as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix in the linear dynamic process.

D. Non-linear Static Analysis

This method is sometimes referred to as "pushover" analysis. To construct a capacity curve, a pattern of forces is applied to a structural model with non-linear features (such as steel yield), and the total force is plotted against a reference displacement. After that, a demand curve (usually in the form of an acceleration-displacement response spectrum (ADRS)) might be added. The problem is effectively reduced to a single degree of freedom (SDOF) system. Nonlinear static processes represent seismic ground motion with response spectra and use similar SDOF structure models.

E. Non-linear Dynamic Analysis

Because nonlinear dynamic analysis combines ground motion recordings with a thorough structural model, it is possible to produce results with a low level of uncertainty. The detailed structural model exposed to a ground-motion record gives estimates of component deformations for each degree of freedom in the model, and the modal responses are merged using schemes like the square-root-sum-of-squares in nonlinear dynamic studies. The non-linear features of the structure are evaluated as part of a time domain analysis in non-linear dynamic analysis.

5. Literature Review

The literature review focused on various authors work on the analysis of seismic forces in diverse earthquake zones. Seismic assessments are carried out with a variety of software.

Mantha and Sanghai [1] studied the Comparison between Seismic Analysis and Non-Seismic Analysis of G+17 Building using SAP2000. In this paper they used much simpler Equivalent Static method to analyze G+17 storey building to resist earthquake forces using SAP2000 software. The seismic analysis results were further compared with non-seismic analysis results using dead load and live load combination. It was observed that the seismic results obtained consisted of drastically increased maximum moments and shear forces as compared to non-seismic analysis. They concluded that if the beam column joints are designed to be ductile, they have more capacity to absorb the forces generated during earthquake and vibration of the structure. They also concluded that relevant design method should be adopted to satisfy additional seismic requirements of the structure.

P. HariharaVenkata Nagasai et al [2] compared Seismic and Non-seismic Analysis of Multi-storey Building using SAP software. In this paper they performed analysis and design of G+7 (Hostel building) & compared the support reactions of seismic and non-seismic analysis of the multi-storey building by using SAP2000 & the loads were assigned as per the IS code provisions. The site conditions considered was AMARAVTI the new capital city of A.P., located in zone III and soil type was mostly black cotton soil. They compared the analysis results and concluded that the bending moment, shear force, axial force and displacement values were drastically higher in the seismic analysis. They concluded that to restrain the additional seismic loads of the structure, relevant design method is to be adapted like using seismic design strategies and devices in the construction.

Suresh and Nanduri [3] compared results of normal and seismic design of building. They state that to design a structure to be earthquake resistant does not require additional cost when proper method of design is utilized. They made conclusion that now-a-days by following the principles of capacity design together with the concepts of ductile behavior will allow a safe and effective earthquake resistant design. By making the structural joints more ductile to sustain the earthquake forces, using more reinforcement bars of smaller diameter and distributing them on all sides can reduce the damage to the structure from lateral forces.

Kumar Pavan E. et al [4] using response spectrum analysis analyzed G+15 storey building in STAAD Pro. They compared static and dynamic analysis results of structural frame and concluded that the performance of dynamic analysis of frame is good in resisting earthquake forces as compared to that of static analysis of frame.

Patil and Sonawane [5] carried out Seismic Analysis of Multistoried Building by using ETABS software. In this paper, they studied earthquake response of symmetric multistoried building by doing manual calculation and with the help of ETABS 9.7.1 software. The study includes seismic coefficient method as recommended by IS 1893:2002. They compared responses obtained by manual analysis as well as by software computing. This paper provides complete guide line for manual as well as software analysis by using seismic coefficient method.

Mohan and Vardhan [6] performed Analysis of G+20 RC Building in Different Zones using ETABS. They studied the behavior of a multi storied RC building irregular in plan subjected to earth quake load by adopting response spectrum analysis. The study was limited to reinforced concrete (RC) multi-storied commercial building with four different zones II, III, IV & V. The analysis was carried out the with help of ETABS software. The building model in the study had twenty storeys with constant storey height of 3m. Four models were used to analyze with different bay lengths and the number of bays and the bay-width along two horizontal directions were kept constant in each model for convenience. Different values of seismic zone factor were taken and their corresponding effects were interpreted in the results. They made following conclusions from the study:

1) Base shear of the structure increases as we go to higher seismic zones.
2) The displacement of building models increases with the increasing of seismic Zones.
3) Storey shear is decreased as height of the building increased and reduced at top floor in all the building models subjected to seismic loads considered. The storey shear is maximum at the base.
4) By using shear walls, dampers, rubber pads, spring we can reduce damage of seismic effect of an R C building resting on high seismic zone.

Vinay Sanjeevkumar Damam [7] carried out Comparative Study on Multistoried R.C.C. Structure with and without Shear Wall by using SAP2000 v17. In his study, main focus was to determine the solution for shear wall location in multi-storey building. The effectiveness of RCC shear wall building was studied with help of four different models. The first model was bare frame system and the other remaining three types were frames having different locations of shear wall. An earthquake load was applied to G+10 storey building located in different zones. The performance of building was evaluated in terms of lateral displacements of each storey. The analysis was done by structural finite element analysis method using SAP2000 software. After study he came to following conclusions: 1) If the dimensions of shear wall are large then major amount of horizontal forces are taken by shear wall. 2) Providing shear walls at adequate locations substantially reduces the displacements due to earthquake. 3) In zone V and IV like high earthquake intensity areas, provide shear walls on all four corners and centroid of the building to reduce deflection.

Rana and Raheem [8] carried out research on Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building. This work shows the performance & behavior of regular & vertical geometric irregular RCC framed structure under seismic motion. Five types of building geometry were taken in this project: one regular frame & four irregular frames. A comparative study made between all these building configurations height wise and bay wise. All building frames were modeled & analyzed in software Staad Pro V8i. Various seismic responses like shear force, bending moment, storey drift, storey displacement, etc. were obtained. The seismic analysis was done according to IS 1893:2002 part-1. Seismic zone IV & medium soil strata was taken for all the cases. The change in the different seismic response was observed along different height. They concluded that the seismic performance of regular frame was found to be better than corresponding irregular frames in nearly all the cases. According to them, regular frames should be constructed to minimize the seismic effects.

Reddy and Kumar [9] performed Analysis of G+30 High rise Buildings by Using Etabs for Various Frame Sections in Zone IV and Zone V. In their work the modelling was completed to examine the outcome of special circumstances along with specific heights on seismic parameters like base shear, lateral displacements and lateral drifts. The gain knowledge had been implemented for the Zone IV and Zone V in Soil Type II (medium soils) as targeted in IS 1893-2002. From the research the following conclusions were made: The behavior of high rise structure for both the zones was studied in present paper. In this paper they got the results from mathematical models. It was also observed that the results were more conservative in Static analysis as compared to the dynamic method resulting uneconomical structure in both zone 4 and zone 5.

Abhay Guleria [10] performed Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations. The case study in this paper mainly emphasizes on structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I-shape. Modeling of 15- storey R.C.C. framed building was done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement were computed and then compared for all the analyzed cases. The analysis of the multi-storied building reflected that the storey overturning moment varies inversely with storey height. Moreover, L-shape, I-shape type buildings give almost similar response against the overturning moment. Storey drift displacement increased with storey height up to 6^{th} storey reaching to maximum value and then started decreasing. From dynamic analysis, mode shapes were generated and concluded that asymmetrical plans undergo more deformation than symmetrical plans.

6. Conclusion

From this study, it is observed that the maximum displacement of top floor of building in seismic analysis is very high as compared to non-seismic analysis. This signifies the importance of ductility of structure during earthquake. If the beam column joints are designed to be ductile, they have more capacity to absorb the forces generated during earthquake and thus reducing vibration of the structure. Thus, the analysis results were compared and it was concluded that the maximum bending moment and shear force values were drastically higher in the seismic analysis. Relevant design method should be adopted to satisfy additional seismic requirements of the structure. With early collaboration between architect and civil engineer during conceptualization phase and by choosing appropriate design approach during construction, buildings can be designed to reduce damage to the structure during earthquake without much increase in cost of project.

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