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Effect of Number and Type of Soil Layers on the Response of Buried Structures to Explosion

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ABSTRACT: In the field of buried or underground structures, the objective of passive defense is to properly design, improve and place such structures. Among the best methods to analyze the problems are numerical and computer models. In the present research, using the previous results, the accuracy of surface explosion loading modeling results was evaluated. Moreover, the structures buried in different soils and the layered system were investigated after ensuring these models. To model the effect of soil-structure interaction, the analysis is performed non-linearly using Abaqus software. The structure is buried in the soil as a single layer, double layers, and triple layers with a burial depth of 8 m above the ground while comparing the displacement and stress. The soils used in this research are soft sand, hard sand, and clay. The results show that the highest displacement is related to the placement of the first layer of soft sand, the second layer of hard sand, and the third layer of clay. However, the lowest amount of displacement is associated with a single layer of soft sandy soil. Also, changes in the material and the number of layers sometimes lead to a reduction of more than 100% and 19% respectively in the resulting stresses and the displacement in the buried structure. This issue shows the necessity of the effect of soil layering in the design of buried structures.

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1- Introduction

Examination of buried structures to safely design them is greatly important. The type and number of the soil layers for burying can be effective on the buried structure's response. Heydari and Zolfaghari [1] investigated the behavior of underground structures buried in a two-layer system against loading due to underground explosion, under different soil behavior models. Their results show that the Mohr-Columbus behavioral model increased compressive stresses compared to the Drager-Prager behavioral model. Habibi et al. [2] assessed the effects of explosions on buried tanks and their dynamic response. From their results, it is indicated that the effect of an explosion on any structure depends on the type, weight, size, and shape of the impact of the explosive. In a study, Negi et al. [3] investigated a structure buried at the depth of 4 m under the influence of a surface explosion. According to the research results, the amount of displacement, acceleration, and stress in the center of the roof is more intense than in the corner of the roof. In this research, a buried structure is modeled numerically under explosion.

2- Methods

In the present research, Abaqus software was used for numerical modeling. To validate the modeling results, the research of Negi et al. [3] on clay was considered. Considering the importance of the accuracy of the results in this study, it was tried to use the default validation materials as much as possible while changing the layering and type of the soils. In modeling, the nonlinear Drager-Prager model was used for three types of clay, soft sand, and hard sand.

3- Results and Discussion

First, the soil types in the single-layer state were studied. Then, increasing the number of soil layers, the two-layer and three-layer states were considered to examine the maximum stress and displacement in different states. The single-layer, two-layer, and three-layer modes are respectively represented in Figures 1-3. Parameters a, b and c are the variable thicknesses of the layer.

Figure 4 represents the comparison of different states for maximum displacement and in Figure 5 for maximum stress. As seen in Figure 4, the highest displacement is related to the three-layer soil conditions. It means that the first layer is soft sand, the second layer is hard sand and the third layer is clay. The lowest displacement is related to the single-layer soft sand soil conditions. The difference of 19% represents the importance of soil layering on the response of buried structures. This proves that the behavioral properties of soils and the interaction of layers can change the displacement

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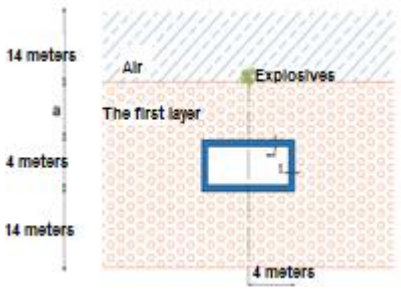

Fig. 1. The schematic illustration of a structure buried in a single layer of soil

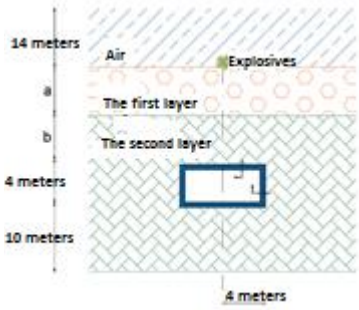

Fig. 2. The schematic image of a structure buried in two layers of soil

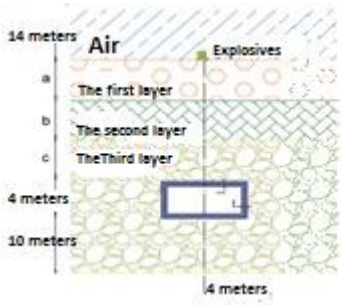

Fig. 3. The schematic image of a structure buried in three layers of soil

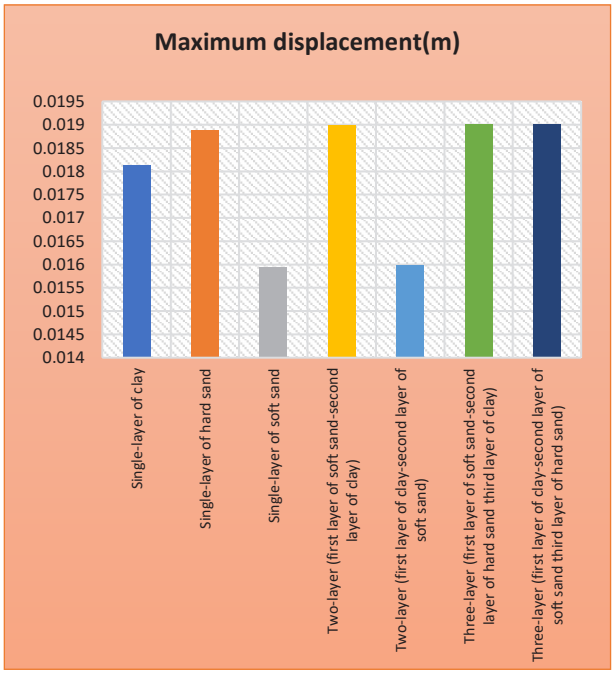

Fig. 4. The maximum displacement for all soil conditions at a depth of 8 m

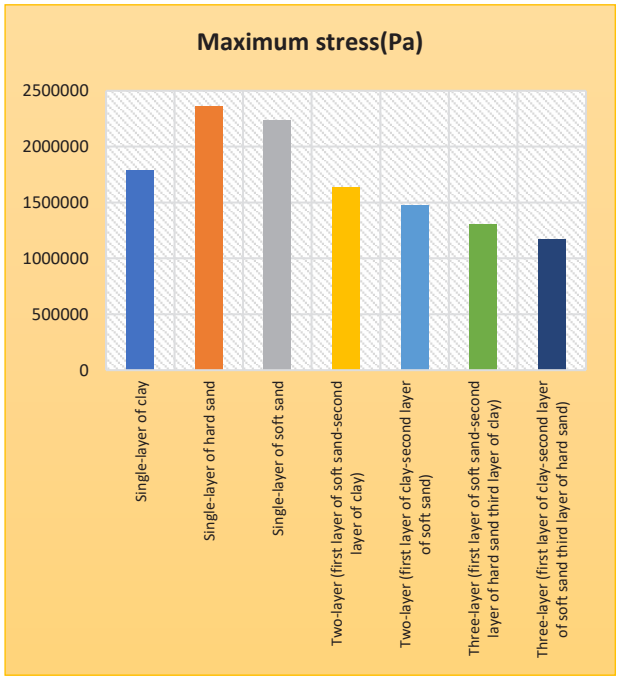

Fig. 5. The maximum stress for all soil conditions at a depth of 8 m

created in the structure by changing their number. Also, single-layer soft sand compared to clay and single-layer hard sand reduced the displacement in the structure. These differences were about 18% and 13%,

respectively. This indicates the importance of changing the behavioral characteristics of the soil on the transmission of explosion waves to the structure. This means that even by not changing the number of layers, altering the soil materials' properties can lead to a difference of more than 20% in the results.

According to Figure 5, the maximum stress values in the layered state in the buried structure are less than in the single-layer soil. A difference of more than about 100% is observed between the state of single-layer hard sand soils to three-layer soils.

4- Conclusion

In this study, using Abaqus finite element software, the effect of soil number and type on the response of buried structures to the explosion was analyzed. It was indicated that the highest displacement was related to the three-layer soil condition, meaning that the first layer was soft sand, the second layer was hard sand and the third layer was clay. The lowest displacement was in single-layer soft sand soil conditions. The rate of this difference was about 19%. Also, single-layer soft sand reduced the displacement in the structure compared to the clay and single-layer hard sandy soil. These differences were about 18% and 13%, respectively. Regarding the effect of soil layers on the response of buried structures, it was indicated that with increasing the number of soil layers, the rate of stresses was decreased. This stress difference is sometimes almost more than 100%.

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