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Shaking table tests on seismic behavior of sand slopes reinforced by carpet strips

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ABSTRACT: In order to investigate seismic behavior of slopes, made of reinforced sand, a series of shaking table tests were performed. Model slopes were prepared in a box with length of 1.8 m, width of 0.5 m and height of 0.7 m. Sand slopes were reinforced with randomly distributed carpet waste stripes. During application of cyclic loading on unsaturated soil, failure surface and acceleration were monitored in models. Result of this study shows the effects of soil reinforcement during cyclic loading. These results are very useful for study the behavior of different soil structure in which soil is reinforced by mentioned type of reinforcements.

1 INTRODUCTION

Engineering practitioners and researchers have shown a growing interest in laboratory tests for assessing the seismic stability of slopes and embankments. Element and model tests are two different useful methods to understand the behavior of soil structures subjected to different types of loading. Shaking table test is a model test, which has been used in many geotechnical researches. The recent trend in finding solution to geotechnical engineering works has resulted in various construction techniques that are based on developments of new materials and concepts. One of them is the use of reinforcement material such as waste carpet stripes that distributed in mixture with soil randomly.

Clough and Pirtz (1956) performed the first well-documented shaking table study on seismic slope stability. Later, Goodman and Seed (1965) performed shaking table tests on an inclined layer of sand. They focused on the yield acceleration (i.e., the acceleration required to bring the slope to a condition of marginal instability) and they found that calculated yield accelerations is comparable with measured test results. Arango and Seed (1974) used a modified version of the shaking table described above to investigate the seismic stability of slopes. They found that strong shaking resulted in development of a distinct "yield acceleration" that marked initiation of permanent deformation in their slopes. Lin and Wang (2006) studied the earthquake resistance of slopes. In their research large-scale shaking table tests were conducted to study the slope behavior under earthquake loading. They found that the failure surface appeared to be fairly shallow and confined to the slope surface, which was consistent with the field observations of earthquake induced landslides.

Many researches have also studied the use of reinforced soil as a material for geotechnical structures such as dikes, slopes and walls.

Rechardsons and Lee (1975) performed a well-documented shaking table study of seismic behavior of slopes, made of reinforced sand with strips of aluminum and Mylar. They investigated two mechanisms including yielding of strips and their pull out force. Perez (1999) used soil, reinforced with geotextile to study the seismic behavior of slopes during cyclic loading in shaking table. He investigated vertical and horizontal displacement in models. Wang et al (2000) used sand, which was reinforced by carpet strips in triaxial tests. They showed that these elements increase the strength and flexibility of soil.

In this research model experiments were performed on a 1*g* shaking table with the objectives of investigating the mechanisms of seismically induced permanent deformations and amplification of strong ground motion.

2 EXPERIMENTAL STUDY

The current study was performed by using a 500 mm wide, 1800 mm long and 700 mm height single-degree-of-freedom shaking table. Data acquisition software was used to acquire signals from different data channels.

The soil used in this study was uniform medium sand (Firouz-Kouh No. 161) which its particle-size distribution curve is shown in Fig. 1. Specimen were

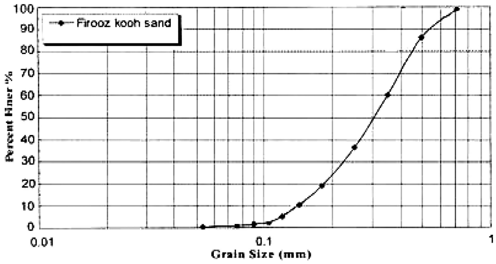

Figure 1. Particle-size distribution curve of the sand (Firouz *kouh* No. 161).

Table 1. Mechanical properties of materials.

Parameter	Reinforced sand
D_{50}	0.3
c' (kpa)	0.05
ϕ'	32
γ_d (kN/m^3)	14.92
e_{max}	0.85
e_{min}	0.608

prepared using volume controlled method of compaction with a water content of 5%.

Reinforced element which used in this research were discrete strips of carpets with 5 mm wide and aspect ratio (ratio of length to width) of 5.

These carpet strips were randomly distributed in sand. Direct shear tests were also performed on the specimens obtained from the slope models. Table 1 shows the results of tests.

3 MODEL PREPARATION

Specimens were compacted into the test box using the volume-controlled method to reach to a unit weight of 14.92 kN/m^3. In this method, specific weight of soil was put in the box first, and then compaction was being continued to get the target height based on density. Figure 2 shows the compaction of model.

After installing the accelerometer in the base of models, other soil layers were compacted similar to the first layer. Finally, another accelerometer was embedded on the crest. Figure 3 reveals the location of accelerometers.

4 LOADING AND TEST RESULTS

Experiments were performed on four slope models as following. The size of the model slope in first test was 0.35 m high, 0.5 m length of crest, and with both side slope of 1:2.5 (horizontal : vertical). Maximum

Figure 2. Compaction of model.

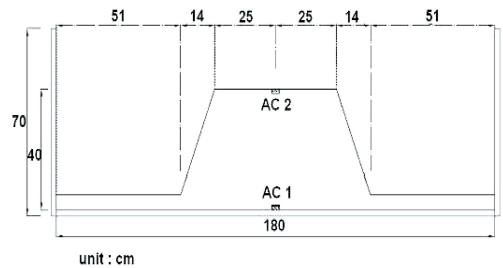

Figure 3. Position of accelerometers.

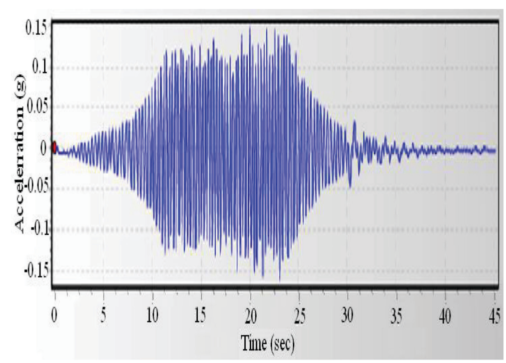

Figure 4. Time history of applied acceleration in base of test No. 1.

amplitude of applied acceleration in the base of model was as 0.153 g. Figure 4 illustrates the time history of applied input acceleration in the base of the model in test No. 1. The maximum amplitude of acceleration in the crest was recorded as 0.188 g. Figure 5 shows the time history of acceleration on crest of model.

Model No. 2 had 0.35 m high, 0.5 m length of crest, and side slopes of 1 : 3 (horizontal : vertical). Similar to model No. 1, Model No. 2 was subjected to a low amplitude motion, and experienced relatively small

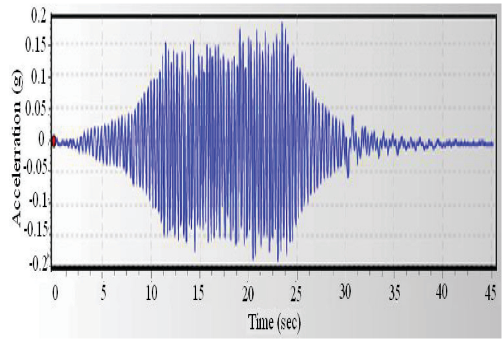

Figure 5. Time history of measured acceleration in crest of test No. 1.

Table 2. Geometry of models, recorded acceleration and amplification.

Model	Side slope H/V	Base Acc. (g)	Crest Acc. (g)	Amplification *n*
No. 1	1:2.5	0.153	0.188	1.229
No. 2	1:3	0.142	0.181	1.275
No. 3	1:3	0.164	0.205	1.250
No. 4	1:3	0.213	0.234	1.100

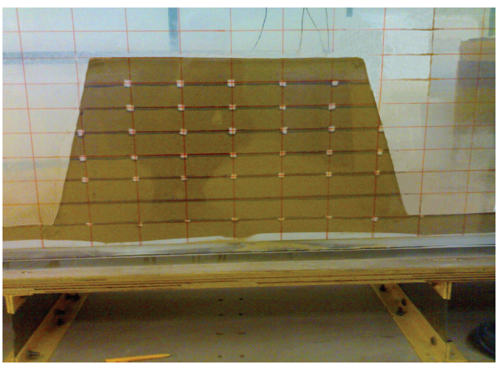

Figure 6. The model No. 4 before shaking.

deformations with development of a localized shear surface.

Models No. 3 and No. 4 were subjected to higher amplitude of acceleration (see Table 2). After application of dynamic loads to these models, model No. 3 experienced small deformation in the crest. However, in Model No. 4 failure surface happened and an unstable block moved downward. Figures 6 and 7 show the model No. 4 before and after shaking. Displacement of the moving block was more than 11 cm in horizontal and 24 cm in vertical direction. The observed failure surface appeared to be relatively deep in the face of the slope. Figure 7 also reveals that the failure surface was near to circular shape.

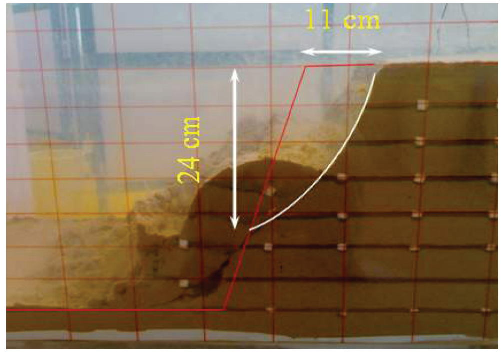

Figure 7. The model No. 4 after shaking.

Results of these tests can also be discussed as viewpoint of soil amplification. Table 2 shows the maximum-recorded acceleration of base, crest and the ratio of crest to base acceleration, which is defined as amplification factor. As it can be seen from this table in all samples amplification of acceleration happened. The range of amplification ratio is from 1.1 to 1.28. It is well known that the amplification of strong ground motion is depends on different parameters such as amplitude and frequency of input motion and geometry and density of soil structure.

Results of these tests and other similar tests can be used for study of dynamic behavior of reinforced sand when they combine with element tests results and numerical analysis.

5 CONCLUSION

In order to investigate the dynamic behavior of reinforced soil with carpet strips a series shaking table tests were performed. Results of these tests shows that:

1. Input acceleration is amplified in all tests. Range of amplification factor is from 1.1 to 1.28. It is known that this amplification depend on different parameters such as amplitude and frequency of loading, geometry and density of soil structure. More tests should be run to clear these effects.
2. Measured shape and geometry of failure surface in model No. 4 and displacement vector of downward moved block is very useful for study the behavior of real scale structures when theses results combine with results of different element test and numerical analysis

REFERENCES

Arango, I., Seed, H. B. (1974). "Seismic stability and deformation of clay slopes", Journal of Geotechnical

Engineering, American Society of Civil Engineering., 100(2), 139–156.
Goodman, R. E., Seed, H. B. (1965). “Displacements of slopes in cohesionless materials during earthquakes.”, Rep. No. H21., Inst. Of Trans. and Traffic Engineering, Univ. of Calif., Berkeley, Calif.
Lin, M. L., Wang, K. L., (2006). “Seismic slope behavior in a large scale shaking table model test”, Journal of Engineering Geology 86, 118–133.
Perez, A. (1999). “Seismic response of geosynthetic reinforced steep slopes” , M.S. Thesis, University of Washington.
Richardson, G. N. and Lee, K. L. (1975). “Seismic design of reinforced earth walls”, Journal of the Geotechnical Engineering, Volume 101, No. GT-2, ASCE, pp. 167-188.
Wang, Y., Frost, J. D. Murray. J. Jones, A. (1999). “Utilization of carpet, textile and apparel waste for soil reinforcement.”, ARC 99, SPE Annual Recycling.