University of Tabriz

Journal of Civil and Environmental Engineering
Volume 53 (2024), Issue 4 (Winter), 85-99

EXTENDED ABSTRACT

Study of the Effects of Particle Size on the Pre-Seismic Behavior of Physical Models of Dry Granular Soils

Yazdan Shams Maleki *

Faculty of Engineering, Department of Civil Engineering, Kermanshah University of Technology (KUT), Kermanshah, Iran

Received: 22 April 2022; **Review:** 25 October 2022; **Accepted:** 12 October 2022

Keywords:
Granular embankment, Natural frequency, Physical model, Pre-seismic model, Particle size.

1. Introduction

To study the dynamics of embankment models, which is the basis for the construction of many engineering structures, physical modeling with different scales can be performed. The pre-seismic behavior of physical models has a great impact on the subsequent results of their seismic modeling. Appropriate experiments in this field can be used for pre-seismic examination of physical models. Free vibration and impact tests are among these tests (Dezi et al., 2012; Capatti et al., 2018; Kramer, 1996). Impact pulse tests (IPT) can be used to determine the natural frequency characteristics of physical models. Interpretation of frequency responses provides researchers with appropriate pre-seismic parameters. According to the evaluation of these findings in the first step, a suitable geometric scale can be selected for physical modeling. In addition, the relationship between soil conditions in terms of density and particle size and frequency response quantities of physical models is also determined. In this paper pre-seismic simulations of a small-scale physical model of a granular soil layer inside a rigid physical modeling box are developed.

2. Methodology

2.1. Experimental study

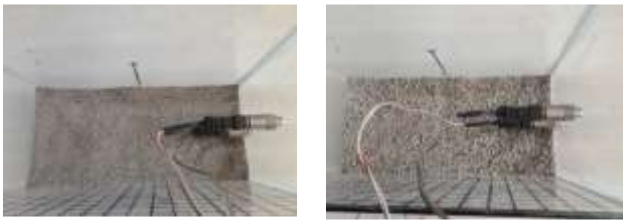
Physical modeling method has been used for laboratory (experimental) studies in this paper. Physical models of the granular soil layer are implemented inside the rigid box. The model embankment layer inside the modeling box includes the separate implementation of three different particle sizes of sandy soil, including fine-grained, medium-grained and coarse-grained sand, as well as a fine-grained gravel case. To investigate the pre-seismic behavior and natural frequency of physical models of granular embankment, acceleration sensors have been installed at the height of the modeling box and the vibration responses of the hammer impact pulse test have been extracted. Sandy and gravelly soils have been selected of the poor-grained type to investigate the side effects of void ratio and density of the models on the frequency responses. Short-term impact acceleration (less than 1 second) has been qualitatively and quantitatively analyzed in both time and frequency domain.

2.2. Physical modeling

Physical modeling of the granular embankment layer inside the rigid box has been performed in two small-scale dimensions of one-hundredth (Fig. 1) and one-thirtieth (Fig. 2) of the prototype. Granular soils with a relative density between 20% to 60% are embedded in the box as a layer of embankment using the sand raining (pluviation) method. The arrangement of the acceleration sensors in the body of the physical modeling box is

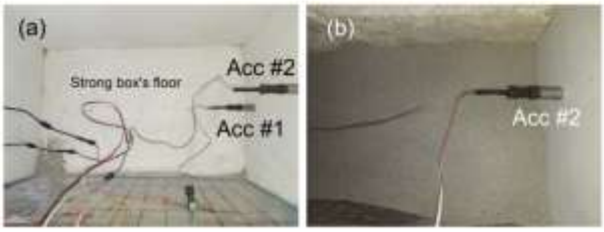
* Corresponding Author
E-mail addresses: y.shamsmaleki@kut.ac.ir (Yazdan Shams Maleki)

such that the time delay between the place of impact (input acceleration) and the impact response (output acceleration) can be measured (Figs. 1 and 2). Butterworth band-pass frequency filter with a frequency range between 0.1 and 100 Hz is applied to eliminate the effects of high frequency of the initial compressive waves (P-waves) generated by the impact on the impact acceleration responses of the extracted. Acceleration data are collected with good frequency resolution to analyze the state of shear stresses and the shear wave propagation velocity at the height of the physical model.



(a) (b)

Fig. 1. Arrangement of acceleration sensors in a small box of physical modeling containing: (a) fine-grained sand, (b) medium-grained sand.



(a) (b)

Fig. 2. Arrangement of acceleration sensors in a large physical modeling box: (a) Empty box, (b) Box with fine-grained sand model.

3. Results and discussion

3.1. Effect of granular soil particle size on the pre-seismic physical models

In physical models of poor-grained granular soils, changes in soil particle diameters are negligible and most particles are in the same group, so compacting them by increasing the size of the soil particle diameter, naturally and unintentionally due to the increase in pore volume, it gets harder. As a very important limitation, in the physical model, the lower the density of a granular soil, which is naturally equivalent to an increase in soil particle size according to the findings of this study, the lower the resonance frequency of the model (and the natural period is increased). That is, in order to implement physical models of coarse-grained granular soil, the dimensions of the modeling box should be enlarged as a minimum (initial) solution. The resonant frequencies and shear wave velocities in the physical (small-scale) model can be estimated with very high accuracy from the peaks of the power spectral density function (or PSD). As shown in Fig. 3, as the size of the sandy soil particles increases, the resonance frequency decreases. In physical models including coarse-grained soils (such as gravel or coarse sand without fine-grained particles or filler) it is not possible to continue the compaction process of coarse-grained soils to increase the relative density of the physical model to the threshold of the maximum density of the fine-grained soils. Because the use of more compaction energy leads to the crushing of coarse particles and changes in the initial-natural (default) particle size.

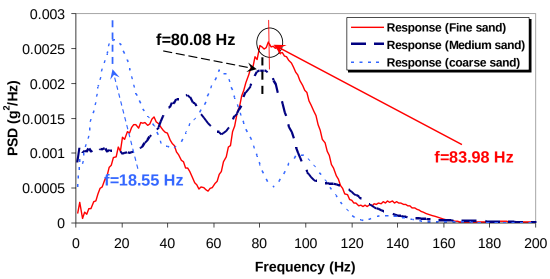


Fig. 3. Power spectral density responses of impact vibrations for three different sizes of sand particles in a small box

3.2. Parametric study findings

According to Fig. 4, a parabolic relationship (quadratic and nonlinear) between the changes in the mean diameter of soil particles D_{50} and the amplification of the acceleration amplitude at the height of the box (with appropriate accuracy) is observed. Accordingly, the empty box response naturally reveals the lowest magnification between the acceleration amplitudes of the input (lower sensor) and the output (upper sensor). Then, as the size of the sand particles increases, so does the magnification. Until the particle size becomes equivalent to gravel particles. In this case, due to the lower achievable relative density of gravel particles in physical modeling (relative increase in void ratio-inter particle voids) and the higher intrinsic stiffness of the gravel particles compared to sand, (in the fixed volume of the rigid box) again the response of the impact acceleration amplitude has been attenuated/reduced. In fact, here the higher stiffness of gravelly materials than sands has reduced the amplitude of the response acceleration. On the other hand, the higher void ratio of these materials (gravel) has reduced the magnification of the response acceleration amplitude compared to the similar coarse sand.

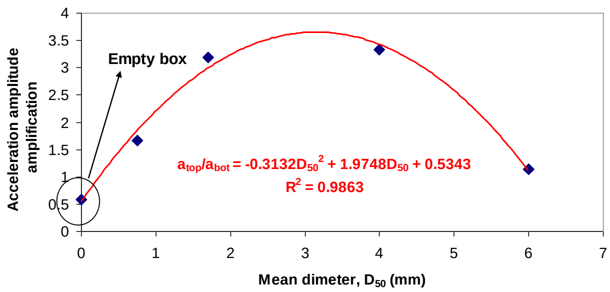


Fig. 4. Parabolic relationship between changes in average diameter of soil particles (D50) and amplification of acceleration amplitude at box height

4. Conclusions

In this study, physical models of the soil layer inside the rigid box have been implemented. There are four sizes for granular soil particles. Sandy and gravelly granular soils were selected. Natural frequency and pre-seismic studies of the physical model have been performed to successfully create the next seismic physical model. Based on the findings of this study, there is a parabolic function between the changes in the mean diameter of granular soil particles, D_{50}, and the amplification of the response accelerations of the physical model, which is due to the clear ascend and descend of acceleration values due to the stiffness-void ratio-compaction effects of the soil aggregates. Also, hammer impact pulse testing for the physical model in the 1g acceleration field can well calculate the free-vibration seismic behavior and natural frequency of granular soils with high accuracy. The separate effects of propagation of compressive and shear waves due to impact have been calculated and observed with high accuracy in the results of this research. The near-impact acceleration sensor is less affected by the generation of compressive waves than the farther sensor. The reason was the issue of wave propagation.

5. References

Capatti MC, Dezi F, Carbonari S, Gara F, "Full-scale experimental assessment of the dynamic horizontal behavior of micropiles in alluvial silty soils", Soil Dynamics and Earthquake Engineering, 2018, 113, 58-74. https://doi.org/10.1016/j.soildyn.2018.05.029

Dezi F, Gara F, Roi D, "Dynamic response of a near-shore pile to lateral impact load", Soil Dynamics and Earthquake Engineering, 2012, 40,34-47. https://doi.org/10.1016/j.soildyn.2012.04.002

Kramer SL, "Geotechnical earthquake engineering", 1996, New Jersey: Prentice-Hall. ISBN-10:0133749436