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Dynamic Behaviour of Small-Scale Soil Slope Model

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Abstract: The shaking table test is an experimental method used to determine the dynamic behaviors of the structure in a laboratory environment to obtain the realistic results which are required to check the stability of the structure before the construction process. In this study, under earthquake-like ground motions which were simulated with the help of a shake table under a controlled environment, the slope experienced significant deformations and displacements. The deformations were calculated in the form of crest settlement and toe settlement. The study also provides insights into the behaviour of soil slopes under different loading conditions and could be useful for designing safer and more stable slopes. The crest and toe displacement of a small-scale model of soil slope at various inclinations to study the behaviour under dynamic loading. The soil slope model behaviour under dynamic loading is observed for the amplitude is ±20mm, ±25mm, and ±30mm for the frequencies varying from 1.2Hz to 1.8Hz for each inclination of 30°, 35°, and 40° keeping the height constant. The displacement was measured in the form of crest and toe settlement every 10 cycles.

Keywords: Displacement analysis, Shaking Table, Slope Stability, Reinforcement, Dynamic Loading.

I. INTRODUCTION

A slope is an inclined ground surface that may be either natural or artificial. Slope stability refers to the situation in which an inclined slope can resist its very own weight and external forces without experiencing displacement. Slope stability uses the concept of soil/rock mechanics. When the stability situations aren't met, the soil or the rock mass of the slope can also experience downward movement which will be either gradual or devastatingly fast. This phenomenon is referred to as a slope failure or landslide. A landslide may be precipitated via an earthquake, rainfalls that cause exceeding pore water strain or degradation of the ground's mechanical residences. In most applications, the primary cause of slope balance analyses is to offer a secure and monetary layout of excavations, embankments, and earth dams. Stability analyses are accomplished to access the secure and helpful layout of an excavated slope or the equilibrium circumstance of the natural slope. Stability analyses are routinely performed to access the safe and functional design of an excavated slope or the equilibrium condition of a natural slope. The primary purpose of slope stability analyses is to provide safe and economical design of excavations, embankments earth dams. The application of the stability analysis method is conducted for successful and effective prediction of earthquake-triggered landslides and slope failures. To ensure the stability of structure under short-term and long-term conditions, to Prevent the loss of human life as well as money, and to assess the safe design of human-made or natural slopes. (Earth dams, landfills, & embankments

II. SYMBOLS AND ABBREVIATIONS

C	Cohesion kPa
Cc	Coefficient of Curvature
Cu	Uniformity Coefficient
S.G.	Specific Gravity
Dr	Relative Density$\gamma_{d(max)}$ Maximum dry unit weight, kN/m^3
$\gamma_{d(min)}$	Minimum dry unit weight, Kn/m^3
Φ	Angle of Friction Degree
E	Modulus of Elasticity MPa
P	Density of Reinforcement kg/ m^2

III. EQUIPMENT

To check the stability of the model for various equipment that has been used in the shaking model test was carried out on the soil slope model constructed at various inclinations to observe the displacement testing process. The uniaxial shake table of size 1.5m x 1.5m is designed with a frequency of 10Hz, load capacity up to 2000 kg and the maximum displacement is ±50 mm. is considered ideal for seismic simulations (vibration testing). The shaker plate is placed on two pairs of rails as shown in **Fig.1.** The model box (1m x 1m x 1m) resting on the platform as shown in **Fig.2**, is made with 18 mm thick acrylic glass and flat and angle structural steel parts for reinforcement. The inner limit of the container, perpendicular to the direction of the shaking table movement, was lined with expanded polyethylene (EPE) foam. The frequency controlling panel for adjusting the desired frequency to control the uniaxial motion can be set from 0.5hz which increases by 0.5Hz. control panel supply voltage is 415volts 50Hz as shown in **Fig.3.** To reduce the boundary impact, an absorbing material was used on the boundary due to the container's artificial borders which aren't created properly and may alter the soil's dynamic reaction.

Fig.1: - Shake Table

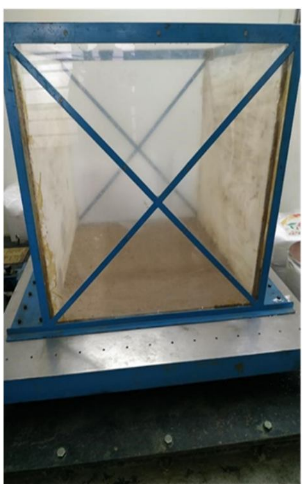


Fig. 2: - Model Box

Fig. 3: - Control Panel

IV. MATERIALS AND PARAMETERS

The sand collected to use in experimental studies was taken locally from the bed of the river. Before using the sand, it was cleaned and air-dried. The sand is the mixture of 80% fine sand and 20% gravel proportion used in the experiment. A few tests are carried out to analyse the soil properties like the bearing capacity, slope stability, and lateral earth pressures on pavement design. **Table 1** shows the properties of the material and **Fig.4** shows the soil material used for testing.

The various reinforcement can be used in the slope model in layers to provide stability.Geosynthetics are products made of plastic that are used in many ways, primarily erosion control, soil stabilization and drainage. These are open mesh-like materials of integrally connected polymers. Geonets or Geospacers are formed by thermoplastic polymers and have a structure similar to Geogrids. They are formed by a continuous parallel set of polymeric ribs at acute angles to one another, forming a net-like pattern. Due to its multifunctional structure, geonet applications have been widely preferred all around the world. **Fig.5** and **Table 2** show the reinforcement (Geonet) and Properties Respectively.

Table 1 Soil Properties

Soil Properties	Symbol	Unit	Test Result
Cohesion	c	kpa	0.0
Coefficient of curvature	Cc	-	0.86
Uniformity Coefficient	Cu	-	4.05
Maximum Density	$\gamma_{d_{max}}$	Kn/m^3	17.17
Minimum Density	$\gamma_{d_{min}}$	Kn/m^3	15.91
Specific Gravity	G	-	2.7
Angle of Internal Friction	Φ	Degree	40°
Modulus of Elasticity	E	Mpa	52.0

Fig. 4: - Soil

Table 2 Reinforcement Property

Reinforcement Property	Description
Color	Black
Thickness	5 mm
Material	HDPE
Rib Spacing	15 mm
Strength	30 KN/m

Fig. 5: - Geonet

V. EXPERIMENTAL SETUP

The slope models were constructed in the model box by compacting the sand up to the desired height by the controlled-volume method. The construction of the slope takes place in different stages. The first layer of the 100mm compacted slope is made by hand modelling apparatus. Subsequent layers are made, and the final slope is constructed. The slope angle is kept critical angle of 40 and a height of 0.5 m is made. The observations were made by performing the test three times on the same amplitude and same frequency for better results. The response of slope is observed at three different loading times i.e., after ±20, ±25, ±30 amplitude on 10 cycles each. A total of 36 tests were conducted for these unreinforced cases. After completion of the unreinforced model test, a similar procedure is carried out further with the addition of geonet reinforcement placed at suitable equal intervals(100mm). **Fig. 6** represents the design profile of the soil model in the shake table for 40°. Similarly, the inclination has changed.

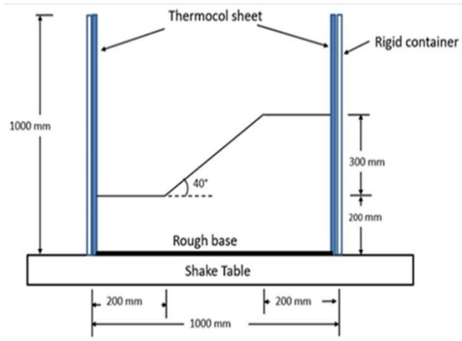
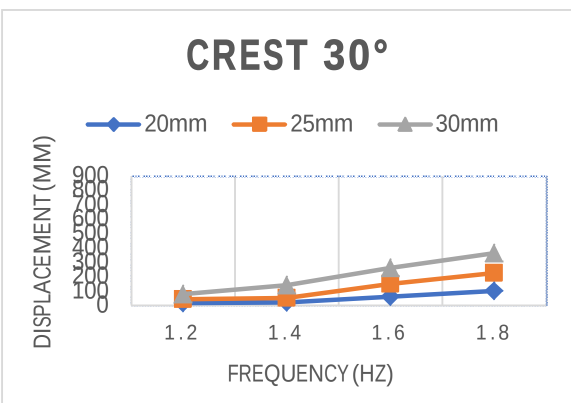


Fig. 6: - Design Profile 40°

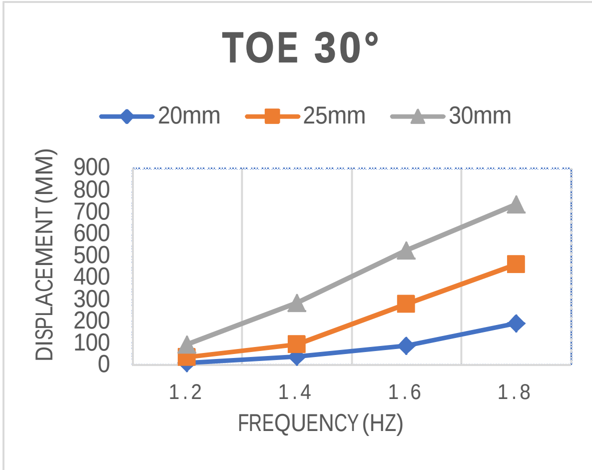
VI. RESULT AND DISCUSSION

The result clearly demonstrates the benefits of geonet reinforced soil slope over unreinforced soil slope. The geonet forces and amplification of motion increase with the increase in slope inclination. The deformation that occurred in the outward direction is found to be more than that of the inward direction in all shake table test results. With the increase in slope angle, the slope becomes more unstable. These results of displacement in the reinforced soil slope model are reduced and made the steeper slope more stable than that of an unreinforced steep slope. According to the unreinforced test results, the crest settlement and toe displacement rises with an increase in frequency from 1.2 Hz to 1.8 Hz. The stability of the slope is also affected by the frequency's amplitude. The crest settlement and toe displacement increase with the increase in amplitude. With a steeper slope, the crest settlement and toe displacement occurred also increase. Where the reinforced slope provides strength to the slope model and increases stability. As there is no reinforcement added towards the toe side of the model the displacement was more. Hence it is necessary to provide the reinforcement at toe also to obtain stability at the toe. According to the observations, the reinforced soil slope model, obtained from the experimental study through the shake table, the graphical representation is compared at minimum frequency 1.2Hz and maximum frequency 1.8Hz at three different inclinations, based on those unreinforced and reinforced soil test results as shown below.

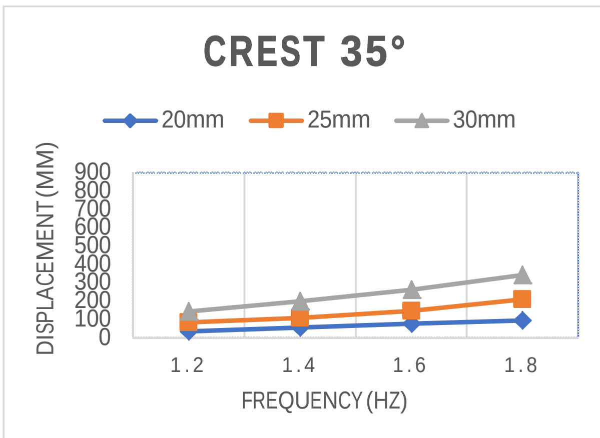
1) Unreinforced soil slope model test results are compared at different frequencies



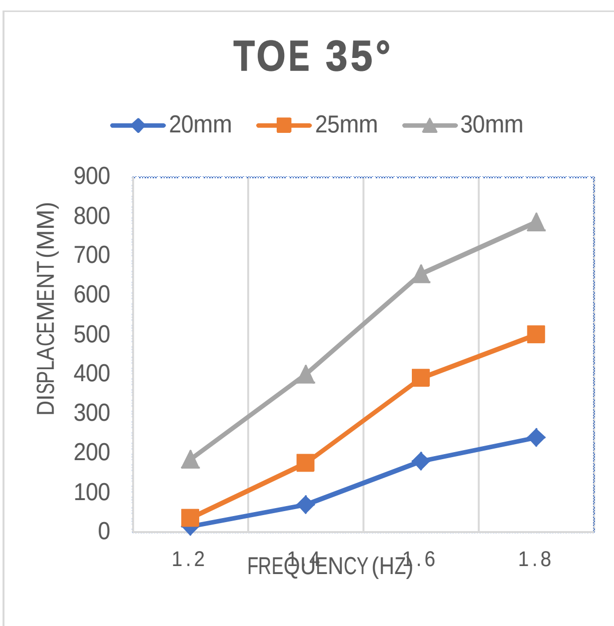
Unreinforced Crest Settlement



Unreinforced Toe Settlement



Reinforced Crest Settlement



Unreinforced Toe Settlement

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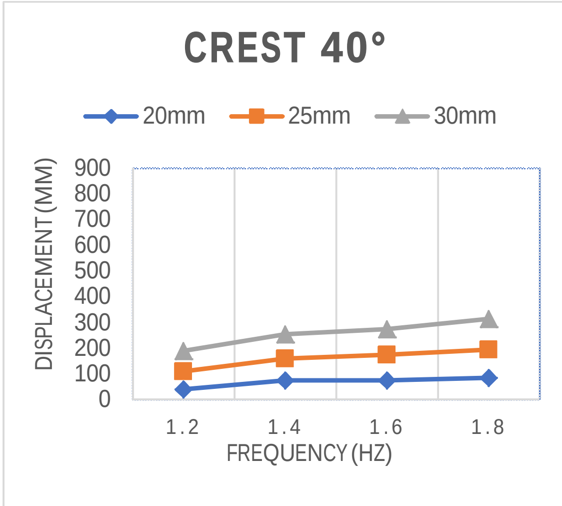
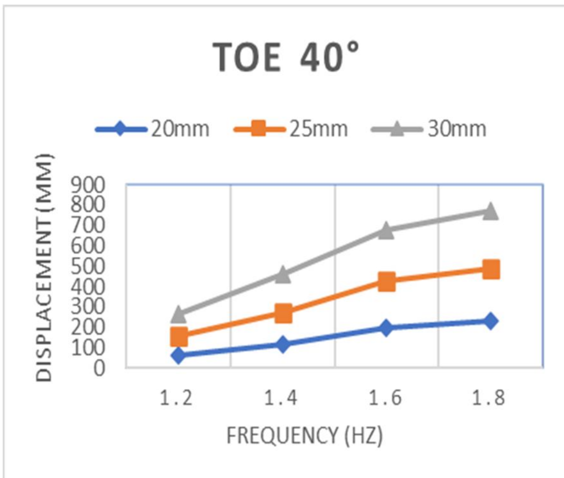
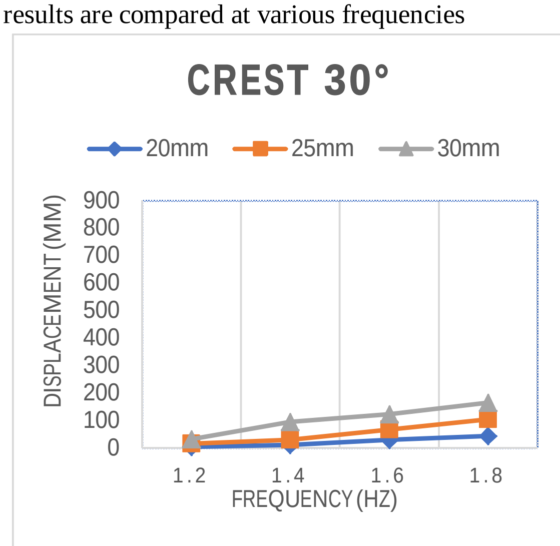


Unreinforced Crest Settlement

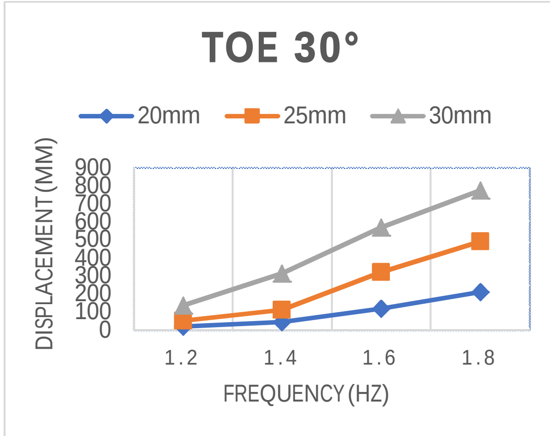


Unreinforced Toe Settlement

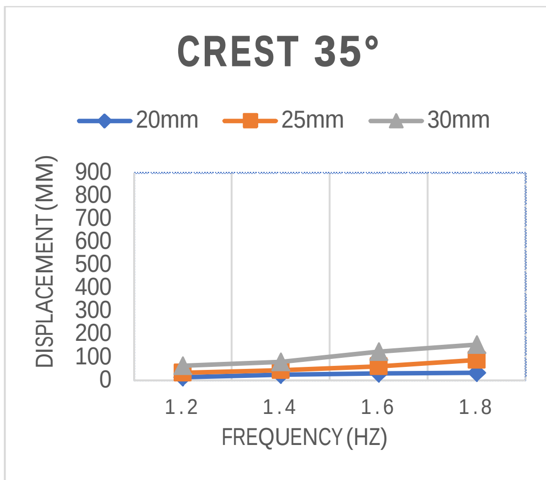
2) Reinforced Soil Slope Model tests results are compared at various frequencies



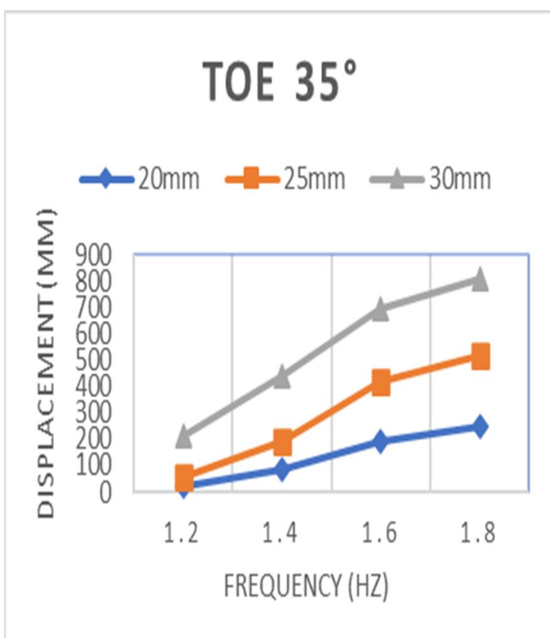
Reinforced Crest Settlement



Reinforced Toe Settlement



Reinforced Crest Settlement



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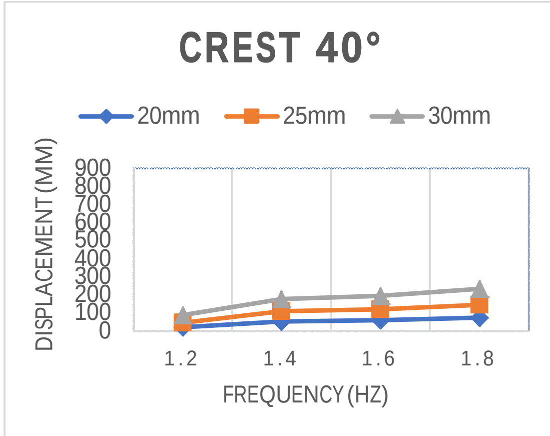
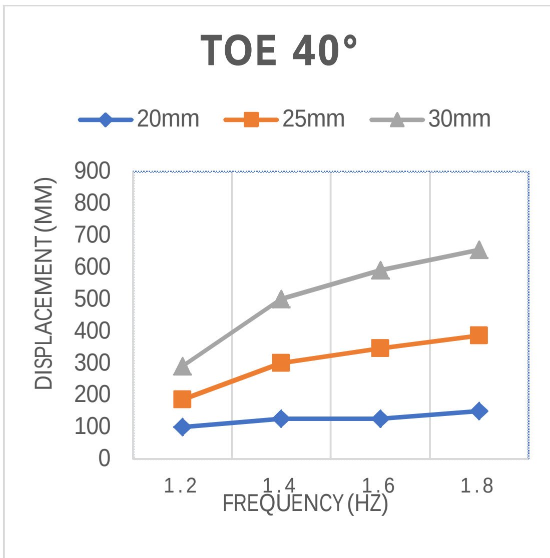
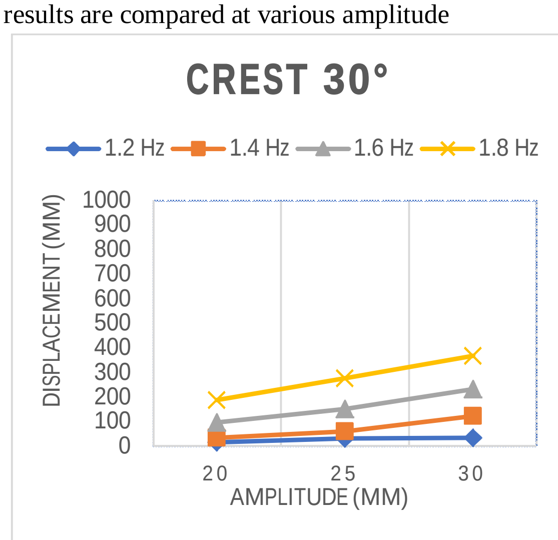


Reinforced Crest Settlement

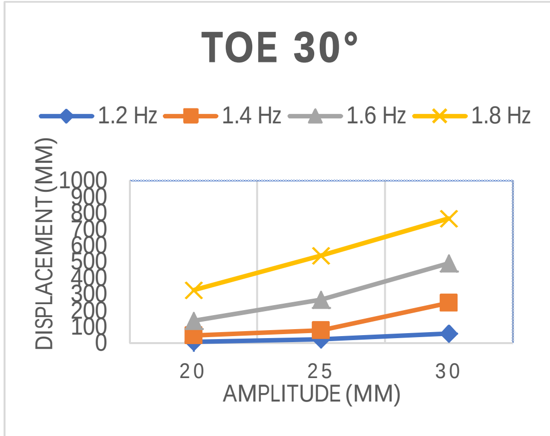


Reinforced Toe Settlement

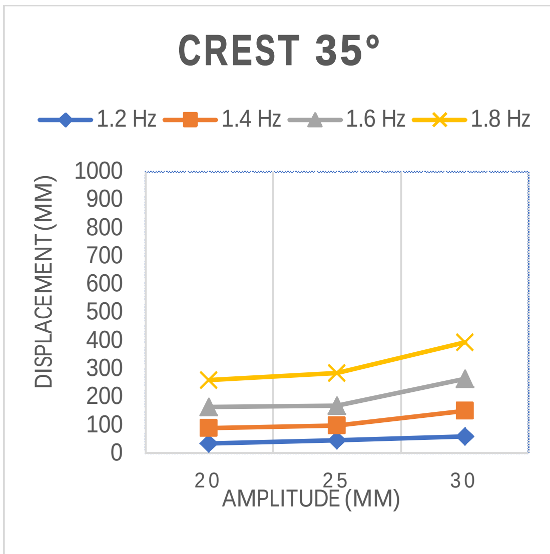
3) Unreinforced soil slope model test results are compared at various amplitude



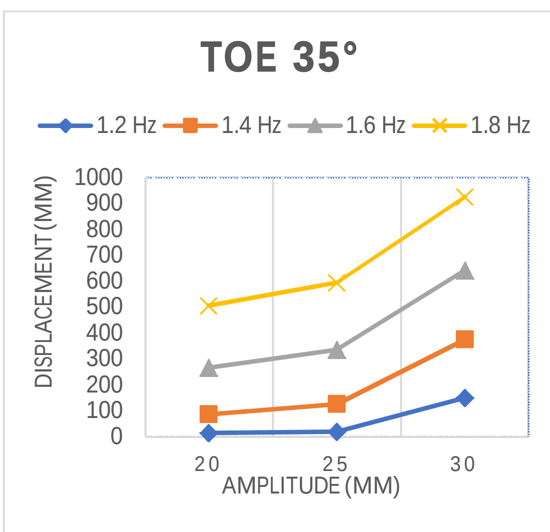
Unreinforced Crest Settlement



Unreinforced Toe Settlement



Unreinforced Crest Settlement



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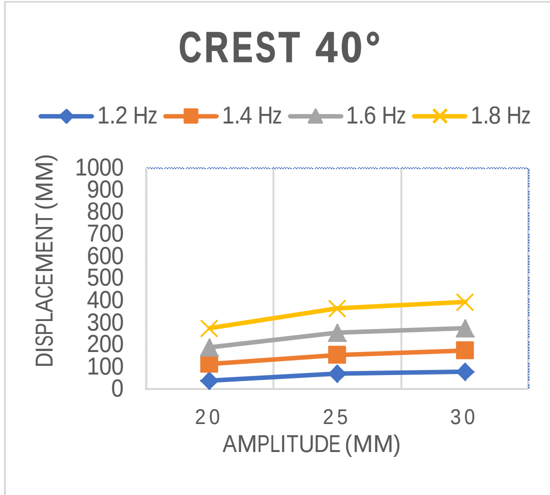

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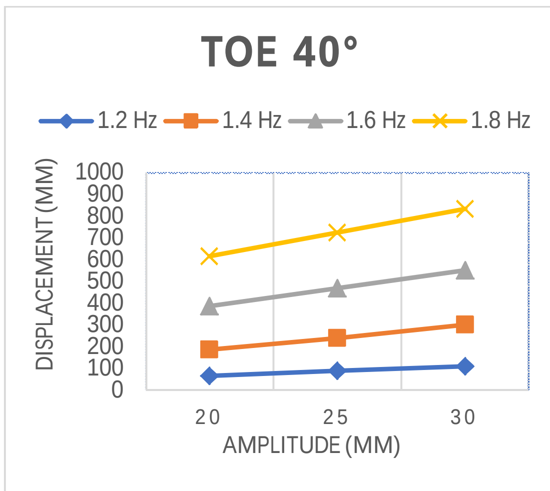
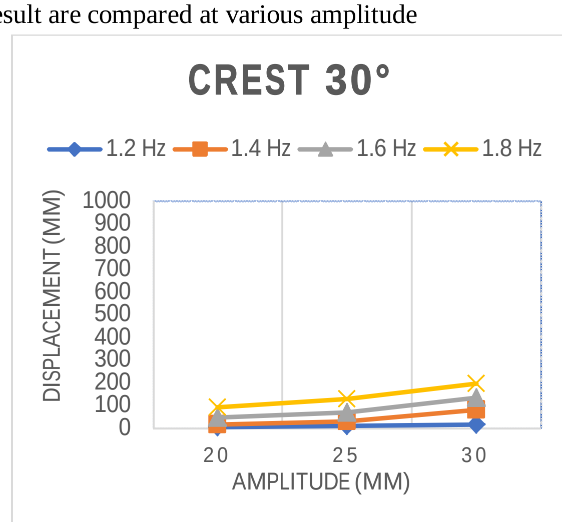
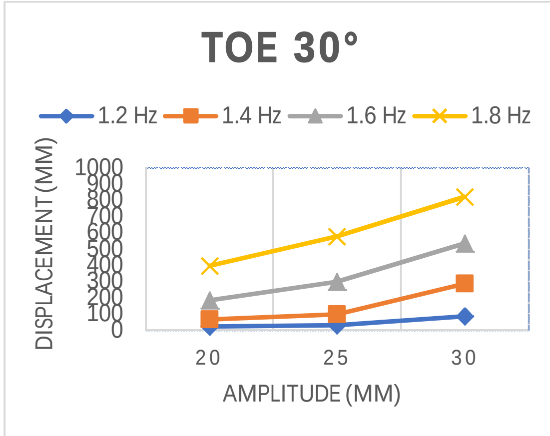


Unreinforced Toe Settlement

4) Reinforced soil slope model test result are compared at various amplitude



Reinforced Crest Settlement



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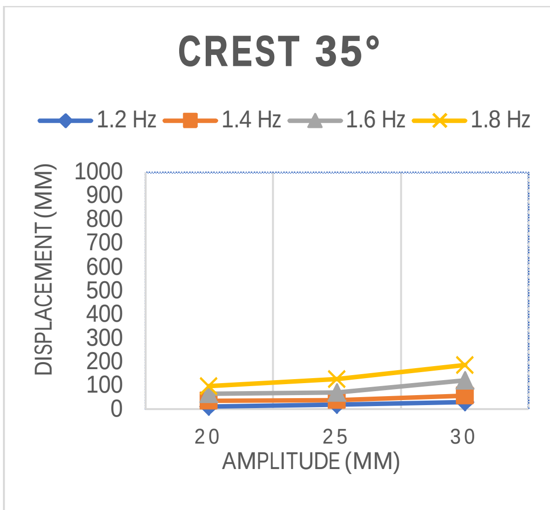

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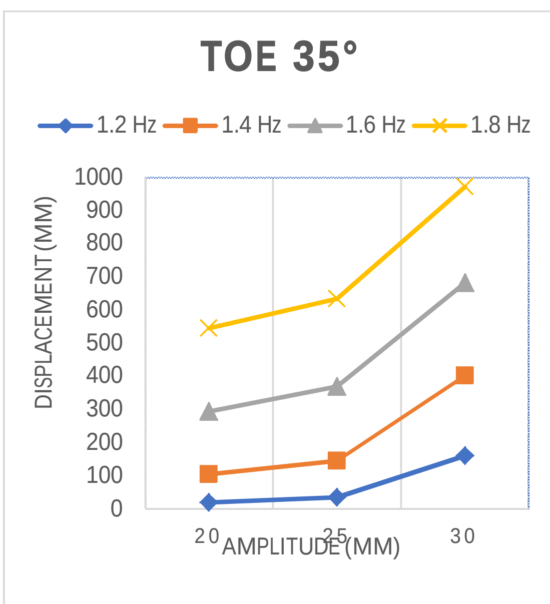

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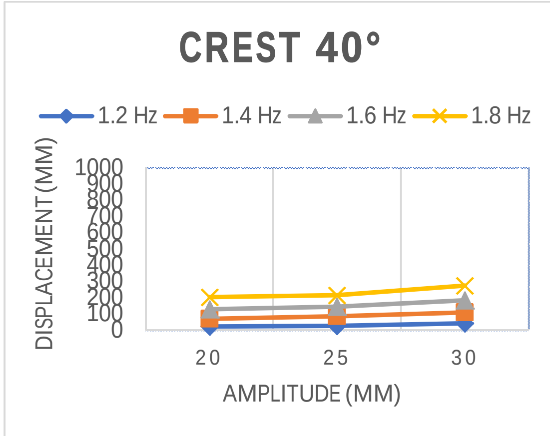

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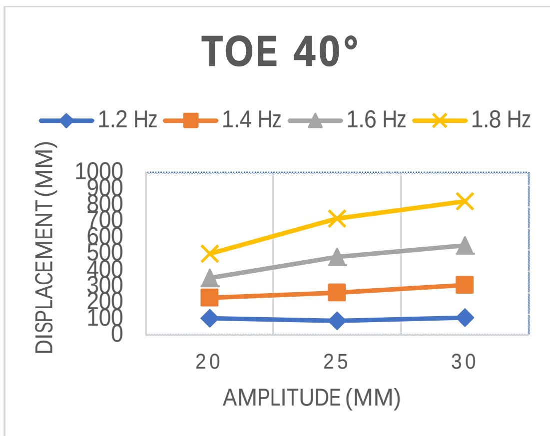

Reinforced Toe Settlement

VII. CONCLUSION

The slope model consisted of surface, weak, and a mixture of sand and gravel i.e., geomaterial compositions. Higher amplitude causes more sever deformations due to increasing dynamic loading. The steeper slope can be constructed with the use of reinforcement whereas, unreinforced slope inclination is limited to slope inclinations of about 40°. The increase in displacement and settlement at desired amplitude and acceleration is observed from the outward side of the model box while performing the shake table test. The stability of the model for embankment can be used from obtained shaking test results. The feature investigation is to find suitable reinforcement to provide maximum stability to the model for the feature construction work. The response of the model was not very uniform along the slope but varies with the inclination and acceleration. Both reinforced and unreinforced slopes present an increasing response with a higher frequency of shaking. At a lower frequency of 1.2Hz, the deformation in the model found is less whereas, at a higher frequency of 1.8Hz the displacement model is drastically high. These reinforced slope deformations are comparatively less than that of the unreinforced slope model. Moreover, the different reinforcement materials as mentioned in above shall be compared to find the best suitable reinforcement to check the stability responses of the model under dynamic loading behaviour. As there was no reinforcement added at the toe direction the displacement found is more whereas the displacement at the crest in reinforcement is less than that of unreinforced. As the slope increases or get steeper the displacement occurred is more. but it is observed that with added reinforcement the steeper slope can be constructed.

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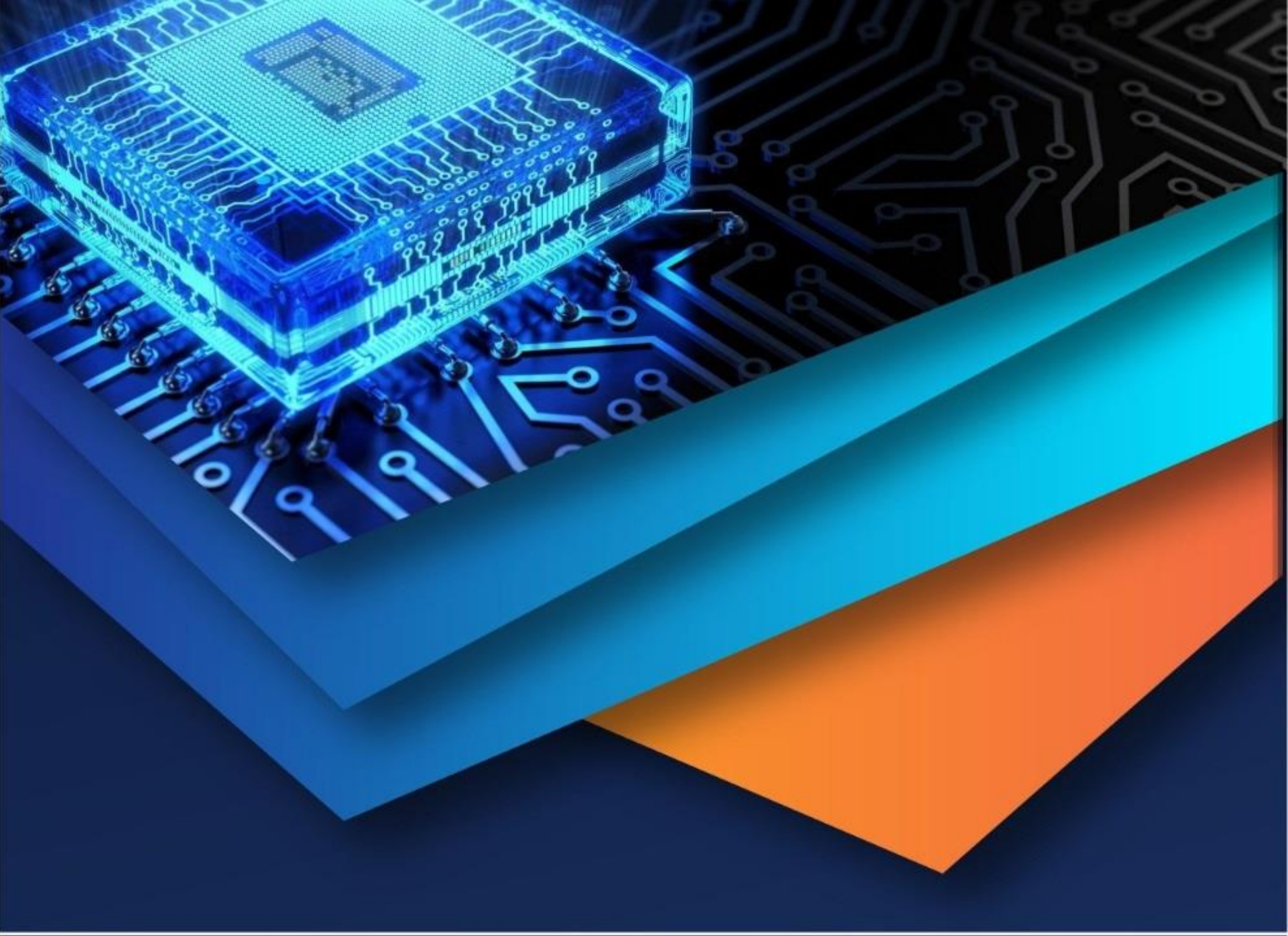

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