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Research Article
Comparative Study of Static and Response Spectrum Methods for Seismic Analysis of Regular RC Buildings

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Abstract

Background and Objective: The main idea in this paper is to study the static and dynamic analysis methods and compare their results in order to determine the optimal conditions for application of each method. **Materials and Methods:** In this research, two structural models are created using the ETABS (V16.1.2) program for regular R.C buildings with typical plans, the first model with a total height of 75 m while the second model with a total height of 24 m. The buildings are analyzed using the static and dynamic methods under ASCE7-10 and IBC 2015 provisions. **Results:** The results show that shear forces obtained using the response spectrum analysis as a dynamic analysis in the X directions are less than those obtained using the equivalent static analysis by 35-60 and by 40-65% in the Y direction for the high-rise building, while for the low-rise building is less by 25% in X direction and 22% in Y direction. The results also show the bending moments in the X directions obtained using the response spectrum analysis are less than those obtained by using the equivalent static analysis by 45-75 and by 30-65% in the Y direction for high-rise building, while for the low-rise building is less by 22% in X direction and 20% in Y direction. **Conclusion:** The results of displacements in the X directions obtained using the response spectrum analysis are less than those obtained by using the equivalent static analysis by 70 and by 80% in the Y direction for the high-rise building, while for the low-rise building is less by 35% in X direction and 38% in Y direction.

Key words: Equivalent static, response spectrum, regular buildings, base shear, displacements, bending moments

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Structural analysis is basically used for determine the behavior of a structure when subjected to loads. The load may be load due to the weight of things such as people, furniture, etc. or due to dynamic loads as wind, explosions and an earthquake. Hence, it is necessary to take into consideration the seismic load in the design of structures[1].

The seismic response of the building systems shows a large dependence on the type of analysis method adopted. In the past years, the analysis methods were confined to static approach due to its simplicity. Static approach is based on replacing concept of the inertia forces at various considerable masses i.e., stories by equal horizontal forces that are corresponding to the weight of the structure and its acceleration. The combination of these concentrated forces is present by a base shear at the structure's base[2].

Nowadays the development of sophisticated computers and analysis programs enabled the researchers to move forward towards a more rational approach by simulating the actual effect of earthquakes on the building models to obtain the realistic seismic response, these methods are categorized under dynamic analysis[3].

Dynamic analysis describes and expects the structural movement cases under the influence of dynamic loads. This science is not based on observation and experience only but is also dependent on logical analysis and complex mathematical equation solving[4]. The response spectrum analysis is considered as one of the most important methods of dynamic analysis which defined as the combination plot of acceleration, velocity and displacement maximum response for all single degree of freedom system to a specific ground motion for a given damping ratio[5]. This combination helps in obtaining the maximum structural responses, which can be used to obtain the lateral forces for earthquake resistance structural design[2].

Kumar *et al.*[6] exposed a case study of earthquake analysis of multi storied residential building. The study shows that bending moment obtained from dynamic analysis are high and the displacement values in static analysis also higher comparable to dynamic analysis.

Mahmoud and Abdallah[7] studied the response of multi-story R.C building under equivalent static and dynamic loads according to Egyptian code (2008). The study concluded that the static analysis gives higher values for maximum displacement especially in higher stories and it has been found that a significant increase in the dynamic shear and moment for higher stories.

Sharma and Maru[8] studied the dynamic analysis of multistoried regular building, where they showed that the bending moment values in beams are 10-15% higher for dynamic analysis. Displacement values are 17-28% higher in beams when dynamic analysis is used.

Arvindreddy and Fernandes[9] carried out seismic analysis of RC regular and irregular frame structures. The study showed that the results obtained from static analysis method are lesser in term of story displacement values as compared to response spectrum analysis.

Adhikari and Rajasekhar[10] compared static and dynamic seismic analysis of column sections in a building, the comparison showed that the values of displacement for dynamic analysis is 16% less than the static analysis displacements. Also, the static analysis gives higher values for forces and moments.

Das and Guha[11] compared the static and dynamic seismic analysis of RC regular and irregular frame structures, the comparison shows that the displacement obtained by static analysis are higher than dynamic analysis for irregular structures.

Kakpure and Mundhada[1] compared the static and dynamic analysis of multistoried building using ETABS program. The comparison shows that the dynamic analysis is economical in terms of bending moments, displacements and axial loads.

The main aim of this paper is to study the static and dynamic analysis and compare the results in order to determine the optimal conditions for application of each case using international code instead of regional standard as per previous literature. This paper deal in particular the story moment and story displacement in addition of story shear which not been studied previously.

MATERIALS AND METHODS

This paper studied two reinforced concrete multistory buildings with typical rectangular in plan, 25 m long and 20.5 m wide as shown in Fig. 1, the high-rise model with 25 ribbed slabs as shown in Fig. 2a while the low-rise with eight ribbed slabs as shown in Fig. 2b. The buildings are with typical floor heights of 3 m. The buildings are intended for residential use. The system adopted to resist the seismic forces consists of elevator cores and shear walls X and Y directions. Figure 3a, b shows the seismic parameters of the models that used in ETABS program under ASCE7-10 and IBC 2015 provisions.

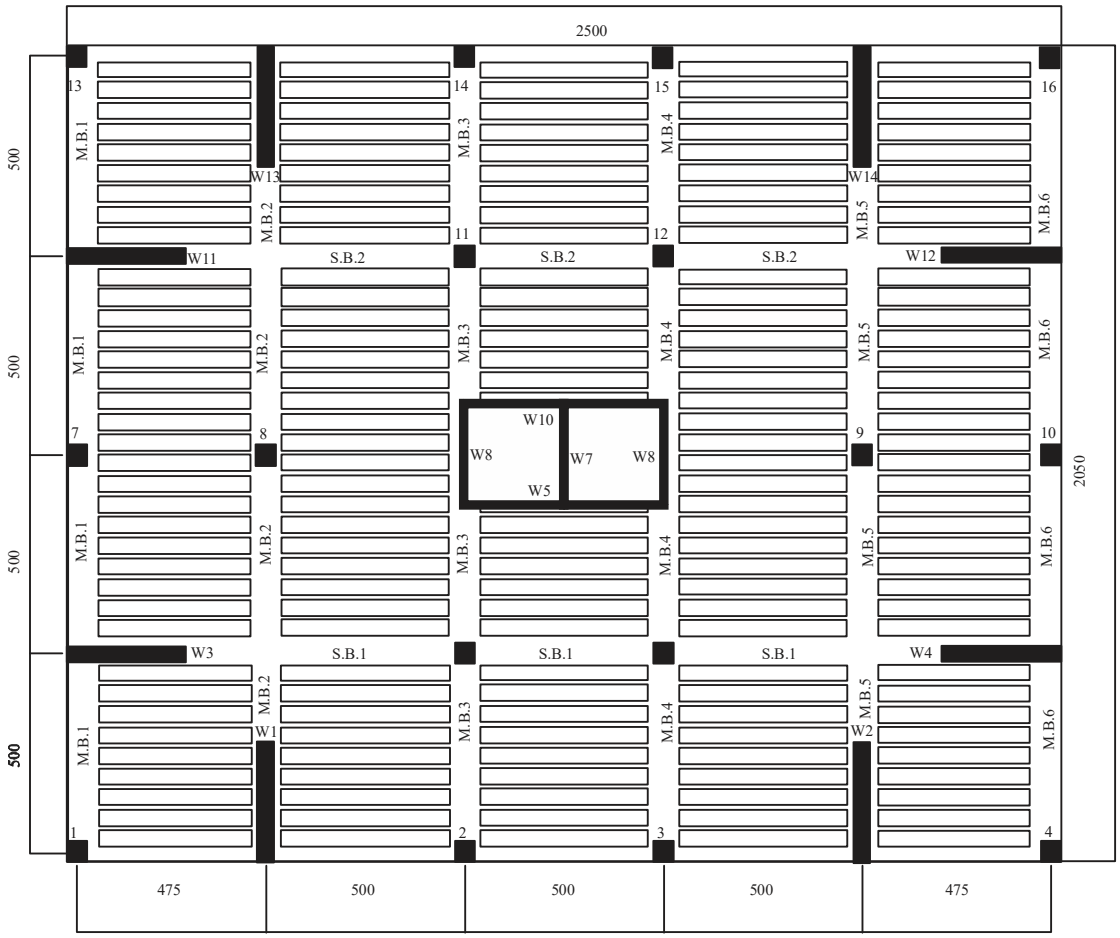


Fig. 1: Regular multistory buildings plan

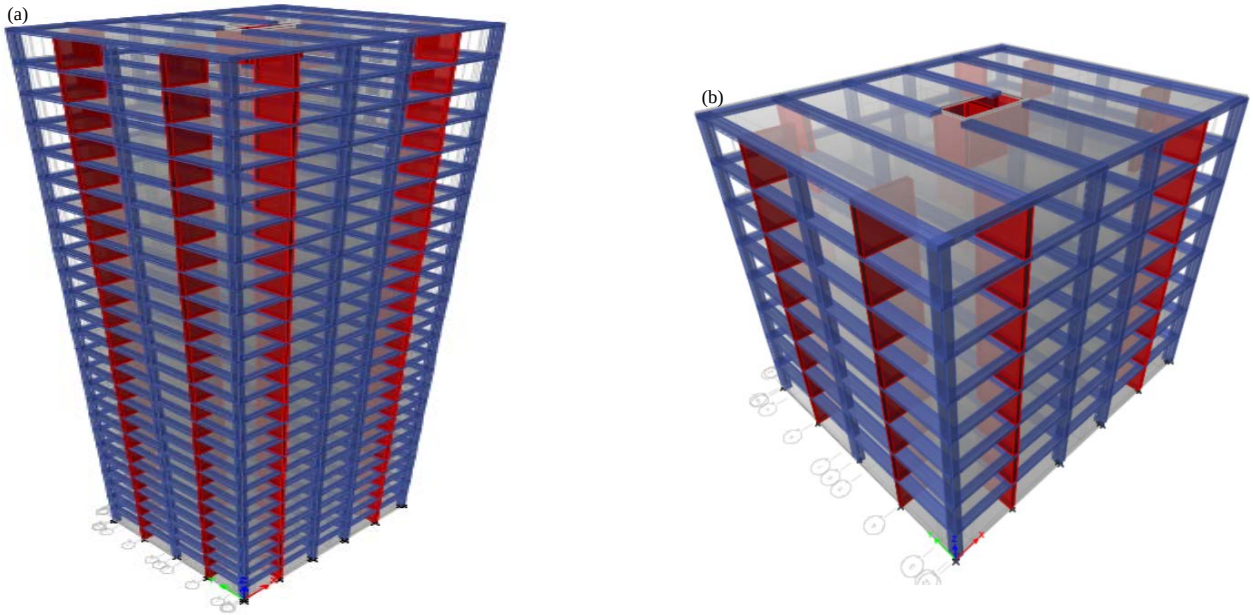
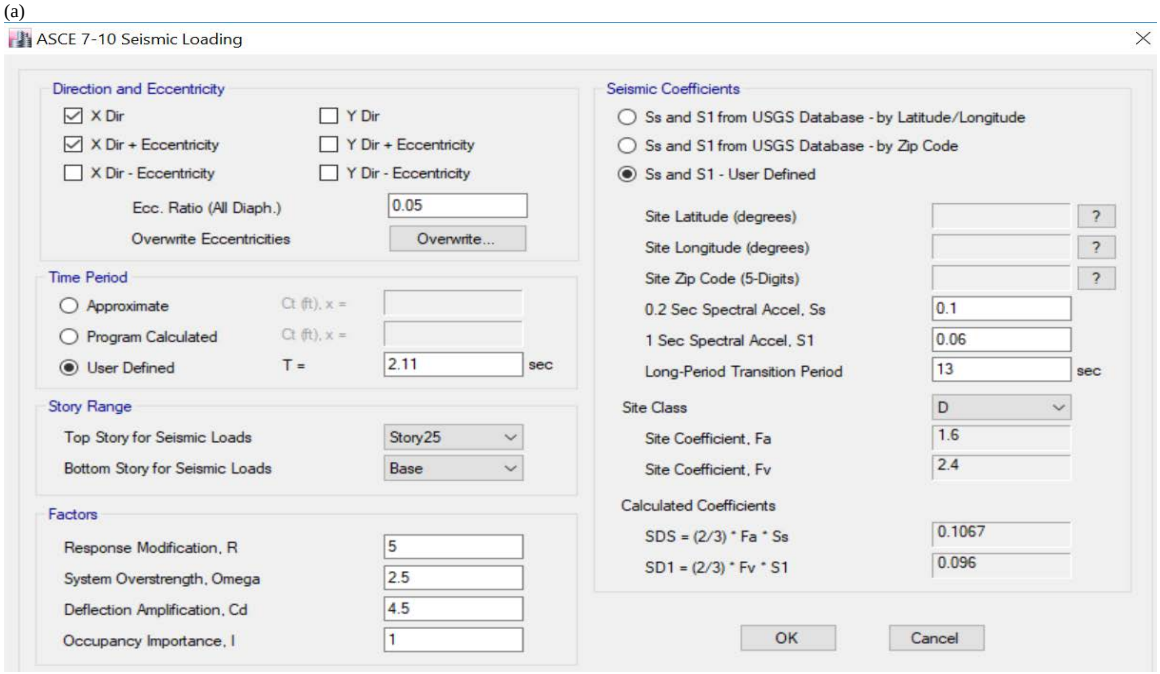


Fig. 2(a-b): Three-dimensional model in ETABS for (a) High-rise and (b) Low-rise building

(a)



(b)

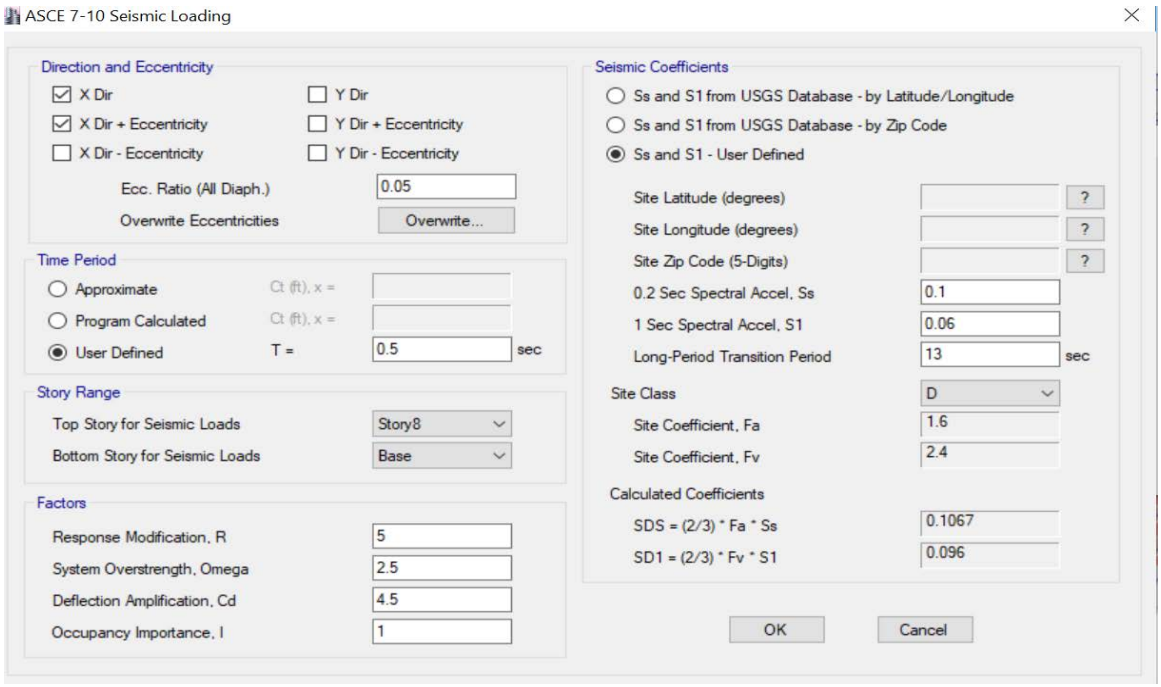


Fig. 3(a-b): ETABS seismic parameters of the model for (a) High-rise building and (b) Low-rise building under ASCE7-10 and IBC 2015 provisions

RESULTS AND DISCUSSION

Shear forces: The results show that for high-rise building the shear forces in the X direction using the response spectrum analysis (RS) are less than corresponding values obtained by using the equivalent static analysis (ES) by 35% for the upper stories and by 60% for the lower stories and in the Y direction the results show that the shear forces using the response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis of 40% for the upper

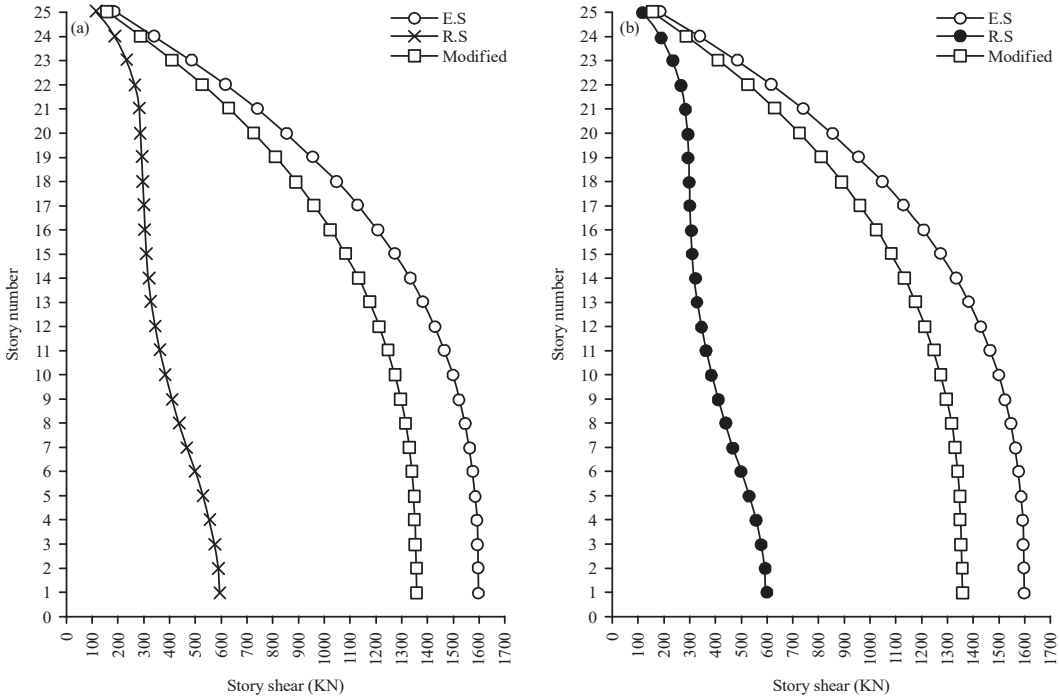


Fig. 4(a-b): High-rise building story shears in (a) X direction and (b) Y direction

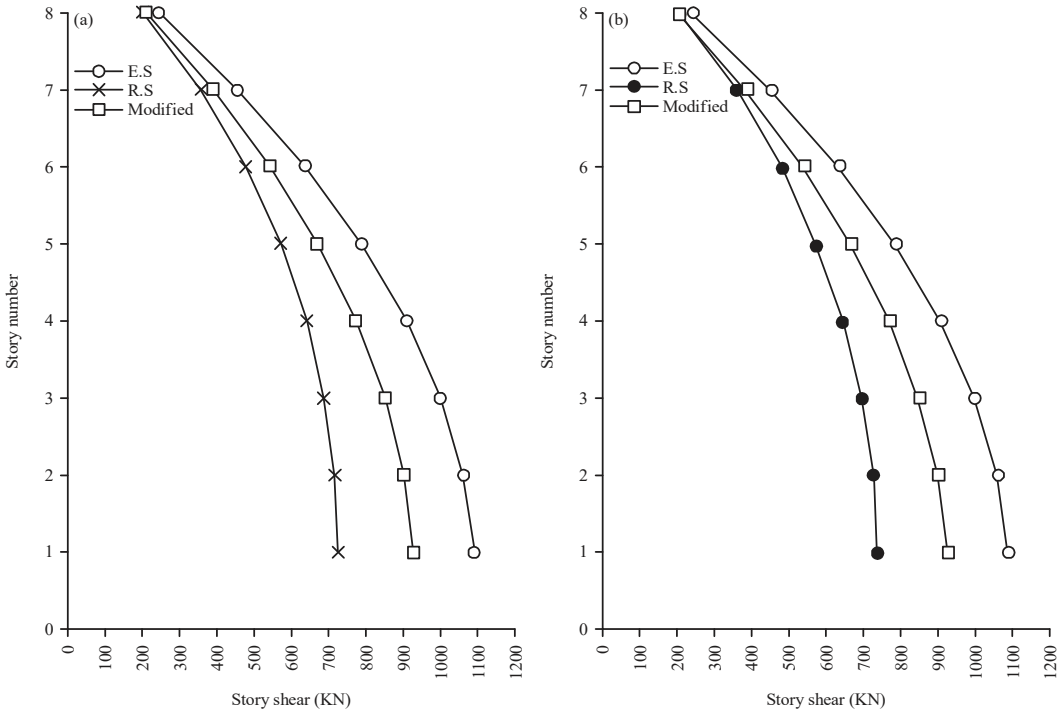


Fig. 5(a-b): Low-rise building story shears in (a) X direction and (b) Y direction

stories and 65% for lower stories as shown in Fig. 4a and b, while for the low-rise building the shear forces in the X direction using the response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis by 25% and in the Y direction the results show that the shear forces using the response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis by 22% as shown in Fig. 5a and b.

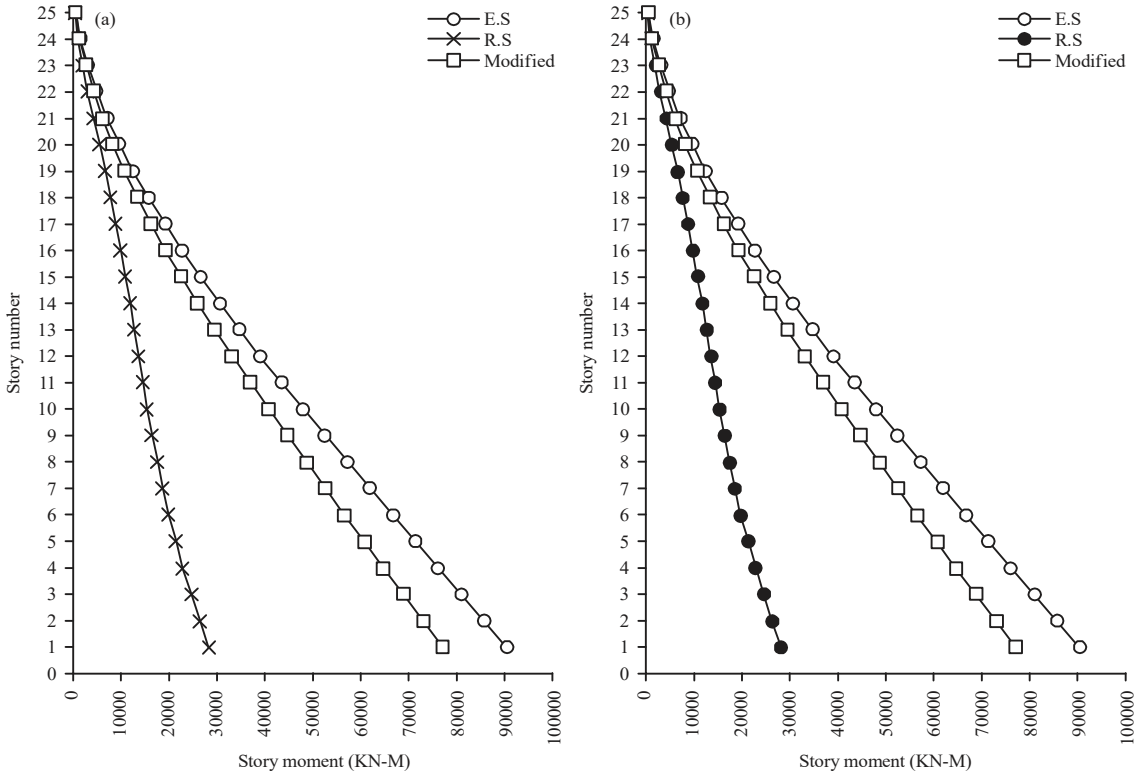


Fig. 6(a-b): High-rise building story moments in (a) X direction and (b) Y direction

According to ASCE 7-10, where t he maximum scaled base shear predicted by the dynamic analysis, V_i is less than 85% of the calculated base shear, V using the equivalent lateral force procedure, the scaled member forces shall be modified by multiplying them by $0.85V/V_i$.

After modifying the dynamics results based on ASCE 7-10 provisions, the story shears in the dynamic analysis are 15% smaller than their corresponding values in the equivalent static analysis.

Bending moments: The results showed that for high-rise building the bending moments in X directions using the response spectrum analysis are less than their corresponding values obtained using the equivalent static analysis by 45% for the upper stories and by 75% for the lower stories and in Y direction the results show that the bending moments using response spectrum analysis are less than their corresponding values obtained using the equivalent static analysis by 30% for the upper stories and by 65% for lower stories as shown in Fig. 6a and b, while for the low-rise building the bending moments in the X directions using the response spectrum analysis are less than their corresponding values obtained by using the equivalent static analysis by 22% and in the Y direction the results showed that the bending moments using the response spectrum analysis are less than their corresponding values obtained by using the equivalent static analysis of 20% as shown in Fig. 7b and 7b.

Displacements: The results showed that for high-rise building the displacements in X directions using the response spectrum analysis are less than their corresponding values obtained using the equivalent static analysis by 70% and in Y direction the results showed that the displacement using response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis by 80% as shown in Fig. 8a and b, while for the low-rise building the displacements in the X directions using the response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis by 35% and in the Y direction the results showed that the displacements using the response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis of 38% as shown in Fig. 9a and b.

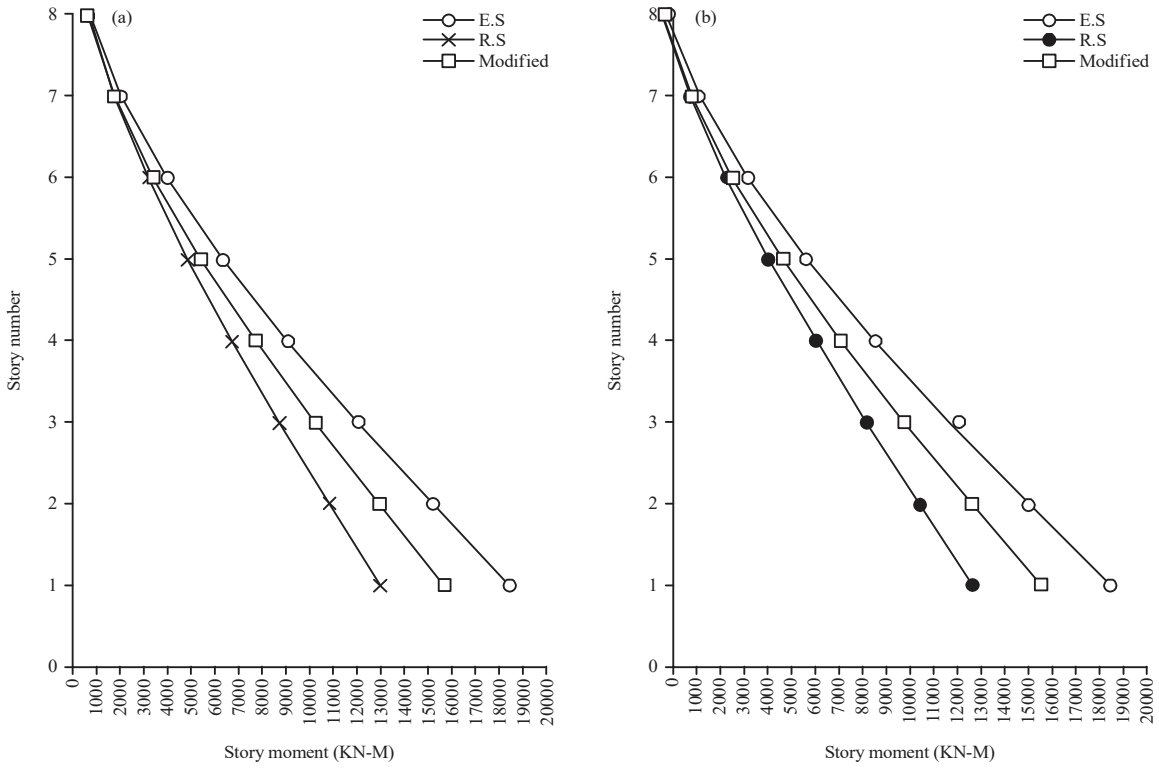


Fig. 7(a-b): Low-rise building story moments in (a) X direction and (b) Y direction

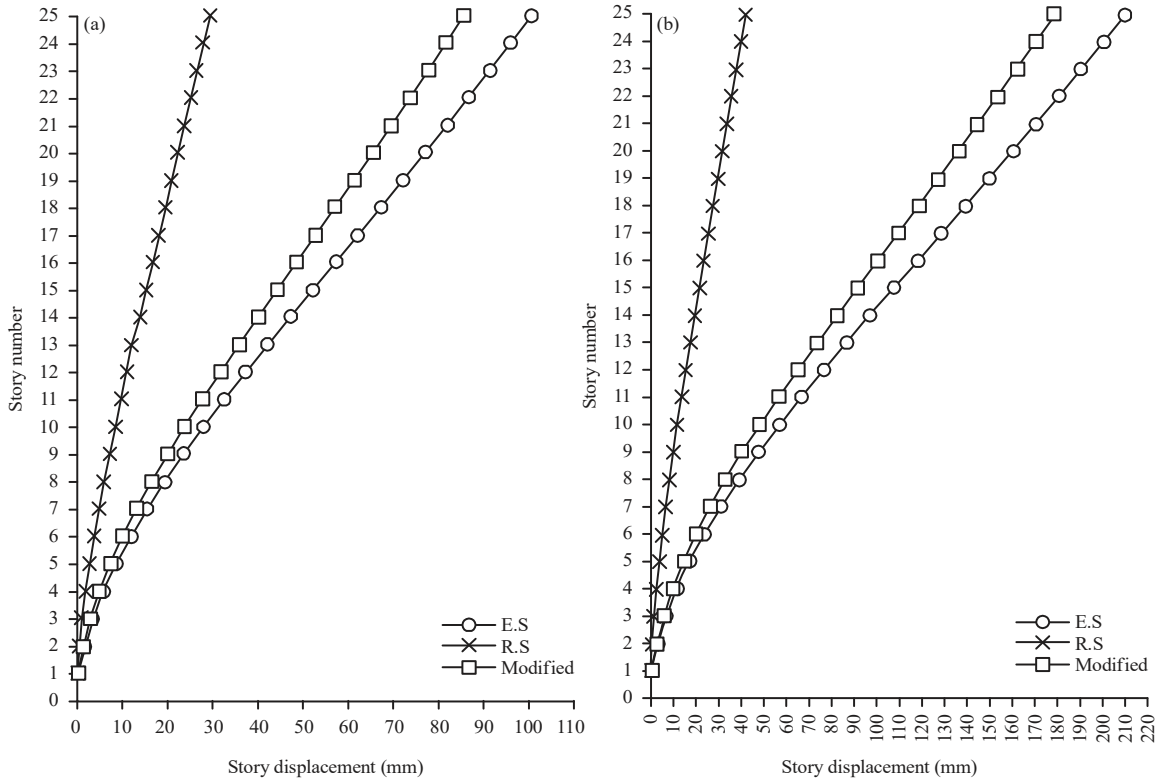


Fig. 8(a-b): High-rise building story displacements in (a) X direction and (b) Y direction

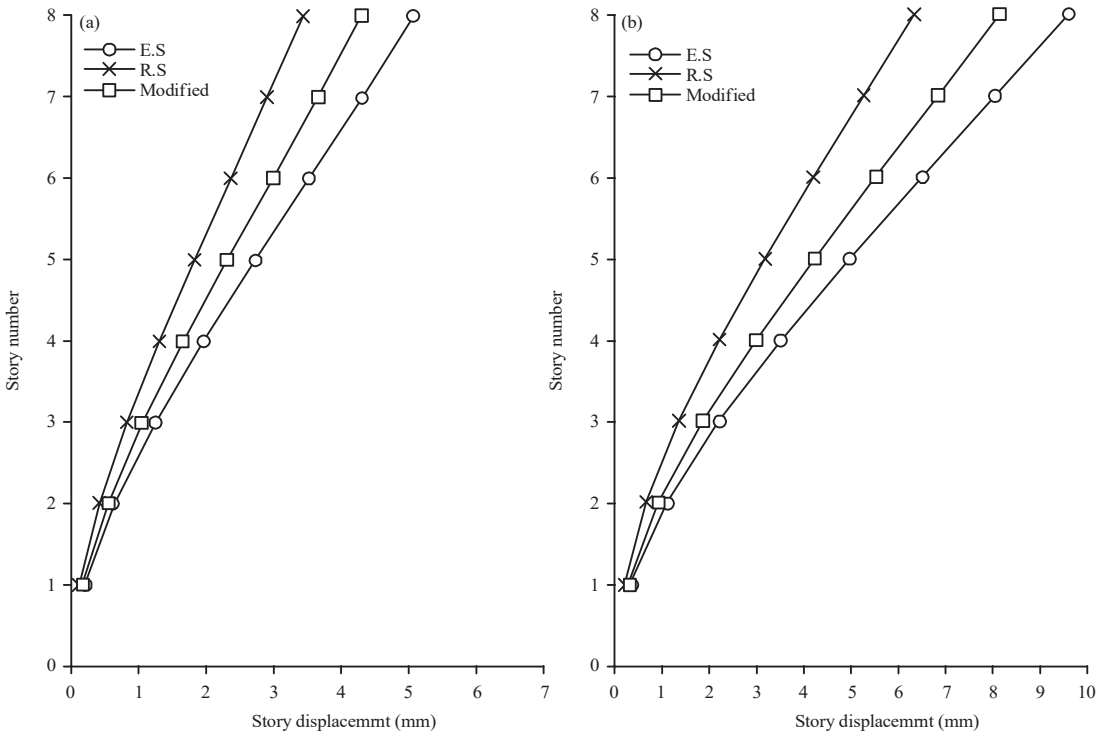


Fig. 9(a-b): Low-rise building story displacements in (a) X direction and (b) Y direction

CONCLUSION AND RECOMMENDATION

- The high-rise building shear forces obtained using the response spectrum analysis as a dynamic analysis in the X directions are less than those obtained by using the equivalent static analysis by 35-60 and by 40-65% in the Y direction, while for the low-rise building is less by 25% in X direction and 22% in Y direction
- The high-rise building bending moments in the X directions obtained using the response spectrum analysis are less than those obtained by using the equivalent static analysis by 45-75 and by 30-65% in the Y direction, while for the low-rise building is less by 22% in X direction and 20% in Y direction
- The high-rise building displacements in the X directions obtained using the response spectrum analysis are less than those obtained by using the equivalent static analysis by 70% and by 80% in the Y direction for the high-rise building, while for the low-rise building is less by 35% in X direction and 38% in Y direction
- After modifying the dynamic result, according to ASCE7-10 provisions, the story shears, bending moments and displacement in the dynamic analysis are 15% smaller than their corresponding values in the equivalent static analysis
- In case of low rise and regular building it is recommended to use the static approach
- Due to technological development and availability of effective computers and software, dynamic seismic analysis is recommended to use in high-rise buildings where the results show that the static method is not economical for those buildings
- For further research it recommended to compare the seismic analysis methods in terms of building height, soil profile, structural system and different analysis software
- It recommended to make a comparison of dynamic static analysis using other building codes, especially that the IBC, ASCE restricts the results obtained from the dynamic analysis

SIGNIFICANCE STATEMENT

This study discovered the static and dynamic analysis methods and compare their results in order to determine the optimal conditions for application of each method. In this research, two structural models are created using the ETABS (V16.1.2) program for regular R.C buildings with typical plans. This study will help the researchers to understand the behavior of the static and dynamic analysis methods for R.C buildings.

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