*Progress Annals: Journal of Progressive Research*
Volume 1, Issue 4, July 2023
ISSN (E): 2810-6466
Website: https://academiaone.org/index.php/8

# Cyclic Behavior Soft Clay Soil in Bangladesh

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**Abstract.** This paper represents the analysis of shaking table tests on wrap faced embankment lying on soft clay. The model embankment in a laminar box mounted on a shaking table, machine. The output results from the shaking table test are verified by numerical analysis. The different surcharge load with different acceleration has been varied in different model tests. It is observed from these tests that the response of the embankment with soft clay has been significantly affected by the base acceleration levels, and magnitude of surcharge pressure. In this research the data of Loma Prieta earthquake (1989) has been used in this experiment. The effects of these different parameters on acceleration response at different elevations of the embankment, and face deformations have also been presented. The result find that the proposed wrap faced embankment is great resist the earthquake especially like Loma Prieta and give an indicative performance measure of the wrap faced embankment on soft clay soil.

**Keywords:** Earthquake, Soft clay, embankment

## 1. Introduction

The analyzing earthquake influence on soil structure, shake table testing has been widely used in the last few decades. The shaking tables are used extensively in seismic research, as they provide the means to excite structures like embankment in such a way that they are subjected to conditions representative of true earthquake ground motions. Sakaguchi et al. (1992) and Sakaguchi (1996) carried out shaking table test on a reinforced model with a specific height and observed the effects on various parameters like relative Density of soil, frequency and amplitude of the motion.

The different researches are found in reinforced soil structure which is closely related to seismic analysis. (Latha and Krishna 2006; 2008, Krishna and Latha 2007 and Sabermahani et al. 2009, Latha and Nandhi Varman 2014, Hore 2022). Latha and Manju (2016) described the performance of geo-cell retaining walls on different seismic condition. Krishna and Bhattacharjee (2017; 2019) analyzed the input ground motions at the base of the rigid-faced reinforced soil-retaining wall. Sahoo et al. (2019) conducted a shaking table test to analyze the behavior and response of a steep soil slope, having a specific angle. A very recent study by Chakraborty (2022) and Hore (2022) a series of shaking table tests was conducted to evaluate the response of model sand wall in different types of local sandy soil.

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Different research on wrap faced embankment on sandy soil of the different countries. The research on dynamic analysis of wrap faced embankment on soft clay soil especially Bangladeshi region is very scarcity. In the present research, a scale model testing platform developed for wrap faced embankment on clayey soil where a wrapped geotextile-sand retaining wall was erected on clay soil subjected to cyclic loading. The effect of base accelerations and displacement of the wrap faced embankment on soft clay foundation along the different elevations are observed in this research where the Figure 1(After Hore, R. et al.2019 ) represent the availability of clay soil layer in Bangladesh and

## 2. Experimental Model

A computer-controlled servo-hydraulic single degree of freedom shaking table facility was used in this experiment, as shown in Figure 2 where the platform is 2 meters by 2 meters size. The payload capacity is 1500 Kg. It had an acceleration range of 0.05g to 2g. The frequency range is 0.05Hz to 50. A large-sized shear box consisting of 24 hollow aluminum layers, built such that the friction between the layers is minimum, as shown in Figure 2. The dimension of laminar box is 915 mm × 1220 mm × 1220 mm.

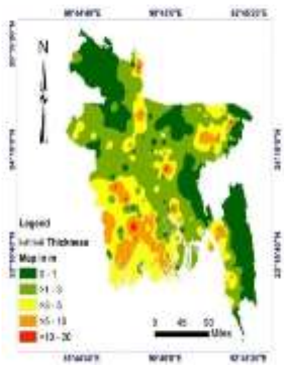

Figure 1: Thickness map Figure 2: shaking table facility

The soil is found from BUET area indicated as Dhaka soil. The model soil has a unit weight of 14.8 kN/m3. A specific gravity is 2.64. The undrained shear strength is 28 kPa. The ultimate bearing capacity is 17.20 kPa. The sand is classified as poorly graded sand (SP) according to the Unified Soil Classification System. General geotechnical properties of the sands are presented in Table 1 (Hore 2021). A woven polypropylene multifilament geotextile (D50) was used for reinforcing the sand in the tests.

Table 1. Geotechnical properties of Sylhet Sand

| Physical properties | Sylhet sand |
|---|---|
| Effective size, $D_{10}$ (mm) | 0.38 |
| Average size, $D_{50}$ (mm) | 0.67 |
| Coefficient of uniformity ($C_u$) | 2.00 |
| Coefficient of curvature ($C_c$) | 0.92 |
| Friction angle (°) | 29 |
| Specific gravity ($G_s$) | 2.64 |

The present study was conducted with a height of 300 mm clayey soil layer foundation above which a 50 mm sand blanket was provided as shown in Figure 3 with approximately 1 $m^2$ geotextile was placed between the clayey soil foundation and sand blanket. The model scale is N=10 and scale factor 1/N. Accelerometers were used to monitor the accelerations of the shaking table. The Linear Vertical Displacement Transducers (LVDT) were placed. The Loma Preita earthquake was fixed for each shaking. Exactly Twelve (12) numbers of earthquake shaking were applied for this research. Embankment model was subjected to several different excitations from 0.05g (low amplitude) to 0.2g (high amplitude) peak base accelerations. The surcharge pressures are 0.70, 1.12, and 1.72 kPa.

## 3. Numerical Method

The PLAXIS 3D software version is employed for performing the analyses. PLAXIS is a finite element package that is developed the specific purpose such as i) analysis of deformation ii) stability, and iii) flow in geotechnical engineering. Definition of soil stratigraphy embankment and retaining wall, Mesh generation are performed to calculate. The initial step for analyzing the model is to create the geometry of the model and the geometry characteristics such as embankment height slope and crest width with the second step is to provide the material properties of the embankment and the under-laying soil. Numerical analysis of wrap faced embankment as shown in Figure 4. As the demonstrated model is symmetric in this research, only half of the whole setup is modeled (in this case the right half is chosen). A representative section of 2 m width is taken for the research with the boundary of the model are $x_{min} = 0$, $x_{max} = 6$, $y_{min} = 0$ and $y_{max} = 2$. A model embankment is four layers of sand. The slice wrapped with geotextile is modeled and the under laying soft layer are inserted. In this model the ultimate tensile strength is 16 kN/m. The normal elastic stiffness of the geotextile was considered as and 2500 kN/m.


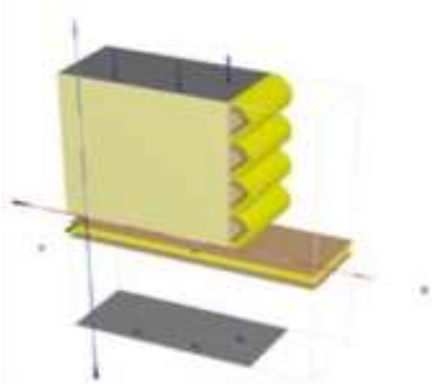

Figure 3: Experimental Model

Figure 4: PLAXIS model

## 4. Result and Discussion

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Progress Annals: Journal of Progressive Research
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The soil layer in equal lifts is 100 mm. To achieve a total wall height (H) of 400 mm the equal lifts (each 100 mm) are inserted. A series of twelve shaking table tests were performed were performed for this research. The variation of the different soil parameters like acceleration amplification, displacement, pore water pressure and strain (LST1, LST2, LST3, LST4, LST5 and LST9) with respect to height for various Loma Prieta earthquakes are presented in this section.

3.1 Acceleration amplification profile

The different base accelerations are 0.05g, 0.10g, 0.15g, and 0.2g. The test pattern are LST1, LST2, LST3 and LST4 tests, respectively, which was conducted at 1.72 kPa surcharge pressure. Acceleration amplifications were increased with increased base accelerations. From the Figure 5, it is observed that the maximum acceleration amplification was 1.52 at an acceleration of 0.2g, whereas it decreased to 1.28 at an acceleration of 0.05g. Results from By PLAXIS 3D analysis showed that acceleration amplification [Profile for tests LST1(P), LST2 (P), LST3(P), and LST4(P)] also at all elevations increased with an increase in Acceleration. The maximum and minimum acceleration amplification from PLAXIS 3D was 11.18% and 12.50% higher than the shake table model test respectively. Acceleration response against different surcharge pressures was presented from tests LST1, LST5 and LST9 are depicted in Figure 6. These tests were conducted with 1.72 kPa, 1.12 kPa and 0.7 kPa surcharge pressures at 0.05g base acceleration. Accelerations at the top of the wall were inversely proportional to the surcharge pressures from the range of tests that were conducted. Results from By PLAXIS 3D analysis showed that acceleration amplification [Profile for tests LST1(P), LST5(P) and LST9(P)] also at all elevations decreased with an increase in surcharge as can be seen from Figure 6. The maximum and minimum acceleration amplification from PLAXIS 3D was 4.27% and 12.50% higher than the shake table model test respectively.

3.2 Displacement Profile

Figure 7 depicts the normalized displacement profile for different base accelerations of 0.05g, 0.10g, 0.15g and 0.20g. The tests are LST1, LST2, LST3 and LST4. By PLAXIS 3D analysis showed that displacement [Profile for tests LST1(P), LST2(P), LST3(P), and LST4(P)] also at all elevations acceleration variation was directly proportional as can be seen from Figure 7. From the same figure, it can also be observed that the maximum displacement was 0.280 mm at an acceleration of 0.20 g, whereas it decreased to 0.088 mm at an acceleration of 0.05 g. The maximum and minimum displacements from PLAXIS 3D were 12.00% and 10.00% higher than the shake table model test respectively.

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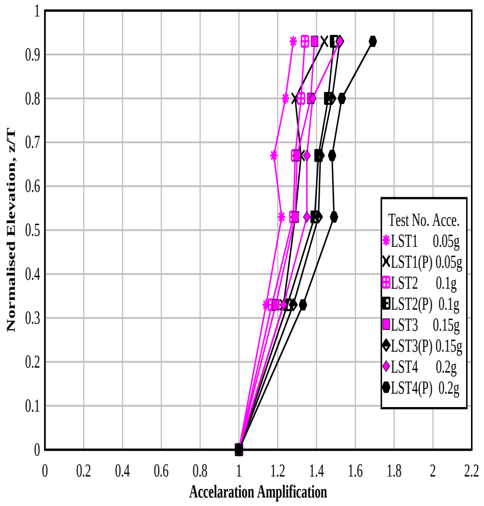


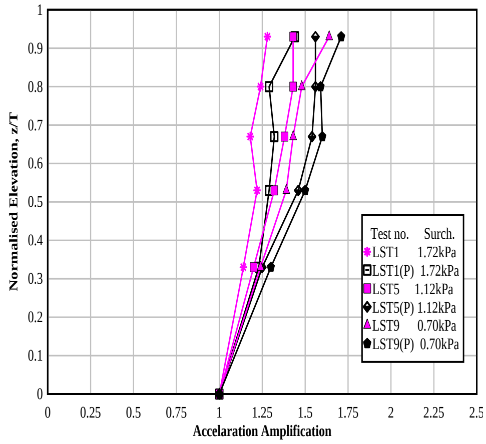
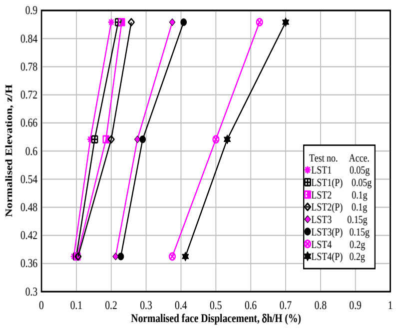




Figure 5: Effect of base acceleration Figure 6: Effect of surcharge

The normalized displacement profile for tests LST1, LST5 and LST9 which were conducted at 0.05g base acceleration were providing an insight into the effect of different surcharge loadings of 1.72 kPa, 1.12kPa and 0.7kPa as shown in Figure 8. It was observed that the displacement response against surcharge variation was inversely proportional at all elevations. The maximum and minimum displacements from PLAXIS 3D were 9.68% and 10.00% higher than the shake table model test respectively. Figure 9 shows the PLAXIS output result.



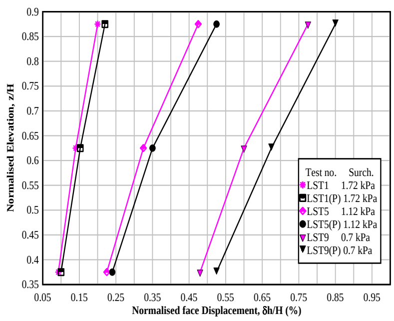




Figure 7: Effect of base acceleration (Disp.) Figure 8: Effect of surcharge (Disp.)

## 5. Conclusion and summary

The analyze the behavior of wrap-face embankment on soft clayey soil is presented in this paper. The Acceleration amplifications were increased with increased base accelerations found from the test and accelerations at the top of the wall were inversely proportional to the surcharge pressures. Apart from this, displacement also at all elevations acceleration variation was directly proportional and the experimental result is found to be lower than the numerical result that is used in PLAXIS 3D for all parameters, though the deviation was less than 5% in all cases. These results are very helpful to indication to build the large amount of wrap faced embankment on soft soil after 200 meters piloting the project. The updating design specification incorporating dynamic loading considering of this type of wrap faced embankment (Railway and Road embankment) will have been accelerated after using these results.

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