WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 2, Feb., 2022

INVESTIGATION OF MODEL RETAINING WALL ON SOFT SOIL

Ripon Hore
Senior Assistant Engineer, LGED, Dhaka, Bangladesh,
E-mail: riponhore@gmail.com

Sudipta Chakraborty
Graduate Student, Department of Water Resources Engineering,
Bangladesh University of Engineering and Technology (BUET) Dhaka, Bangladesh,
E-mail: sudipta.ckr@gmail.com

M. A. Ansary
Professor, Department of Civil Engineering,
Bangladesh University of Engineering and Technology (BUET) Dhaka, Bangladesh,
E-mail: riponhore@gmail.com

ABSTRACT
This paper presents the results of shaking table tests on geotextile-reinforced embankment lying on soft clay. Construction of model embankment in a laminar box mounted on a shaking table, instrumentation, and results from the shaking table tests have been discussed in detail. The base motion parameters have been varied in different model tests. It has been observed that from these tests the response of the embankment with soft clay has been significantly affected by the base acceleration levels, frequency of shaking and magnitude of surcharge pressure on the crest. The effects of these different parameters on acceleration response at different elevations of the embankment, pore pressures and face deformations have been measured. The results obtained from this research are helpful in understanding the relative performance of reinforced soil-embankment under different test situations applied in the experiments.

Keywords: Laminar box, Soft soil, Amplification and acceleration

INTRODUCTION
The soil-foundation composed of clayey soil has become the focus of earthquake engineering in more cases. However, it is rather scarce to study the characteristic of pore water pressure in such soil-foundations with cohesive or clayey soil under earthquake action due to its clay content is thought of relatively high. Although such

soil-foundations of higher clay content are not easily susceptible to liquidity, a rise of excess pore water pressure triggered by earthquakes and a drop of effective stress may lead to the soil softening. Also, soil-foundation softening may cause damage to the embankment. Today, there is no absolute conclusion on whether the softening effect of cohesive or clayey soils under earthquake excitation should be considered and under what shake condition the damage induced by excess pore water pressure may not be considered in analysis. Based on shaking table tests, this paper attempts to investigate the changing characteristics of the amplification, displacement and pore water pressure (due to input acceleration) in soft soil-foundations under harmonic wave. The soil-foundation in the test has been built with soft soils in Dhaka clay. The physical mechanism responsible for variation behavior of the pore water pressure in the repeated process has been studied. The results of experimental investigation have been expected to provide some research basis for softening problems of clayey embankment under earthquake actions.

METHODOLOGY

Previous Research Developments of model testing in earthquake geotechnical engineering, two aspects of model testing have been given importance, namely rigid and laminar box. Design, development, calibration and performance of this equipment are very important (Prasad S. K. et al., 2004). Latha M. G. et al. (2006) has presented Shaking table studies which have been carried out on wrap-faced reinforced soil retaining walls to gain insight into their behaviour under dynamic loads. Soft soil with the larger void ratio, the higher water content and higher the saturation degree, the peak of excess pore water pressure during the repeated loading process will not be significantly higher than that of the previous cycle (Zhang, Z. et al., 2009). Moss, R. et al (2010) has proposed scale soil-structure models to mimic the coupled seismic response of underground structures and surrounding/supporting soil (termed soil-structural-interaction or SSI). Currently the seismic design of subways and other critical underground infrastructure rely on little to no empirical data for calibrating numerical simulations. Srilatha et al. (2014) has also been conducted series of laboratory shaking table tests for observing the performance of without reinforced and reinforced soil slopes through. Frequency of base acceleration has been varied from 1 Hz to 7 Hz in different tests. Acceleration of base shaking has been kept as 0.3 g in all the tests. A recent laboratory test has been conducted by Yazdandoust (2017) to assess the behavior and performance of steel-strip reinforced-soil retaining walls during seismic loading, a series of 1-g shaking table tests have been conducted on 0.9 m high reinforced-soil wall models with different strip lengths.

Current Investigation

Based on the aforementioned necessities the present research targets the seismic design of subway/ road way or railway embankment. A scale model testing platform has been developed for single degree of freedom shaking table tests that mimics the dynamic free-field conditions of Dhaka clayey soil where a sand retaining wall has been erected on clayey soil has been subjected to seismic loading. A total of 90 shaking table test have been carried out on this model embankment. The effect of frequency, amplitude, surcharge, pore water pressure and displacement along the different elevations (effect of input acceleration) has been observed.
Equipment and Materials

Shaking Table

A computer-controlled servo-hydraulic single degree of freedom shaking table facility has been used to simulate the horizontal shaking action, associated with seismic and other vibration conditions. The testing platform is a square having 2×2 m^2 dimension and approximate payload capacity of 1000 kg, which has been made from steel plates. Shaking has been provided by a digitally controlled servo-hydraulic actuator with ±200 mm stroke and 30 kN force rating. The shaking table can be operated over an acceleration range of 0.05g to 2g and frequency range 0.05 to 50 Hz with a maximum amplitude of ±200 mm. Maximum velocities are 0.3 m/s.

Laminar box:

In this study, embankment with soft clay soil models has been constructed in a laminar box to reduce boundary effects as far as practicable. The laminar shear box developed at BUET has composed of 24 hollow aluminum layers of frames. Each layer consists of an inner frame with inside dimensions of 915 mm × 1220 mm × 1220 mm. Laminar box mounted on the shake table has been presented in Fig. 1(a).

WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 2, Feb., 2022

Backfill Material & Reinforcement

Dry sand (Specific gravity=2.64) has been used as the backfill material. The sand has been classified as poorly graded sand (SP) according to the Unified Soil Classification System. Maximum dry density of the sand is 18 kN/m^3 and minimum dry density observed in the loosest state is 15 kN/m3. A non woven polypropylene multifilament geotextile has been used for reinforcing the sand in the testsModel Construction and testing procedure

Re Constitute Clay Soil Sample

In this research work Dhaka soft clay soil has been used. The liquid limit of this soil has been found 40%. The water content of this soil sample has been found 23%. For preparing the soil sample used 50% of water content (1.25 times of liquid limit). From the direct shear test cohesion and friction have been found 14.8 KN/m2 and 10.03 respectively. After loading had been done, the water content of soil sample was 15% and unconfined compression strength (qu) was 20 kPa. The constitute clay layer thickness of the soil sample is 18 inch. Preparation of re constitute sample has been shown as Fig. 1(b). Two pore water pressure sensor: one is base level of sample and another is 18 inch above the base level have been used in this soil sample. Two acceleration sensors have been placed in the soil sample.

a)

b)

[Fig. 1]. Detail setting of Shake table test. (a) Laminar box mounted on shaking table (b) Placement of reconstitute soil sample

Testing Process

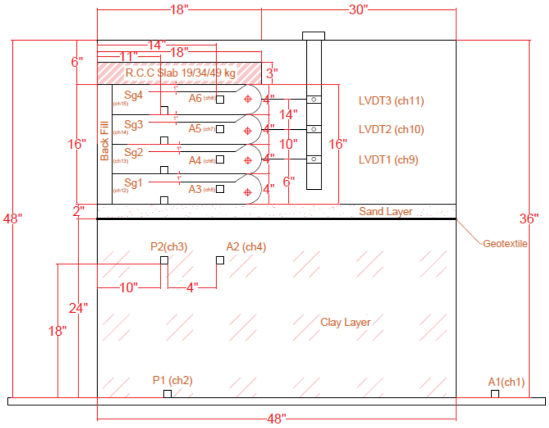
The model embankment has been constructed in a laminar box to a size of 915 mm x1220 mm in plan area and 1220 mm deep. Each geotextile layer has been wrapped at the facing for a length of 150 mm. To achieve uniform density, sand was placed in the laminar box using the pluviation (raining) technique (Hossain and Ansary, 2018). After the completion of all lifts up to full height of the wall (406 mm), surcharge in the form of three type concrete slabs (19/34/49 kg) have been applied to anchor the top wrapped geotextile. The facing formwork was removed carefully in sequential lifts from bottom to top after the backfill layers (2 inch) and surcharge have been completed. Fig. 2 shows the finished embankment for four-layer with 2 ft clay layer. A typical model configuration showing the instrumentation for the test wall with four layers of reinforcement has been shown in Fig. 3. Two pressure sensors; P1 and P2 have been placed inside the wall, in contact with the measure horizontal displacement, three displacement sensors (LVDTs), L1, L2 and L3, have been positioned at elevations 32, 42 and 56 inch, respectively, along the facing for the tests with four-layer configurations.

RESULTS AND DISCUSSIONS

Results obtained from sixteen different shaking table tests from ninety combinations on embankment with soft clay models have been discussed in this paper. The parameters varied in model tests are base acceleration, frequency and surcharge pressure on the crest. The base acceleration has been kept as 0.1g, 0.2g, 0.3g, 0.4 g and 0.5g in different tests. The frequency has been varied from 1 Hz to 15 Hz. The surcharge pressure on the embankment has been kept as 19, 34 and 49 kg. Soft clay layer has been used (24 in) which unconfined compression strength is 20 kPa. Model has been constructed using sand on the clay layer in equal lifts (Sv) of 4 and total wall height (H) is 16 in. The length (L) of the geotextile reinforcement at the interface of the sand layers has been kept the same in all tests as 15 in. Model wall was subjected to 20 cycles of sinusoidal shaking. The average unit weight and relative density achieved were within the ranges 18 kN/m3 and 60% respectively for the same height of fall.

WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 2, Feb., 2022

[Fig. 2].Setting of Setting of displacement sensor.

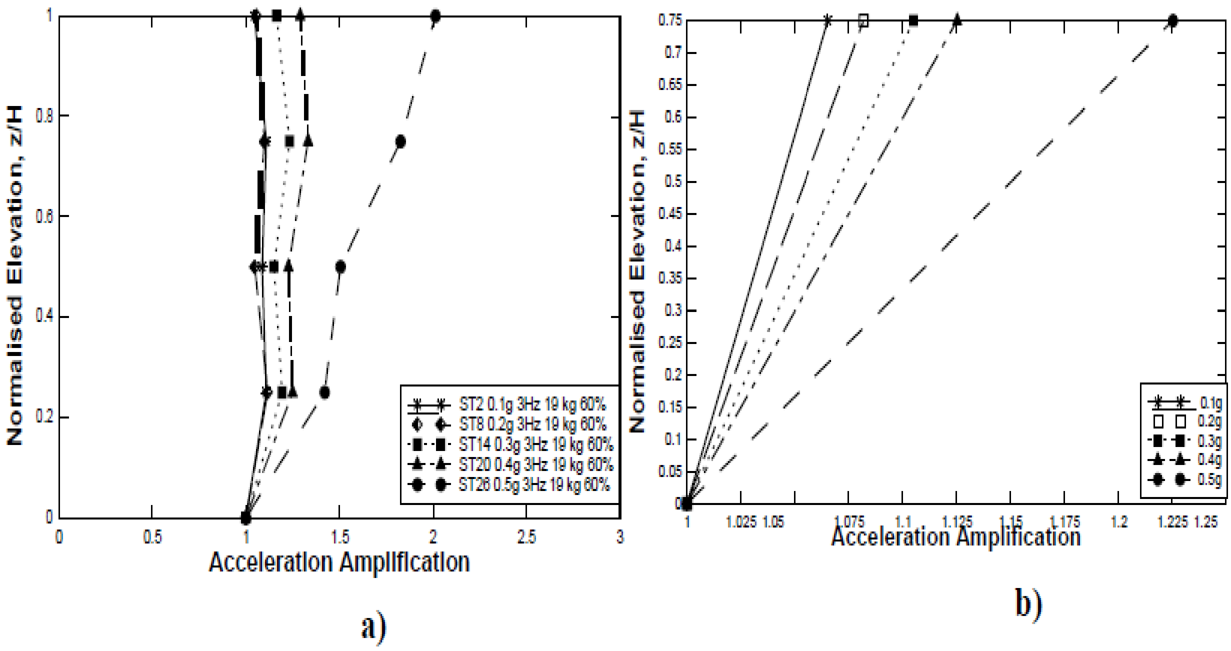


[Fig. 3]. Schematic diagram of typical test wall configuration and instrumentation

Acceleration Response

Fig. 4(a) and Fig. 4(b) compare the acceleration amplification profile along the height of the wall for different configurations of wall and base motion after each test of 20 cycles of sinusoidal motion. Here the elevation (z) has been represented in non-dimensional form after normalizing by the full wall height (H). Maximum acceleration amplification has been observed at the top of the wall in all the tests. This observation is in concurrence with the results of physical tests reported by Telekes et al. (1994), El-Emam and Bathurst (2005) and Krishna et al (2007). Fig. 4(a) shows the acceleration amplifications along the height of the wall for different base accelerations of 0.1, 0.2, 0.3, 0.4 and 0.5g from ST2 (0.1g, 3 Hz and 19 kg) , ST8 (0.2g, 3Hz and 19 kg), ST14 (0.3g, 3Hz and 19 kg), ST20 (0.4g, 3 Hz and 19 kg) and ST26 (0.5g, 3Hz and 19 kg) model tests, respectively, which have been conducted at 3 Hz frequency, 19 Kg surcharge. However, within the range of tests conducted, acceleration amplifications at the top of the wall for 0.1,0.2, 0.3, 0.4 and 0.5g base accelerations are 1.06 to 1.22. Fig.4(b) shows the two sensor in clay soil sample layer for different base accelerations of 0.1, 0.2, 0.3, 0.4 and 0.5g from ST2, ST8, ST14, ST20 and ST26 model tests, respectively, which were conducted at 3 Hz frequency, 19 Kg surcharge

WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 2, Feb., 2022



[Fig. 4]: a) Effect of base acceleration on acceleration amplification b) Effect of base acceleration on acceleration amplification (Clay layer)

Face Displacement Response

Horizontal face displacements along the height of the wall have been monitored using three LVDTs positioned as shown in Fig. 3. Fig. 5 presents the displaced face profiles from various tests after 20 cycles of sinusoidal motion. Here elevation (z) and horizontal displacements

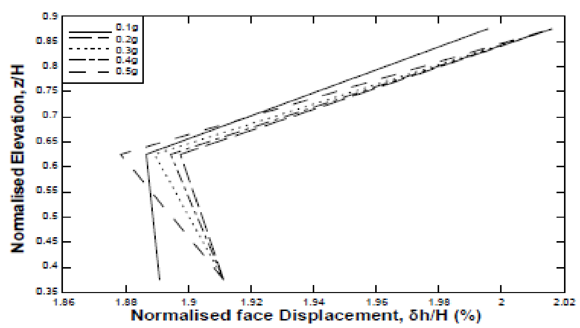
(h) have been presented in non-dimensional form after normalizing them by the total height of the wall (H). Fig. 5 shows normalized displacement profiles of the facing after 20 cycles for different base accelerations of 0.1, 0.2, 0.3, 0.4 and 0.5g from tests ST1 (0.1g, 1Hz and 19 kg), ST7 (0.2g, 1Hz and 19 kg), ST13 (0.3g, 1Hz and 19 kg), ST19 (0.4g, 1Hz and 19 kg) and ST25 (0.5g, 1Hz and 19 kg) respectively. The normalized displacements are relatively high at the higher base accelerations. A maximum horizontal displacement of 2.02% of the total wall height, H, for 0.5g have been observed compared with 0.01% for 0.1g base acceleration. The displacements obtained in the present study are in close agreement with the results presented by Sakaguchi et al. (1992) and Krishna et al (2007) corresponding to the accelerations and frequency levels used in the present study.

Pore Pressure Response

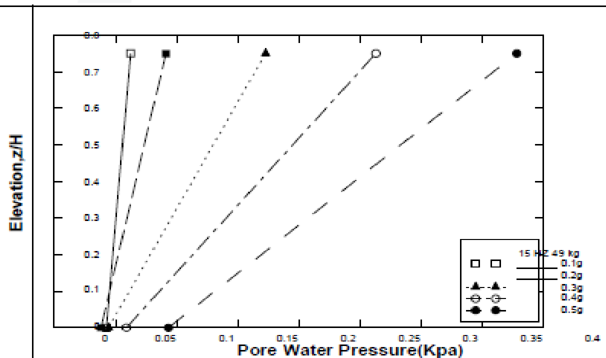
Fig. 6 presents typical pore pressure variations obtained from the model tests. Fig. 6 shows variations of the pore pressure from model tests ST66 (0.1g, 15Hz and 49 kg), ST72 (0.2g, 15Hz and 49 kg), ST78 (0.3g, 15Hz and 49 kg), ST84 (0.4g, 15Hz and 49 kg) and ST90 (0.5g, 15Hz and 49 kg) with of base acceleration 0.1, 0.2, 0.3, 0.4 and 0.5g respectively for 15Hz frequencies and surcharge load 49 kg. It is observed that pore water pressure has been increased with elevation. The highest pore water pressure is 0.38 kPa at base acceleration 0.5g. The highest pore water pressure for model tests ST66, ST72, ST78, ST84 and ST90 is 0.06, 0.09, 0.17, 0.26 and 0.38 kPa respectively.

CONCLUSIONS

The seismic response of geotextile-reinforced embankment on soft clayey soil has been investigated by conducting shaking table tests on model test. A model test with variations in acceleration and frequency of base motion, surcharge pressure on the crest and pore water pressure (effect of input acceleration) have been described along with the model preparation, testing methodology and results. It has been observed that the seismic response of the embankment has significantly been affected by the variations of the base motion, surcharge pressure on the crest and pore water pressure. In fact, accelerations have been amplified at higher elevations with low surcharge pressures. The acceleration amplification response with change in base shaking frequency clearly indicates the role of the fundamental frequency on the response of the system. In some case the face deformations are high with high base accelerations



[Fig. 5]: Effect of Acceleration on displacement profile



[Fig. 6]: Variations of pore water pressure with respect to Elevation (Effect of base acceleration)

REFERENCES

1. Chakraborty, S., Hore, R. Ahmed, F., Ansary, M. A., Soft ground improvement at the Rampal Coal Based Power Plant Connecting Road Project in Bangladesh, Geotechnical Engineering Journal of the SEAGS & AGSSEA, AIT December 2017.
2. Hore, R. & Ansary M. A., SPT-CPT Correlations for Reclaimed Areas of Dhaka, Journal of Engineering Science, JES, KUET, June 2018.
3. M. R. Arefin, Hore, R., Ansary, M. A., Development of liquefaction potential map of Dhaka city using SPT test, Journal of Civil Engineering (IEB), 46 (2), 2018, 127-140.
4. Hore, R., M. R. Arefin, Ansary, M. A., Development of Zonation Map Based on Soft Clay for Bangladesh, Journal of Engineering Science 10(1), 2019, 13-18
5. Hore, R., Chakraborty, S., Ansary, M. A., Field Investigation to Improve Soft Soils Using Prefabricated Vertical Drain, Transportation Infrastructure Geotechnology, September 2019. (https://doi.org/10.1007/s40515-019-00093-8).
6. Hore, R., Chakraborty, S., Shuvon, A. M., Ansary, M. A., Effect of Acceleration on Wrap Faced Reinforced Soil Retaining Wall on Soft Clay by Performing Shaking Table Test, Proceedings of Engineering and Technology Innovation, 2020.
7. Hore, R., Chakraborty, S., Bari, M. F., Shuvon, A. M., Ansary, M. A., Soil Zonation and The Shaking Table Test of The Embankment on Clayey Soil, Geosfera Indonesia, August 2020 (DOI: https://doi.org/10.19184/geosi.v5i2.17873)
8. Hore, R., Chakraborty, S., Ansary, M. A., Experimental Investigation of Embankment on Soft Soil Under Cyclic Loading: Effect of Input Surcharges, Journal of Earth Engineering (JEE) Vol. 5, No. 1, (2020).
9. Hore, R., Ansary, M. A., Different Soft Soil Improvement Techniques of Dhaka Mass Rapid Transit Project, Journal of Engineering Science 11(2), 2020, 37-44. (https://doi.org/10.3329/jes.v11i2.50896)
10. Hore, R., Al-Mamun. S., Climate Change and its diverse impact on The Rural Infrastructures in Bangladesh, Disaster Advances, Vol. 13 (9) September (2020).
11. Hore, R., Chakraborty, S., Ansary, M. A., "Liquefaction Potential Analysis based on CPT and SPT" Geotechnical Engineering Journal of the SEAGS & AGSSEA, December 2020
12. Chakraborty, S., Hore, R., Shuvon, A. M., Ansary, M. A, Dynamic Responses of Reinforced Soil Model Wall on Soft Clay Foundation, Geotechnical and Geological Engineering, January 2021. (https://doi.org/10.1007/s10706-020-01665-z)
13. Hore, R., Chakraborty, S., Ansary, M. A., Seismic Response of Embankment on Soft Clay Based on Shaking Table Test, International Journal of Geosynthetics and

Ground Engineering, March 2021. (https://doi.org/10.1007/s40891-020-00246-7)

14. Hore, R., Chakraborty, S., Shuvon, A. M., Ansary, M. A., Dynamic Response of Reinforced Soil Retaining Wall Resting on Soft Clay, Transportation Infrastructure Geotechnology, February 2021. (https://doi.org/10.1007/s40515-021-00156-9).
15. Chakraborty, S., Hore, R., Shuvon, A. M., Ansary, M. A, Physical and numerical analysis of reinforced soil wall on clayey foundation under repetitive loading: effect of fineness modulus of backfill material, Arabian Journal of Geosciences, June 2021. (DOI:10.1007/s12517-021-07317-7)
16. Zhang, Z., Cho,C., Pan, Q. & Lu, X. (2009) Experimental Investigation on Excess Pore Water Pressure in Soft Soil-Foundations under Minor Shocks.World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering Vol:3, No:2, 2009.