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Evaluation the impact of weak layer in layered soil media using MASW method

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Abstract

Detecting the subsurface anomaly and characteristics of the soil such as weak layer is one of the most important parts of an engineering project. In this paper, the multichannel analysis of surface wave (MASW) is used to identify the subsurface anomaly. The effect of weak layer between soil layers is evaluated by simulating in ABAQUS software. In this regard, the effect of changes in the depth and thickness of weak layer are compared with the results of a two-layer soil media. In examining of thickness parameter, the values of 2, 4, 6 and 8 meters are chosen for thickness of the weak layer. Also, in the investigation of the depth parameter, the location of the weak layer at the depths of 2, 4, 6 and 8 meters are selected. The results showed that the presence of the weak layer caused discontinuity and jump in phase velocity spectrum of Rayleigh wave. It was determined that the position of jump is moved from higher to lower frequencies by increasing the buried depth of the weak layer. In accordance to the increase in the thickness of the weak layer, the number of jumps are increased, and these jumps are inclined towards lower frequencies.

Keywords: *Weak layer, Rayleigh wave, inversely dispersive layers,* phase velocity spectrum*, Depth and thickness.*

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Extended Abstract:

1. Introduction

The presence of subsurface anomalies such as holes, sinkholes, weak subsurface layers, faults, tunnels that created by humans or nature can create serious risks to the environment or engineering projects. The presence of anomalies such as cavity or weak layer between two stiff layers is increased the settlement potential, so identifying the thickness and depth this anomaly are more important (Aminnejad and Butt, 2003; Mirassi and Rahnema, 2014, 2016, 2017, 2020; Coduto, 2015; Rahnema et al., 2021). Multichannel analysis of surface wave (MASW) is a non-destructive seismic method that has been used since the middle of the 20th century until now to identify the characteristics of soil layers and subsurface anomalies (Nazarian et al., 1983; Ivanov et al., 2003; Chai et al, 2012; Park et al., 1999; Rahnema et al., 2020). In this paper, Rayleigh waves have been used, which include 67 percent of the energy of the wave field in a wave field, and therefore have the greatest potential for identifying subsurface anomalies. Subsurface cavities are investigated by transferring the recorded data of refracted Rayleigh wave to the distance and frequency domain (energy spectrum), that show there is a concentration of energy at cavity location (Rahnema and Ehsaninezhad, 2016). Therefore, the presence of a weak subsurface layer similar to cavity has a serious impact on engineering designs, and its identification helps engineers to prevent the occurrence of possible problems.

2. Materials and methods

The seismic data recorded by the seismograph device or obtained from numerical modelling are in the time-interval (x-t) domain, and in order to draw the dispersion curve of these data, these data must be transferred using the Fourier transform method and transferring to frequency-wavenumber (f-k) domain. The Finite Elements Method (FEM) has been used as a successful method in wave propagation problems. The simulation of finite elements for impact loads on the free surface causes a significant energy return from the boundaries of the unbounded elements, which is solved by using the absorbent boundary method under the headings of absorbent layers by increasing the damping of 10 layers. Linear elastic behaviour is used in modelling. The model used in this article has 14 meters depth and 40 meters long (Figure1). The layers are simulated horizontally and the number of 48 geophones are arranged at a distance of 0.5 m from each other (Figure 1). Ricker source load with a central frequency of 50 Hz is applied on the left and right side of receivers on the ground surface.

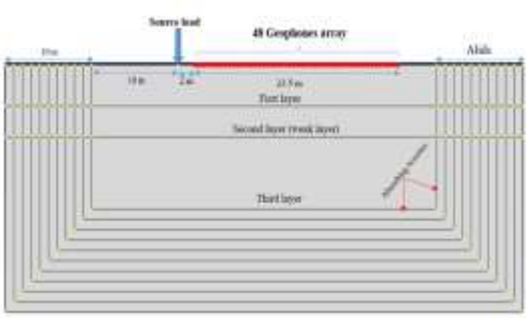

Figure 1. Specifications of the three-layer soil model and how to place the layers and details of the model

3. Results

In this article, four different models have been used to investigate the effect of depth and thickness of weak layers. In order to evaluate the effect of depth, a weak layer with a thickness of 2 meters, which has less hardness than its upper and lower layers, is located at depths of 2, 4, 6, and 8 meters from the ground surface. Also, to identify the effect of thickness, a weak layer with thicknesses of 2, 4, 6 and 8 meters are considered.

The phase velocity spectrum of each model is obtained and compared. The results show a different number of jumps and discontinuities in certain frequencies by changing the depth and thickness of weak layer. The first jump in the Rayleigh wave velocity spectrum of weak layers with thicknesses of 2, 4, 6, and 8 meters occurred at frequencies of 37, 24, 17, and 13 Hz, respectively. Also, more jumps have been created for a thickness of 8 meters compared to 2 meters. The number of jumps for a weak layer with a thickness of 8, 6, 4, and 2 meters are equal to 6, 4, 2, and 1, respectively.

4. Conclusion

The results of this study show that:

- By increasing the thickness of the weak layer, two types of changes are observed in the Rayleigh dispersion spectrum, the first is the change in the number of jumps created and the second is the difference in the frequencies at which such jumps were observed. For example, 6 jumps were created in the weak layer with a thickness of 8 m, while 2 jumps appeared for the weak layer with a thickness of 4 m.
- When the depth of weak layer is increased, the jump and discontinuity are moved from the high frequencies to low frequencies in the phase velocity spectrum. The obtained result is in good agreement with the fact that the higher frequencies in dispersion spectrum are related to the shallow surface and the low frequencies which is related to deep layers.
- The appeared jumps are in proportion to the increase in depth and thickness in the lower frequencies of Rayleigh waves, for example, for the weak layer at the depths of 2, 4, 6, and 8 meters the jumps appeared at frequencies of 37, 27, 21, and 17 Hz, respectively, in the dispersion spectrum which means that the lowest frequency is associated with the deepest weak layer. Also, the number of jumps for the weak layer with a thickness of 8, 6, 4, and 2 meters are 6, 4, 2, and 1, respectively, which indicates that there are more jumps for a thickness of 8 meters than for 2 meters.

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