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Behavior of High-Rise Structures near Deep Excavations in Near-Fault Regions

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Abstract: *Due to ever-increasing population, the need for construction is increasing, and construction is feasible if civil infrastructures are expended. On the other hand, the lack of desirable lands (where soil has suitable mechanical properties for construction) in densely populated cities, as well as the high cost of land in some areas, have led to the constructions to be taken place at depths below ground level. Obviously, to prevent possible accidents, excavations must be stabilized. On the other hand, deep excavations are often carried out for high-rise structures. In a city, the high-rise structures are also usually built besides each other. Therefore, excavations cause some problems for high-rise structures near them. These problems can be exacerbated during an earthquake. Since near-field earthquakes have greater and more different effects on the structures than far-field earthquakes, they can be very dangerous for high-rise structures near deep excavations and put them in critical conditions. In present study, three 20-, 25- and 30-storey structures at three distances of 20, 40 and 50 meters from the excavation are studied by applying near-field earthquake in order to analyze the seismic behavior of high-rise structures next to deep excavations. The results show that as the structure height increases and the distance between the structure and the excavation edge decreases, the probability of excavation collapse and the risk for high-rise structures increase.*

Keywords: *Excavation, High-Rise Structures, Near-Field Earthquake*

INTRODUCTION

It is difficult to determine the characteristics of those buildings in the high-rise structure group because height is a relative property and one cannot categorize or define buildings in terms of height or number of floors. The height of a building depends on the social conditions and individual's perceptions of the environment, so it is impossible to provide a universally acceptable benchmark for defining the structure height. From an engineering viewpoint, a building can be called a high-rise structure, if due to its height, the lateral forces caused by wind and earthquake significantly affect its design. Also, like the gravity forces, the effects of lateral forces on structures completely vary and are rapidly intensified with height (Akbari, Moghaddaripoor and Rahmani, 2011). Three major factors should be considered in designing all high-rise structures: 1. Strength 2. Rigidity 3. Stability. Strength is the dominant factor in the design of low-rise structures, but as the height increases, rigidity and stability becomes very important. Therefore, in a high-rise structure, lateral and vertical load resisting system will vary according to the structure height, type of use as well as the nature and type of forces. One of the important issues in civil engineering is to retrofit buildings to make them resistant to earthquake-induced forces. To do this, usually, braces are used in steel structures and shear walls in concrete structures. Additionally, the bending frame power can also be used in retrofitting the buildings, especially high-rise structures, to make them resistant to earthquake (Taghizadeh Ghahi, 2008). What has not been seriously addressed so far and there are no regulations for it is the use of braces in concrete structures to restrain earthquake forces. In contrast, using a shear wall is common in steel structures and this is approved according to the Iranian seismic code (IS 2800-05). Although using of shear wall, rather than a brace, has been common in steel structures in recent years, in many cases, the earthquake-resistant brace is better than shear wall in terms of economic aspect, quick and easy implementation and also due to its better ductility of steel element (Chowdhury and Xu, 1995). The seismic behavior analysis of structures under large earthquakes represents significant damages, even in buildings designed based on engineering principles, meaning the inadequacy of the strength parameter, especially under large earthquakes and at the collapse level. The undesirable behavior of structures during the earthquakes has led the researchers to take other parameters into account in designing the structures (Kasebzadeh, 2013). According to the researchers' new attitude to the behavior of structures, one of these parameter is the concept of energy in structures. The idea of optimal energy balance in the structure is being expanded through damage optimization. Due to the earthquake-induced damages, researchers always attempt to seek solutions to prevent these damages. A long time ago, considering ductility and energy dissipation in designing structures was raised, and they were included in the regulations as the behavior coefficient of structure, R. Different earthquakes cause various small or large damages to the structures, depending on structures' strength and stability (Christian, Ladd and Baecher, 1994). Therefore, it has become very important to enhance the stability and strength of the structures to make them resistant to earthquakes and also to prevent total or partial destruction of them as well as the loss of financial capital and lives. There are various ways to stabilize steel structures against lateral forces caused by wind and earthquake (Manafi Qarabaei, 2011). In present study, first, various types of supporting structures used in high-rise structures are introduced and explained. Then, those all-purpose supporting structures commonly used in high-rise buildings are investigated. That is those structures, which are designed to be used in buildings, especially steel buildings, in order to strengthen them against lateral loads such as forces caused by wind or earthquakes, are investigated in terms of properties of their materials, including stiffness, ductility, modulus of elasticity, plastic modulus, or earthquake energy absorption. The more ductile the lateral supporting structure is, the higher earthquake energy absorption capacity it has. This means that the lateral force caused by an earthquake results in more deformation of structure before collapse, thereby reducing loss of lives (Manafi et al., 2011; Abramson, 2002; Ang and Tang, 1984).

Problem Statement and Details of Modeling

Under drained conditions, soil strength often increases with increasing average pressure and frictional properties appear further. According to this fact and the results of previous studies, the Mohr–Coulomb model is used to study the earth materials in present study. In order to correctly transfer, the wave with a given frequency of about 10 knots per wavelength λ is required. Using less than 10 knots can lead to numerical damping, as discretizing the problem leads to the loss of distinct peaks of the wave. In order to determine the maximum meshing distance, the maximum frequency, f_{max}, is calculated by performing Fourier analysis of the input motion. In the seismic analysis, maximum frequency, f_{max}, is usually considered equal to about 10 Hz (Aven and Vinnem, 2007; Baecher, 1987; Baecher and Christian, 2005; Box and Muller, 1958).

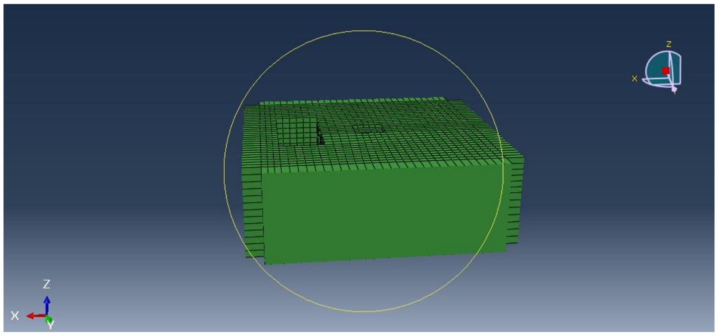


Figure 1: Three-dimensional model of soil near and far from the structure

Three 20-, 25- and 30-storey structures at three distances of 20, 40 and 50 meters from the excavation edge are studied. Fig.2 shows the position of them against the excavation edge.

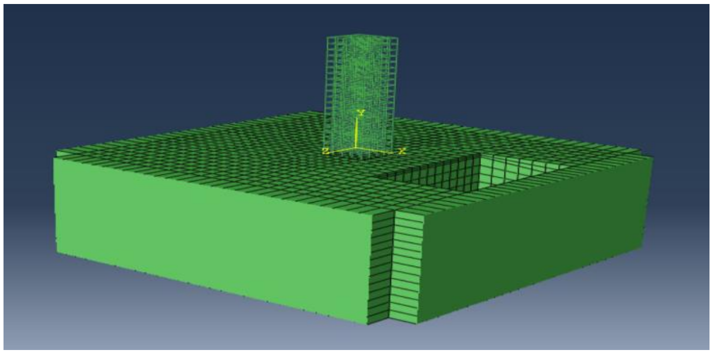


Figure 2: Position of the structure against the excavation edge

The modeled structures in present study are firstly modeled using the sap software. Then, they are modeled using the finite element software after determining the characteristics of the elements. The structure modeled in the Abaqus finite element software is shown in the following figure. The width of frame spans is 4 meters and their height is 3 meters. The structures have 4 spans in each direction. The roof of the structures is considered as shell type.

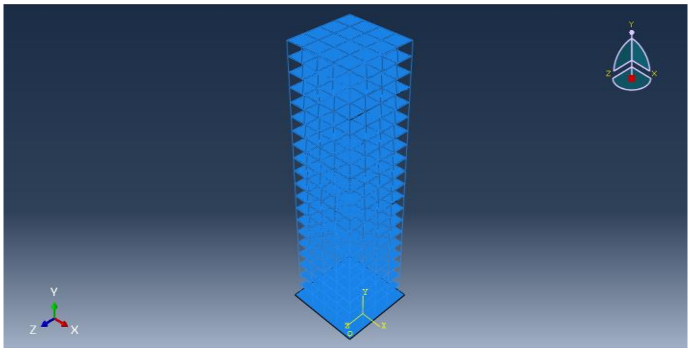
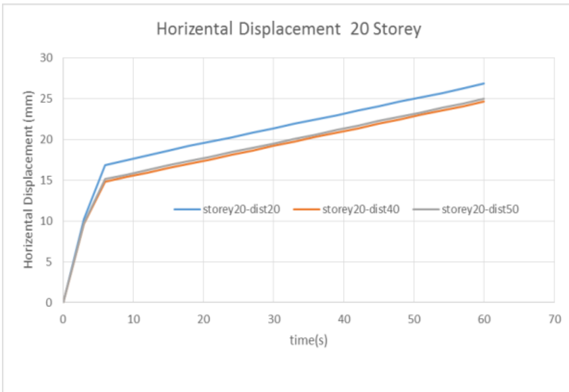


Figure 3: Modeled Structure

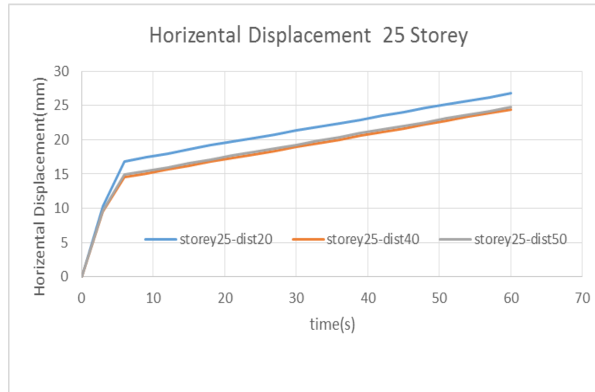
Discussion and Results

Horizontal displacement of excavation

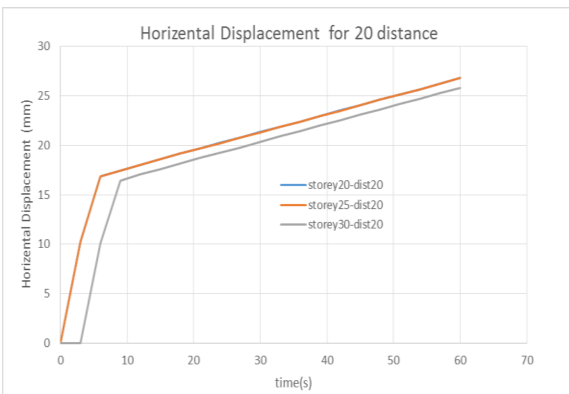
In this section, the effect of high-rise structure on the horizontal displacement of excavation is investigated. In this section, the results are examined in two separate parts (Cao, 2012). In the first part, the effect of the distance is investigated. For each of the 20-, 25-, and 30-storey structures, the results are presented against three distances of 20, 40 and 50 meters from the excavation edge in a figure.



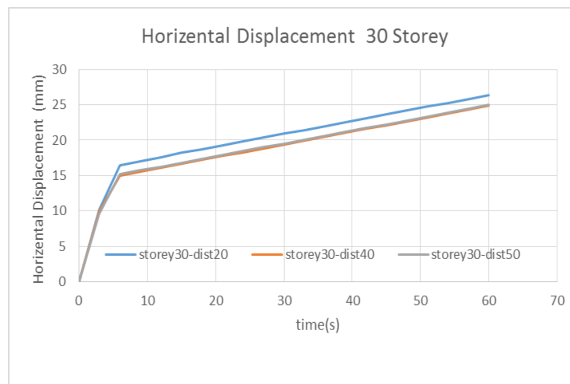
Horizontal displacement of excavation edge at a distance of 20 m



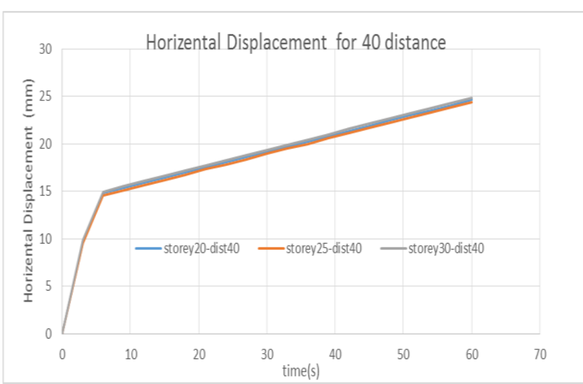
Horizontal displacement of excavation edge at a distance of 25 m



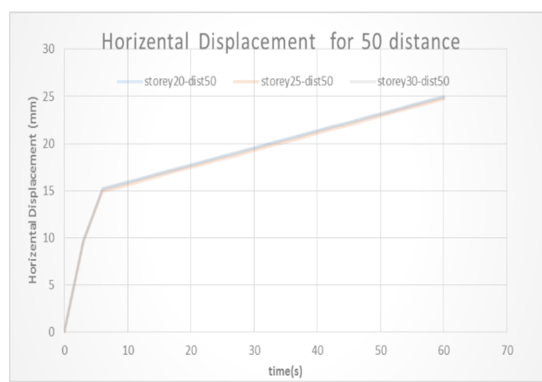
Horizontal displacement of excavation edge at a distance of 20 m



Horizontal displacement of excavation edge at a distance of 30 m



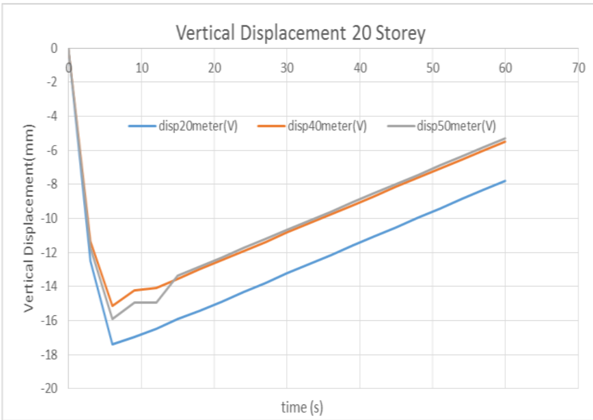
Horizontal displacement of excavation edge at a distance of 40 m



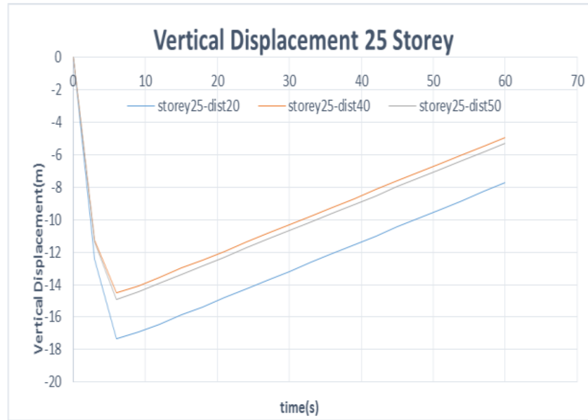
Horizontal displacement of excavation edge at a distance of 50 m

Vertical displacement of excavation

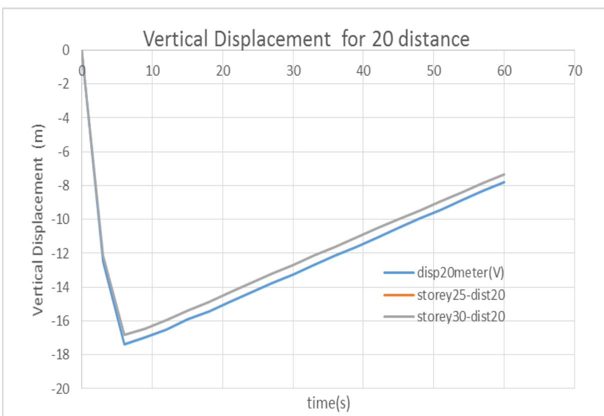
In this section, the effect of high-rise structure on the vertical displacement of excavation is investigated. In this section, the results are examined in two separate parts. In the first part, the effect of the distance is investigated. For each of the 20-, 25-, and 30-storey structures, the results are presented against three distances of 20, 40 and 50 meters from the excavation edge in a figure. In the second part, the effect of the structure height is considered at each of the studied distances.



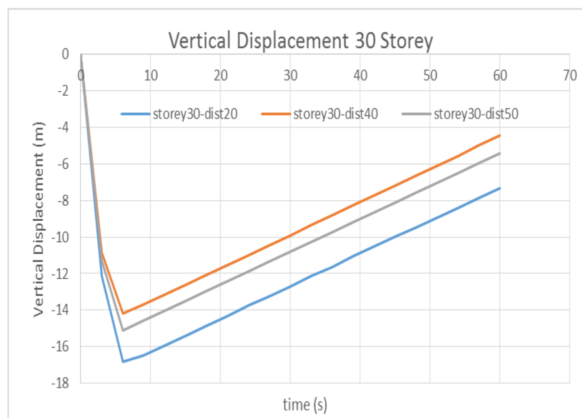
Vertical displacement of excavation edge at a distance of 20 m



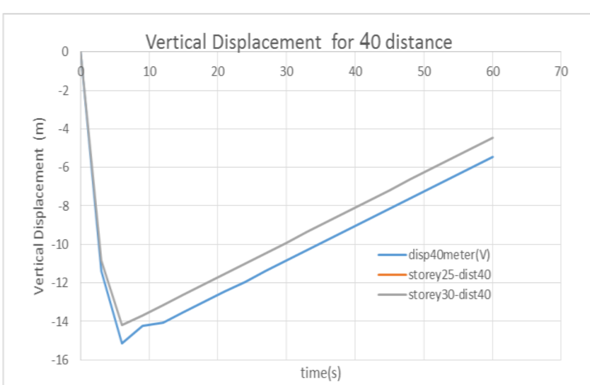
Vertical displacement of excavation edge at a distance of 25 m



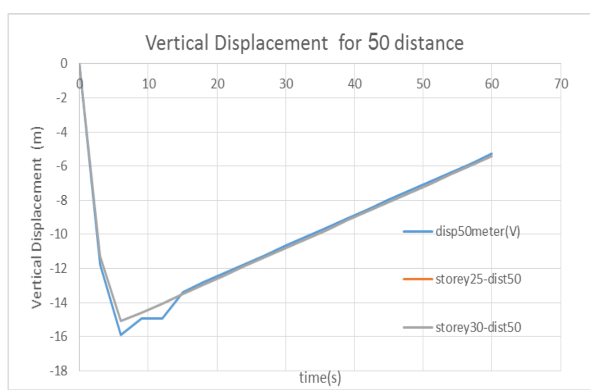
Vertical displacement of excavation edge at a distance of 20 m



Vertical displacement of excavation edge at a distance of 30 m



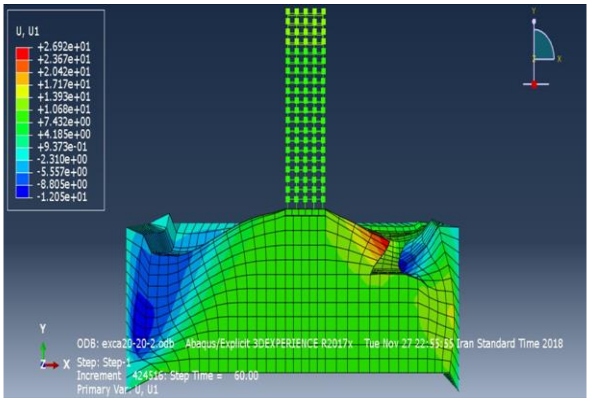
Vertical displacement of excavation edge at a distance of 40 m



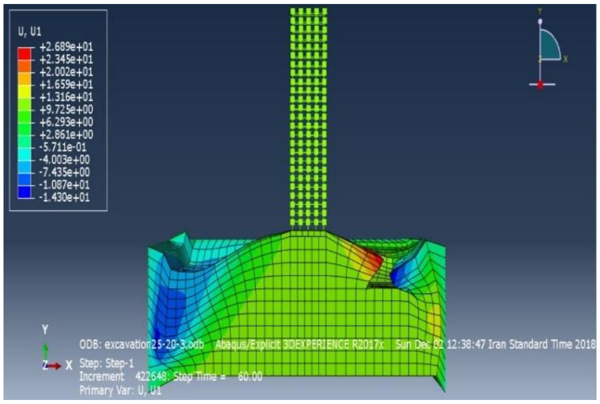
Vertical displacement of excavation edge at a distance of 50 m

Settlement distribution

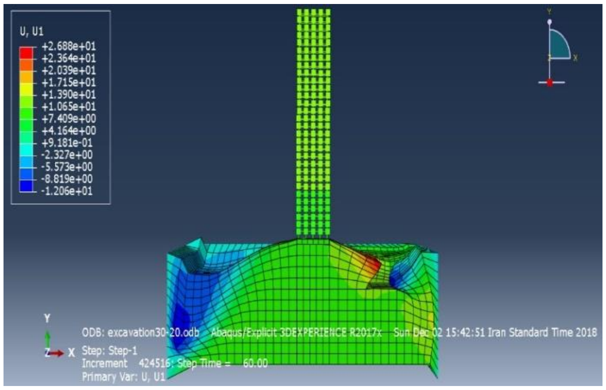
In this section, vertical settlement in soil, excavation and structure foundation is investigated. The settlement is investigated in three 20-, 25-, and 30-storey structures at three distances of 20, 40 and 50 meters from the excavation edge. The amount of settlement is shown in different sections based on the contour.



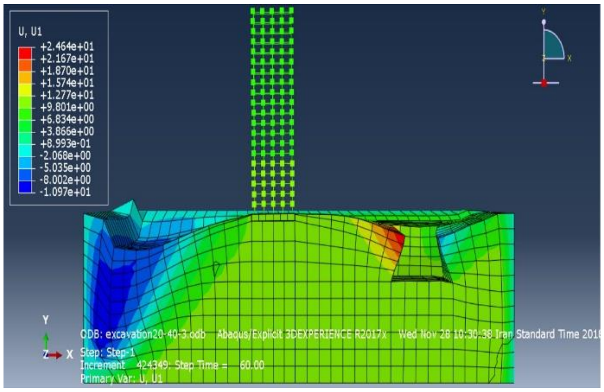
Displacement distribution in the 25-storey model at a distance of 20 m



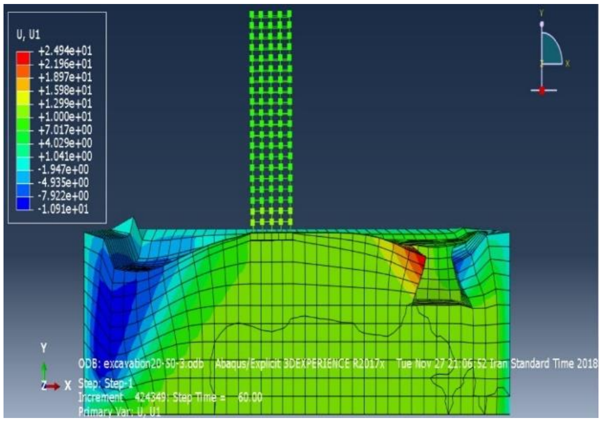
Displacement distribution in the 20-storey model at a distance of 20 m



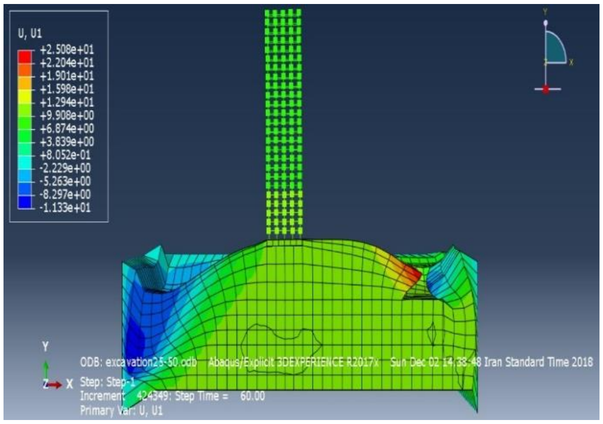
Displacement distributions in the 20-storey model at a distance of 40 m



Displacement distribution in the 30-storey model at a distance of 20 m



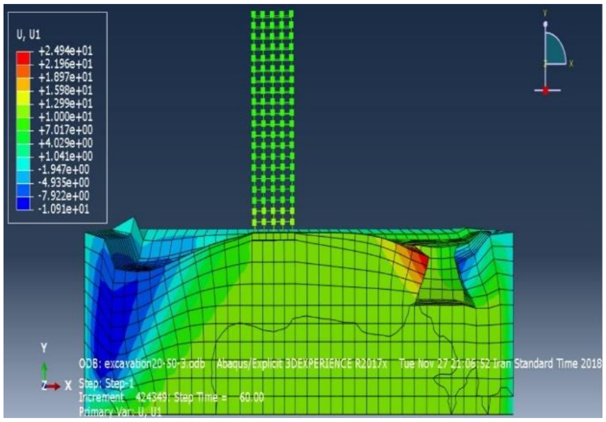
Displacement distributions in the 30-storey



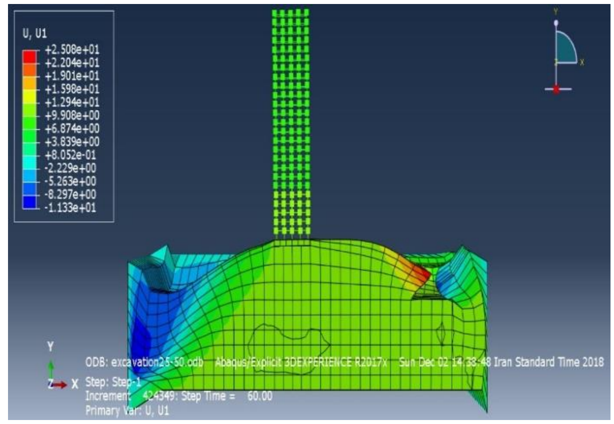
Displacement distribution in the 25-storey model

model at a distance of 40 m

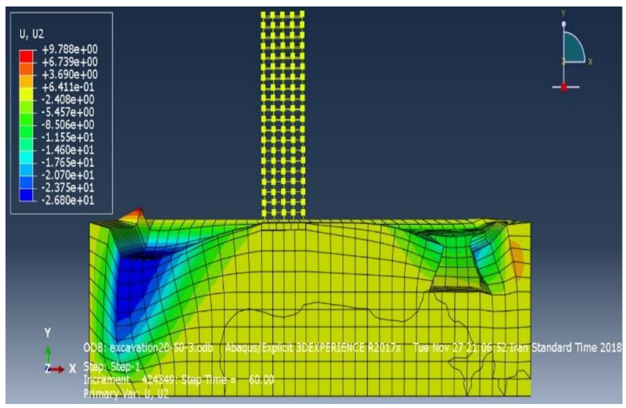
at a distance of 40 m



Displacement distributions in the 25-storey model at a distance of 50 m



Displacement distribution in the 20-storey model at a distance of 50 m



Displacement distribution in the 30-storey model at a distance of 50 m

Conclusion

According to the results of present study on the behavior of high-rise structures near deep excavations, it can be concluded that:

- The lateral displacement of excavation decreases as the distance increases, so that the distance doubles, lateral displacement decreases by 25%. But when the distance increases by 25%, the lateral displacement decreases by 3%. This is almost the same in 20-, 25- and 30-storey structures (Cardenas, Halman and-Jibouri, 2009).
- The results indicate that at a given distance, changing the structure height does not have significant effect on the lateral displacement and instability of the excavation, and lateral displacement of excavation depends on the number of floors as much as about 3-5% (Chandler, 1996).
- The results indicate that the vertical displacement of excavation is greatly sensitive to the distance of the structure from the excavation edge. This is fully observed in 20-, 25- and 30-storey structures and as the distance of structure from the excavation edge doubles, the vertical displacement decreases about 30% (Chowdhury, 2009).
- The results of the displacement distribution indicate that the most critical area is the excavation edge in terms of lateral and vertical instability. This is quite obvious in all three structures and at all three distances (Chowdhury, 1987).

References

1. Abramson, L. (2002). Slope Stability and Stabilization Methods. McGraw-Hill, New York.
2. Akbari Hamed, A. Moghaddaripoor, M. and Rahmani, I. (2011). Reliability analysis of the nailed walls using the Monte Carlo probabilistic method. Proceedings of the second conference on reliability engineering. Tehran, Aerospace Research Center.
3. Ang, A. S., Tang, A. H. (1984). Probability Concepts in Engineering Planning and Design. Inc, New York, vol. vol. II, 1984.
4. Aven, T., Vinnem, J. E. (2007). Risk Management Principles and Methods-Review and Discussion. Risk Management: With Applications from the Offshore Petroleum Industry, 19-75.
5. Baecher, G. B. (1987). Geotechnical Risk Analysis User's Guide (No. FHWA/RD-87-011).
6. Baecher, G. B., Christian, J. T. (2005). Reliability and Statistics in Geotechnical Engineering. John Wiley & Sons, New York.
7. Box, G. E., Muller, M. E. (1958). A Note on the Generation of Random Normal Deviates. Mathematical Statistics, Vol. 29, pp. 610-611.
8. Cao, Z. (2012). Probabilistic Approaches for Geotechnical Site Characterization and Slope Stability Analysis.
9. Cardenas, I. C., Halman, J. I. M., & Al-Jibouri, S. H. (2009). An Uncertainty-based Framework to Support Decision-making in Geotechnical Engineering Projects.
10. Chandler, D. S., (1996). Monte Carlo Simulation to Evaluate Slope Stability. Conference Proceeding on Uncertainty in the Geologic Environment, Wisconsin, Vol. 1, pp. 474-493.
11. Chowdhury, j. (2009). Geotechnical Risk Assessment and Hazard Management Guidelines. Principal Engineer Geotechnical.
12. Chowdhury, R.N., (1987), Practical Aspects of Probabilistic Studies for Slopes, Soil Slope Instability and Stabilization, Sydney, pp. 299-304.
13. Chowdhury, R.N., Xu, D.W. (1995), Geotechnical System Reliability of Slopes. Reliability Engineering and System Safety. Vo1.47, pp. 141-151.
14. Christian, J. T., Ladd, C. C., & Baecher, G. B. (1994). Reliability applied to slope stability analysis. Journal of Geotechnical Engineering, 120(12), 2180-2207.
15. Kasebzadeh, Dj. (2013). Evaluation of soil liquefaction potential through reliability analysis. Master's Thesis, Civil Engineering, Soil Mechanics and Foundation, Faculty of Water and Environmental Engineering, Shahid Beheshti University.
16. Manafi Qarabaei, S.M. (2011). Investigation of the slope instability of the earth dam body in safety management using risk assessment. Master's Thesis, Civil Engineering - Soil Mechanics and Foundation, Faculty of Water and Environmental Engineering, Shahid Abbaspour Power and Water University of Technology.
17. Manafi Qarabaei, S.M., Noorzad, A., Mahdavifar, M.R. and Bagheri Khalili, F. (2011). Investigation of the slope instability of the earth dam body using the Monte Carlo method (Case study: Doosdi Dam). First International Conference and Third National Conference on Dam and Hydroelectric Power Plants. Tehran, http://www.civilica.com/Paper-NCHP03-NCHP03_400.html.
18. Taghizadeh Ghahi, E. (2008). Stabilization of deep excavation walls in urban areas with nailing. Honar-Ha-Ye-Ziba Journal, Issue. 35, Autumn 2008, pp. 51-61.