

# Evaluation of Pore Water Pressure Characteristics in Embankment Model.

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## ABSTRACT

For the assessment of embankment behavior when under seismic force, a simulation model on a shaking table is one of the accurate and feasible methods. This research focused on behavioral studies of embankments when rested on fully saturated subsoil. The data recorded from the tests included time histories of excess pore water pressure at salient locations. They were used to determine the dynamic behavior of the system including mechanism of failure of the model embankment and also the excess pore water pressure generation in the model embankments.

(Keywords: embankment, pore water pressure, dense layer, liquefaction)

## INTRODUCTION

Earthquakes are the most catastrophic natural phenomenon cannot be predicted. They are characterized by a shaking of the ground in all possible directions, causing hazards of varying intensities to mankind throughout the entire world. However, it is possible to control and minimize the effects of earthquakes with some understanding and observations.

Developments in earthquake geotechnical engineering, which includes understanding ground behavior during shaking, effects of earthquakes on geotechnical facilities, site amplification studies, etc., have shown tremendous progress. Studies in earthquake geotechnical engineering can be broadly classified into four groups, namely:

1) Understanding the ground behavior through element tests

- 2) Carrying out model tests to capture finer points such as rise in excess pore water pressure, ground amplification, etc.
- 3) Development and use of analytical/numerical model to simulate ground behavior
- 4) Application of the above concepts to field problems and to ensure their behavior [1].

Jack W. Baker et al. in 2008 conducted research by using Random-field theory and geostatistics tools to model soil properties and earthquake shaking intensity for the potential extent of liquefaction by accounting for spatial dependence of soil properties and potential future earthquake shaking [2]. They presented research that deals with the earthquake response analysis of soil liquefaction.

Researchers have considered the effects of excess pore water pressure on stress analysis. The paper proposes a method for laboratory tests to predict changes in the pore water pressure with simplified conditions for analysis, based on the cumulative damage concept [3].

An investigation has also been done on liquefaction in silty soil during earthquakes with consideration of onshore and offshore structures. Investigations were for cohesive soil. Results indicate fine-grained soils in certain situations may be susceptible to liquefaction [4].

This paper deals with understanding of pore water pressure behavior in the system when seismic force is applied up on model. Our model is fully saturated and the seismic force is created by means of a single direction shaking table.

## METHODOLOGY AND EXPERIMENTS

The experimental set up and manual-shaking table developed at the Earthquake Engineering Laboratory, Sri Jayachamaraja College of Engineering, Mysore, India was used to carry out these experiments [5]. In the present experiments, a transparent rigid boundary acrylic box with an opening at the top was used to study the behavior of embankments in fully submerged ground.

The box is made of perplez glass of 12 mm thickness with dimensions of 1,650 mm in length, 500 mm in breadth, and 600 mm in depth. The bottom portion of box has an arrangement of baffle walls for regulating water uniformly to saturate the sand placed in the box. A small orifice is provided at the bottom to allow water for saturation of the model. Filter plates with a size of 2 microns were provided above the baffle walls, which could be easily removed and placed back. The use of filter plates helped in restricting the entry of sand into the baffle wall portion.

The outer surface of the acrylic box was marked with grids of 100 mm by 100 mm, using a permanent marker, in order to lay the color sand in proper layers. The manual-shaking table was used to vibrate in one direction. It consisted of two wooden panels with steel plates between them for producing harmonic vibration at a frequency of 1 Hz to 3 Hz. The thickness, height, and number of plates were so designed to achieve a relatively rigid platform and to vibrate at resonance. The platform was 1.8 m long, 0.6 m wide, and 0.35 m in depth. The steel plates were bolted between the top and bottom surfaces of the wooden panels using angle sections. The pore pressure sensors (P1-P4) were used to measure the excess pore water pressure developed during dynamic loading (Figure 1).

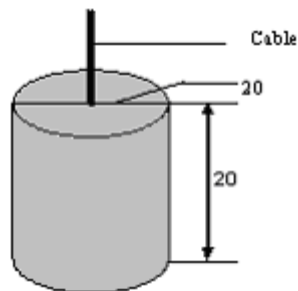


Figure 1: Pore Pressure Sensor.

The data acquisition system consists of transducers, pore pressure sensors, and a computer to store the data. The respective transducers were connected to their signal conditioners. These were, in turn, connected to the C.P.U. of a computer. The sensors sense the signals and then relay them to signal conditioners. The signals are converted to the digital form (Figure 2). The experimental methodology is illustrated in the following flow chart (Figure 3).

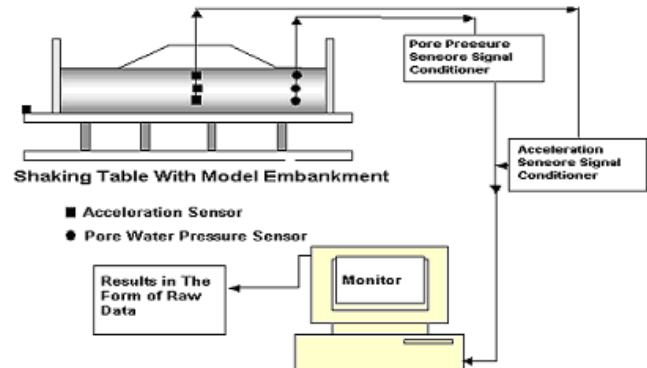


Figure 2: Schematic Diagram of Shaking table with Model Embankment.

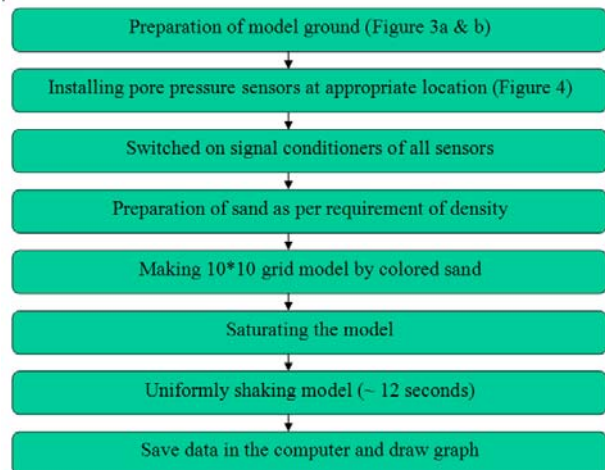
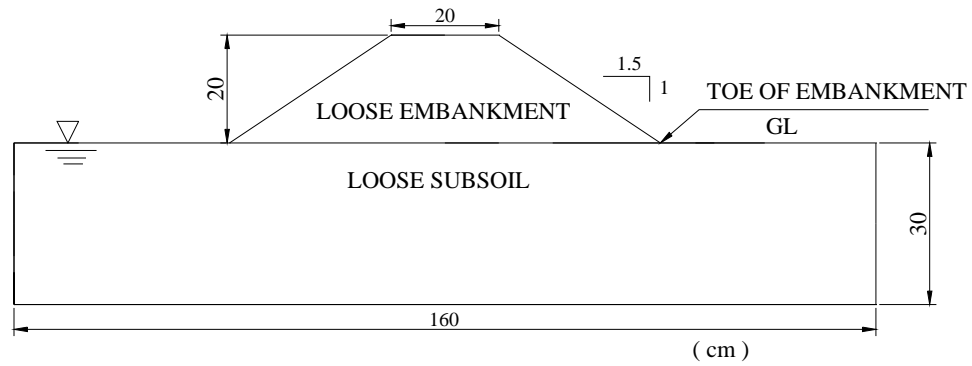
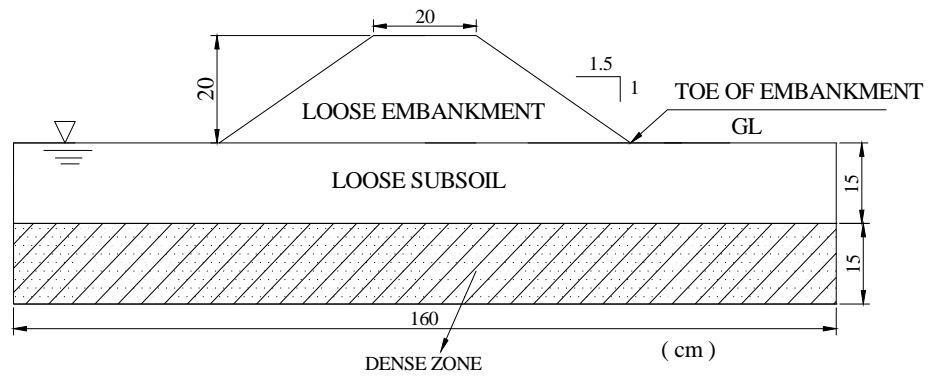


Figure 3: Flow Chart of Test Procedures.

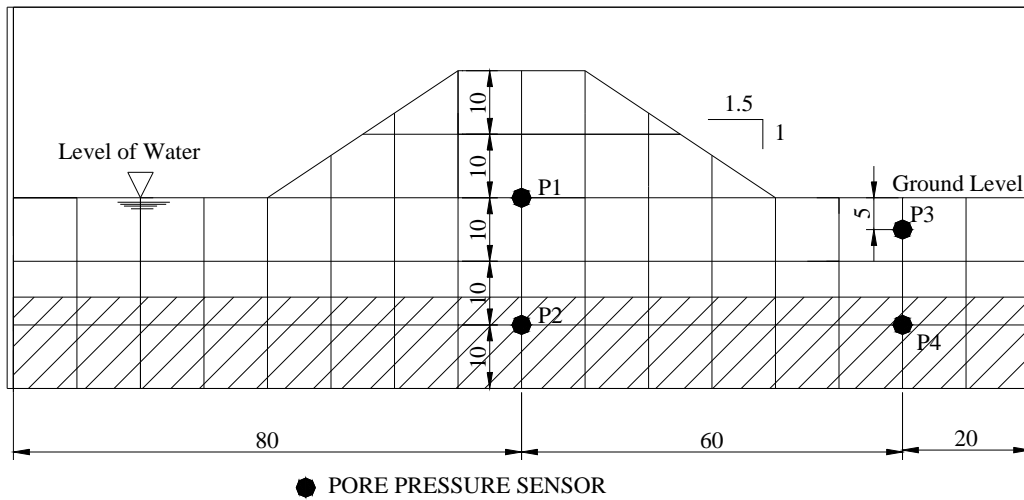
There are two types of embankment experimental models considered. The first one is without a dense layer and second type is with a dry loose embankment and subsoil fully saturated with two layers; a dense lower layer (15 cm) and a loose upper layer (15 cm) (Figure 3a and b). Figure .4 shows the cross section of ground level with sand, water level and positions of pore pressure.



**Figure 3 a:** Model of Moist Loose Embankment and Loose Subsoil Fully Saturated Without Mitigation.



**Figure 3 b:** Dry Loose Embankment and Subsoil with Fully Saturated in Two Layers, Dense Lower Layer (15 cm) and Loose Upper Layer (15 cm).



**Figure 4:** Position of Transducer.

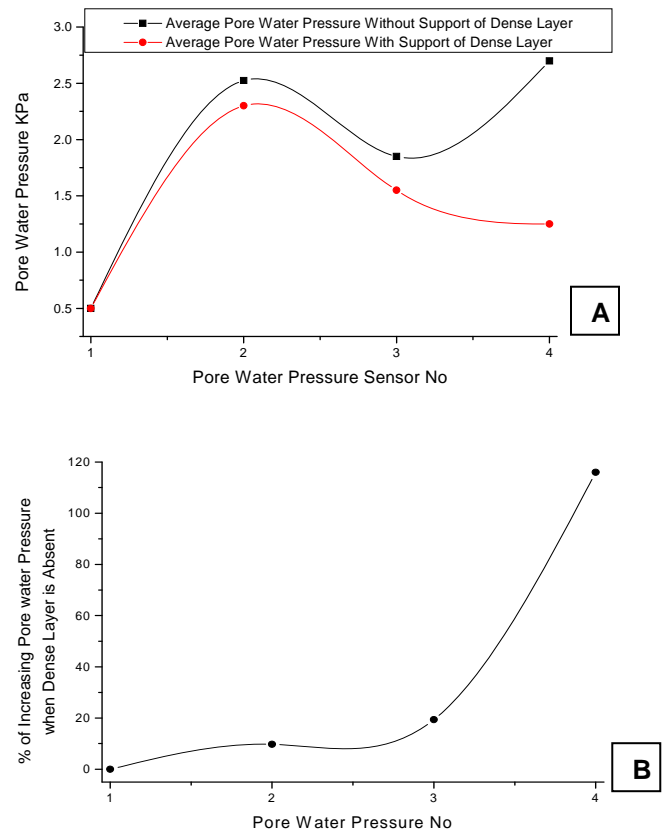
## RESULTS AND DISCUSSION

In the present work, a dynamic load was induced manually by shaking of the shaking table, which can generate an acceleration of about 0.5 g at a frequency of around 2 Hz in one direction at a payload of 750 N. Saturated sandy ground was prepared with extremely loose density. Four pore water pressure sensors were installed in the model set-up to monitor the response of model ground. The soil foundation mostly included multi layer of soil - combination of soil behavior at any group layer during the application of seismic force on model and showed a soil foundation with new behavior.

Results of the experiments recorded through the pore pressure sensors (P) in two models are illustrated in Table.1. The level of stress applied in these experiments is very sensitive and directly depends on the strength and availability of the dense layer for controlling lateral force in subsoils during the collapse of the embankment. In the absence of a dense layer, the stability time of the embankment was reduced and the level of pore water pressure increased. In the case of a dense layer rested in the model, the density of soil has greater effect on reducing the level of pore water pressure and controlling liquefaction.

In the results shown in Model B (Figure 3 b), loose saturated subsoil with dense lower layer (15 cm) and loose upper layer (15 cm), is nonlinear with time with a minimum level of pore water pressure in P2, P3, and P4. The pore water pressures recorded by P1 are same in both

models, due to placement of P1 on the ground surface (Figure 5a).



**Figure 5 a and b:** Detail of Pore Pressure Characteristics of Test A & B.

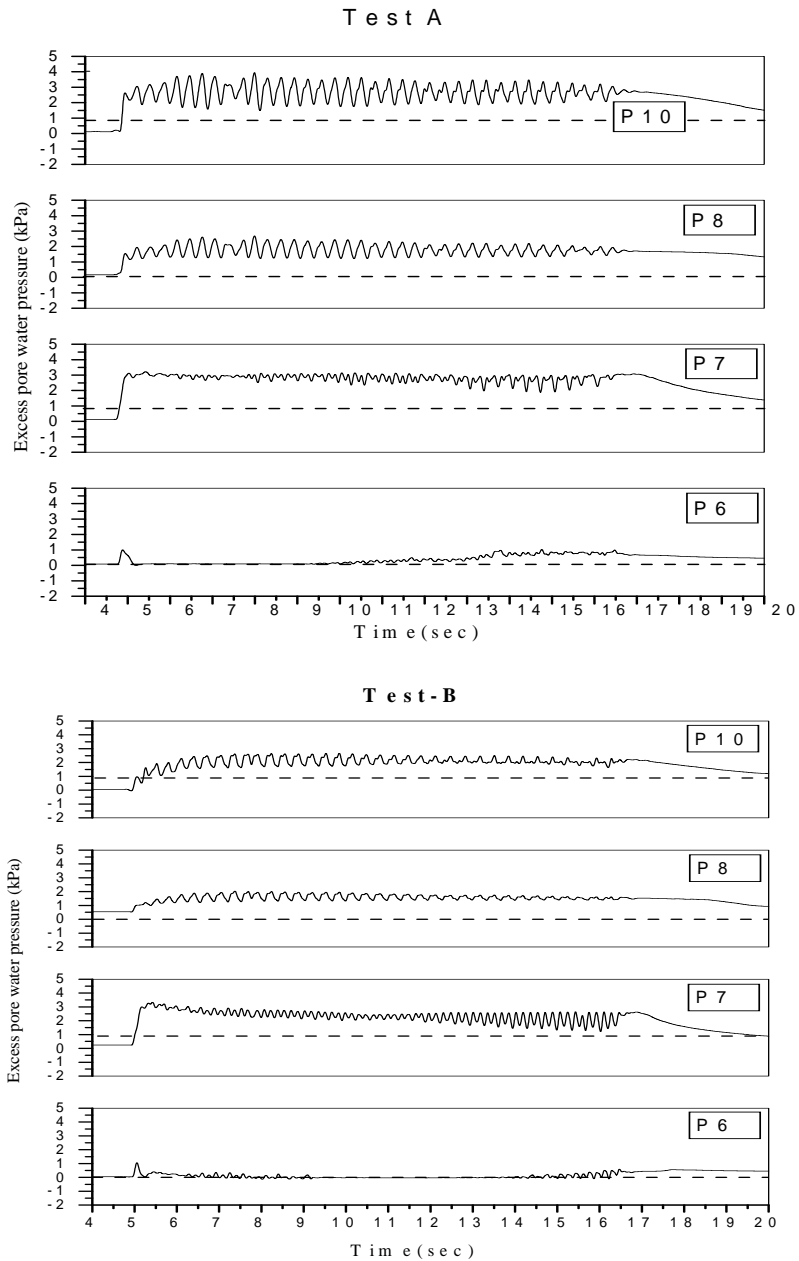
**Table 1:** Detail of Pore Pressure Characteristics of Test A & B.

Sl. No	Features	Test Name	P1	P2	P3	P4
1	Maximum pore water pressure (kPa)	A	1	3.25	2.5	4
		B	1	3.3	2	2.5
2	Minimum pore water pressure (kPa)	A	0	1.8	1.2	1.4
		B	0	1.3	1.1	0
3	Average pore water pressure (kPa)	A	0.5	2.525	1.85	2.7
		B	0.5	2.3	1.55	1.25
4	Shape of excess pore water pressure history	A	GD	GD	UF	GI
		B	UF	UF	GD	UF

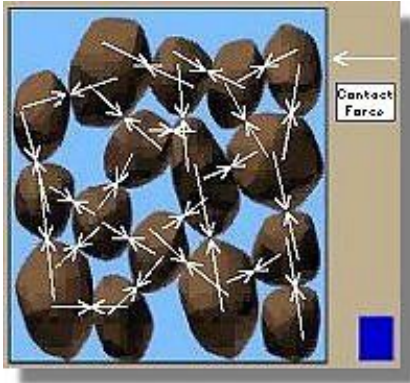
*GD= gradually decrease; GI= gradually Increase; UF=uniformly; SI=same as input*

The results in both models show a maximum level of pore water pressure in P4 (Figure 5 a). When the dense layer is absent, P4 recorded increasing pore water pressure compared to the other three pore pressure sensors; this is due to the nature of the collapsing of the embankment during shaking (Figure 5b). The dense layer placed in the bottom of the embankment model behaved like a foundation with enough stability and hence

possessing sufficient resistance against seismic force during shaking, to reduce both the settlement of embankment and magnitude of liquefaction. Changing levels of pore water pressure in both models are indicated in Figure 6 a and b. Positions of soil particles before and during liquefaction indicated decreasing soil density during liquefaction (Figures 7 a and b).



**Figure 6 A and B:** Time Histories of Excess Pore Water Pressure for Tests A and B.



**Figure 7 a:** Contact Pressure Between Particle Before the Rise of Pore Water.



**Figure 7 b:** Soil Liquefaction Due to Excess Pore Water Pressure.

Liquefied soil exerts higher pressure on retaining walls, which can cause them to tilt or slide. This movement can cause settlement of the retained soil and destruction of structures on the ground surface. Increased water pressure can also trigger landslides and cause the collapse of dams [6]. Deformation during cyclic loading will depend on the density of the soil, the magnitude and duration of the cyclic loading, and the amount of shear stress reversal [7]. Effective stress is not the sole factor that governs the soil volume change behavior. The application of net stress leads to the understanding of the true soil shear strength behavior and enables the understanding of soil volume change behavior [8].

## CONCLUSION

The seismic force applied to the embankment models is very sensitive and the effect on model depends on soil foundation characteristics. The embankment suffers from increasing pore water

pressure due to strong dynamic force. Provision of dense layer under the embankment decreases excess pore water pressure. Due to increasing unit weight of sandy soil foundation, stability of the embankment has been increased. One of the economical methods in controlling liquefaction is increasing subsoil density.

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## SUGGESTED CITATION

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