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The Investigation of Traffic and Near-Field Earthquake Loads Effects on the Nailed and Braced Excavations

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ABSTRACT

Considering the statistical and probabilistic characteristics of construction conditions, the investigation of dynamic overloads' effects on the urban excavation wall is of great importance. In the present study, the performance of nailed and braced excavations under two vibrational dynamic excitations, traffic and near-field earthquake loads, have been investigated in four regions of Ahvaz. Critical boreholes with the lowest static bearing capacity have been selected by analyzing the layers' strength parameters in each region. Numerical models have been designed to limit the seismic waves' reflection at the excavation boundaries with 20 x 100 meters and with absorbing walls. Also, the damping ratio was assumed to be 2%. A harmonic wave at different speeds has simulated the excitation caused by the traffic passage. Resonant frequencies due to traffic induced vibration have been recorded in the speed range of 56 to 72 km/hr. Due to the traffic load, the bracing and the nailing systems showed less vertical and lateral displacements, respectively. Moreover, the excavations have been analyzed under 7 acceleration with compatible near field characteristics of the Ahwaz plan acceleration (0.25g). The golestan region showed the highest displacement difference between the two systems. Due to earthquake loads, the nailed system showed less vertical displacement and the braced system showed less horizontal displacment. The error of the analytical models' results in vertical displacement was 15% and in lateral displacement was 26% less than a nailed excavation located in the Kiyanpars region.

Keywords:

Urban excavation, Ahvaz, Traffic induced vibration, Resonance frequency, Near-field earthquake

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1.Introduction:

Increasing the depth of urban vertical excavations to provide car parks is a challenge in high-rise buildings in large cities. The time-consuming nature of building operations typically causes the vertical excavation walls to be exposed to dynamic overloads in this time period in addition to the usual static pressures such as lateral soil thrust and overloads due to the weight of adjacent buildings. Due to the statistical and probabilistic nature of dynamic overloads and their correlations with the environmental and site conditions, it is necessary to locally assesse the impacts of dynamic overloads[1]. To enhance the stability potential of urban excavations, nailing and bracing are typically employed. Numerical finite element (FE) analyses have shown that not only the geometry, slope, and soil properties but also the bracing bar inclination angle, bar properties, and bar spacing influence the suitability of a nailed slope wall[2]. Pile retaining walls are a specific type of bracing with vertical steel bars that are placed at a spacing of 1.5-3.0 m. Furthermore, it can sometimes be implemented by adding an inclined member (which is occasionally referred to as the truss bracing method)[3]. San and Duan (2013) studied asphalt cracks and used a sinusoidal wave to simulate the traffic load [4].The fault in Ahvaz, Iran, increases the vibration risk of structures under excitation with near-fault record characteristics (e.g., directivity and a pulse with large amplitude and medium-to-high period). Fakher et al. (2016) provided tables to determine the damage of adjacent structures based on the horizontal displacement of the excavation crest point in three types of soil [5].

This study analyzes vertical excavations stabilized by nailing and bracing in four regions of Ahvaz under dynamic loads, including traffic-induced vibration and near-fault ground motions. The output graphs of the designed models in PLAXIS are provided to compare the frequency content of the vertical and horizontal displacement responses of the excavation crest point under traffic load and a number of graphs to compare the peak horizontal and vertical displacement responses of the excavation crest point under records with near-fault characteristics in the regions of Ahvaz.

2.Methodology:

The FE analyses were performed in PLAXIS 2D on four excavations with a depth of 7 m in Kianpars, Zeytoon, Padad, and Golestan Regions. Each excavation was stabilized by nailing and bracing, evaluating slope wall performance in the excavation crest displacement.

The critical boreholes of each district were selected by measuring the weakest strength parameters of the soil layers. Parameters C and φ were obtained using unconsolidated-undrained (UU) tests. The excavations had a depth of 7 m, and the groundwater level was assumed to be 2 m in the analytical models based on the boreholes. The hardening soil model was adopted to analyze the models. This model defines three types of stiffness. Researchers have proposed the approximate relations of $E_{ur}^{ref} \approx 3E_{oed}^{ref}$ and $E_{50}^{ref} \approx E_{oed}^{ref}$ for most soils. This study adopted these relations. The values of E_{oed}^{ref} and E_{50}^{ref} were assumed to be equal to the elasticity modulus of the soil [5].

In pavement engineering, load induced by a falling weight deflectometer is often used to simulate moving loads with different amplitudes and frequencies [6]. The deflectometer-induced load is a bouncing load and can almost can approximately decribed by a half sinusoidal load in Eqs. (1) and (2) [4]:

$$p(t) = p_0 \sin(\frac{\pi}{T} t) \qquad (1) \qquad T = 12\frac{a}{V} \qquad (2)$$

Here, p_0 is the vehicle axle weight, T is the loading cycle period, a is the tire-surface contact radius, and V is the axle velocity introduced to the model for a moving axle with a width of 6 m. Different velocities can be simulated by changing the cycle period. To calculate the excavation crest displacement, seven near-fault records that had good consistency with the borehole sites and were aligned with the design acceleration of Ahvaz were used.

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3.Results:

Figure 1 compares the nailing and bracing stabilization systems under the traffic load in terms of the vertical and horizontal excavation crest displacement amplitudes, respectively.

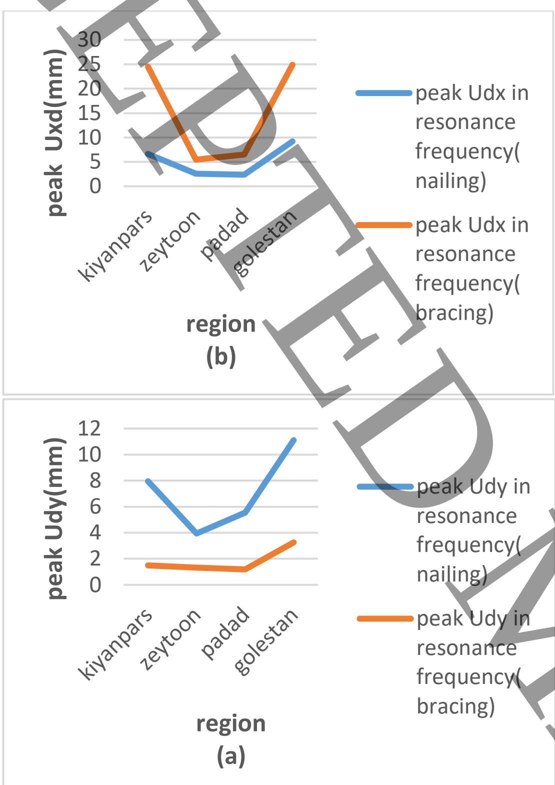

Figure 1. Comparison of nailing and bracing systems in (a) vertical displacement amplitude and (b) horizontal displacement amplitude

Figure 2 shows the bar charts of the average permanent displacement and maximum displacement of the excavation crest point with bracing and nailing stabilization under near-fault motion excitation for three regions in Ahvaz.

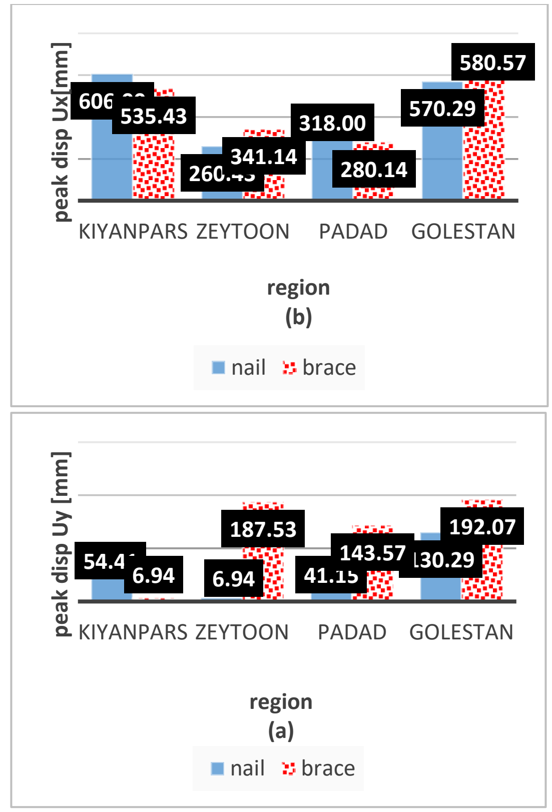

Figure 2. Comparison of nailing and bracing systems in (a) peak vertical displacement and (b) peak horizontal displacement of the excavation crest point

4-Conclusion:

Although vibration caused by the traffic load is a low-frequency phenomenon, the results of the analysis of the retrofitted excavation model under this type of excitation have shown that the occurrence of resonance at specific frequencies can result in larger deformations in the excavation wall, which can be destructive over time.

1- The peak vertical displacement of the nailed excavation crest point under traffic excitation was found to be 8.5, 3.9, 5.5, and 11.1 mm in Kianpars, Zeytoon, Padad, and Golestan regions, respectively. The peak horizontal displacement of the nailed excavation crest point under traffic excitation was obtained to be 6.6, 2.5, 2.3, and 24.9 mm in Kianpars, Zeytoon, Padad, and Golestan regions, respectively. The peak displacements in nailing occurred in the frequency ranges of 23, 7-9, and 11-13 Hz.

2- The peak vertical displacement of the bracing excavation crest point was found to be 1.5, 1.3, 1.1, and 3.2 mm in Kianpars, Zeytoon, Padad, and Golestan region, respectively, The peak horizontal displacement of the bracing excavation crest point was obtained to be 9.6, 5.1, 6.5, and 24.0 mm in Kianpars, Zeytoon, Padad, and Golestan region, respectively. The peak displacements in bracing occurred in the frequency ranges of 2-3, 7-9, and 11-13 Hz.

3- The dominant resonance frequency was found to be 7-9 Hz for most regions and the stabilization systems. It is equivalent to a speed of 56-72 m/s. It falls in the traffic speed limit range in urban areas and should be controlled by the axle speed and weight in traffic planning.

4- The bracing system had lower sensitivity (distortion) to vertical and horizontal displacement in the response spectra of the regions since its elements have higher stiffness. Lower distortion eliminates the resonance frequency at higher modes, leading to close frequencies of the dominant modes in different regions.

5- In addition to the resonance peak displacement at 7-9 Hz, the excavation crest displacement response spectra had lower yet significant peak values at the frequencies of 2 and >11 Hz. They occurred when the excitation frequency became the same as the frequency of the higher modes of the site and stabilization structure. These displacements were sometimes very close to the peak displacement at the resonance frequency. Therefore, the site and its higher modes must be evaluated.

6- The soil behind the slope wall and the stabilization structure function as an integrated system and have a very similar natural frequency but not the same as the intrinsic modes of the site.

7- The nailing system had lower horizontal excavation crest displacement control under the traffic load and higher horizontal stability. The bracing system had lower vertical excavation crest displacement control and higher vertical stability. Despite the challenges in bracing implementation due to unstable soil in Ahvaz (i.e., the need for wooden support and shotcrete to prevent collapse in semi-deep excavation), it had lower horizontal displacement in the excavation crest point since it utilizes continuous and stronger elements compared to the thin shell of the nailing system.

8- The nailing system showed lower vertical displacements and provided higher vertical stability under ground motion excitation in all the regions, except for Kianpars. The bracing system provided lower displacement and higher stability under ground motion excitation for all the regions, except for Golestan.

5.References

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