Evaluation of seismic mitigation of embankment model

Abdollah Namdar
Mysore University, Mysore 570006, India, sina_a_n@yahoo.com

ABSTRACT. Conducting experiment on embankment model by shaking table could be an accurate method to evaluate the behavior of embankment or any structures under seismic loading. In this research work, in order to assess the function of seismic force and accurate placement of dense zone in the embankment model, the results of three experiments have been considered. To evaluate the reaction of the embankment model, it was measured the stress in the system and photographs were taken. The results of three experiments indicated that suitable arrangement of dense zone is the main factor at the play in embankment stability, and in predicting the possibility of embankment behavior.

KEYWORDS. Liquefaction, Stress, Dense Zone, Pore Water Pressure

INTRODUCTION

Seismic liquefaction refers to a sudden loss in stiffness and strength of soil as a result of cyclic loading effects of an earthquake. This loss arises from the soil tendency to contract under cyclic loading. If such contraction is prevented or curtailed by the presence of entrapped water in the pores, it leads to a rise in pore water pressure and a resulting decrease in effective stress. If the effective stress drops to zero (100 per cent pore water pressure rise), the strength and stiffness also drop to zero and the soil behaves as a heavy liquid [1]. At the time of the earthquake, the embankment rested on saturated loose sandy subsoil faces high level of liquefaction risk and may bridge to failure of the embankment. Seismic force creates liquefaction due to nonlinear stress up on the model. Constructing dense zone in the subsoil is a method to reduce the effect of stress in the embankment model [2]. A research work on Dynamic properties and liquefaction potential of soils has been presented [3]. Jack W. Baker and Michael H. Faber [4]conducted a research by using Random-field theory and geostatistics tools to model soil properties and earthquake shaking intensity. He wanted to present a potential extent of liquefaction by accounting spatial dependence of soil properties and potential future earthquake shaking. Dash et al. investigated the use of reinforcement in increasing stability of soil foundation [5]. Schimizu and Inui [6] carried out load tests on a single six-sided cell of geo-textile wall buried in the subsurface of the soft ground and also Mandal and Manjunath [7] used geo-grid and bamboo sticks as vertical reinforcement elements and studied their effect on the soil bearing capacity. Rajagopal et al. [8] have studied the strength of confined sand and the influence of geo-cell confinement on the strength and stiffness behavior of granular soils. Seismic motion could be responsible for instability of embankment model. It is possible to control seismic motion by provision of a dense zone in the subsoil as a feasible method. Embankment with good enough foundation stability could be more resistant against seismic force and could increases the safety factor in the system.

METHODOLOGY AND EXPERIMENTS

The evaluation of embankment model behavior, when it is under seismic force by manual-shaking table, provided insight in understanding seismic mitigation of embankment. The dense zone, consisted of composite material confined in geo-textile in loose saturated sandy subsoil, was studied to assess disability of liquefaction. The manual-shaking table was used to vibrate in one direction Figs. 1-3. It consisted of two wooden panels with a steel plate in between which produced harmonic vibration at frequency of 1 Hz to 3 Hz when an approximately around 75Kg force

was applied on model. One type of transducer (acceleration sensors (A1-A3)) was used to measure the acceleration and its results integrated to draw shear stress graph.
Test Procedure of Experimental are following as
- The filter plates were fixed and sealed on top of baffle walls inside the acrylic box.
- The aluminum channels were fixed with gum tape inside the acrylic box.
- Signal conditioner of acceleration sensor was switched.
- The prepared sand was laid.
- Acceleration sensors were placed at required locations.
- The colored sand was laid at every 10 cm height horizontally and at 10 cm vertically in aluminum channels.
- The water was allowed through baffle walls at very slow rate for saturating the ground.
- The shaking was carried out uniformly.
- The results recorded in the computer and created in the form of the graphs.

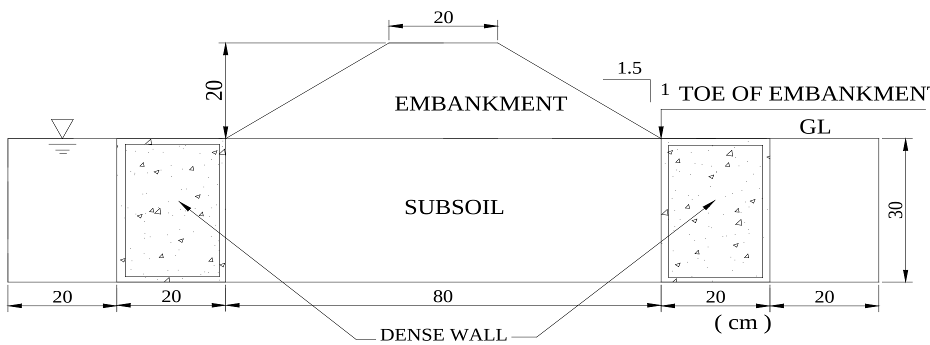


Figure 1: Model of loose sandy embankment and loose sandy saturated subsoil consists of dense wall made up from composite material (60 % sand and 40 % gravel) confined in geo textile installed outside toe of embankment

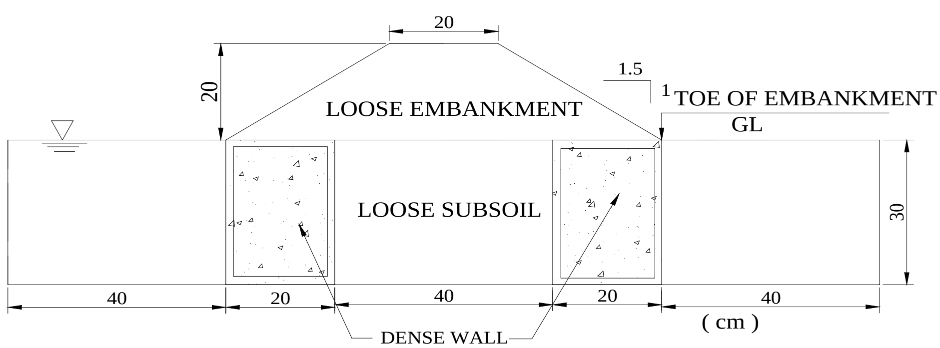


Figure 2: Model of loose sandy embankment and loose sandy saturated subsoil consists of dense wall made up from composite material (60 % sand and 40 % gravel) confined in geo textile installed inside toe of embankment

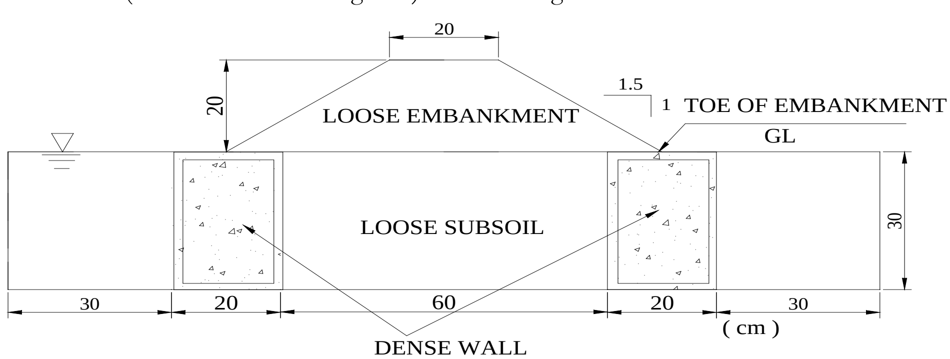


Figure 3: Model loose sandy embankment and loose sandy saturated subsoil made up from composite material (60 % sand and 40 % gravel) confined in geo textile centrally installed on the toe of embankment.

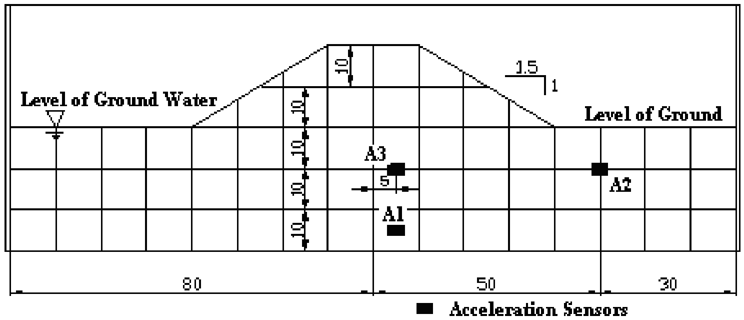


Figure 4: Transducer position

Three different types of models have been developed. The first model is loose sandy embankment and loose sandy saturated subsoil. It consists of dense wall made up from composite material (60 % sand and 40 % gravel) confined in geo textile installed outside toe of embankment . The second model is loose sandy embankment and loose sandy saturated subsoil consists of dense wall made up from composite material (60 % sand and 40 % gravel) confined in geo textile installed inside toe of embankment . The third model is loose sandy embankment and loose sandy saturated subsoil made up from composite material (60 % sand and 40 % gravel) confined in geo textile centrally installed on the toe of embankment. (Figs. 1-3). Fig. 4 shows the cross section of ground and water level with positions of acceleration transducers in the model. The horizontal shear strain γ is obtained from the differential displacement between two adjacent accelerometers, as illustrated in Fig. 5. It is given by

$$\gamma = \Delta d / \Delta h$$

where

Δd = differential horizontal displacement between two adjacent points

Δh = Distance between the two acceleration points

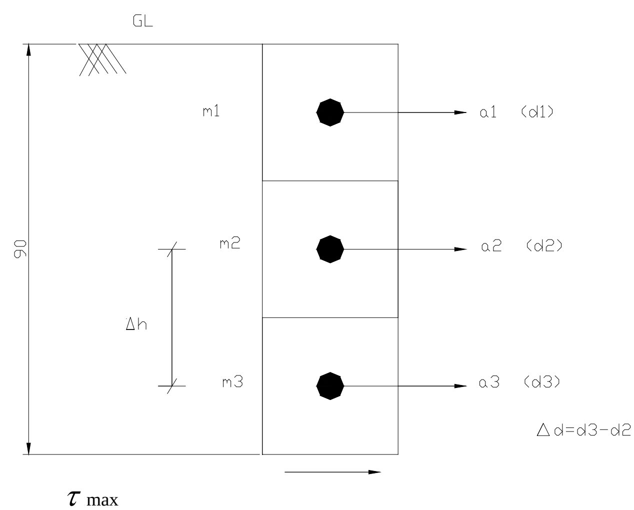


Figure 5: Key sketch for the computation of shear stress and shear strain in the embankment (a = Acceleration, d = Corresponding displacement).

Displacement can be obtained by double integration of the acceleration records.

In a sand deposit, let's consider a column of soil of height 'h' and unit area of cross section subjected to maximum ground acceleration a_{max}. Assuming a soil column to behave as a rigid body, the maximum shear stress τ_{max} at a depth '*h*' is given by:

$$\tau_{max} = \sum \{\gamma_s h / g\} a_{max}$$

where

g = Acceleration due to gravity

γ_s= Unit weight of soil

RESULTS AND DISCUSSION

Installing a dense zone in the subsoil is the easiest method to make an embankment enough stable, when it is subjected to a dynamic force. The aim of this investigation has been to find the right location of the subsoil for a dense zone installation. The results of experiments has been recorded in the form of tables, graphs and photos. The stress characteristic is responsible for controlling liquefaction at the time that the system is under shaking. From the results of all experiments, it could be mention that the main reason of increasing embankment instability is the weakness of dense zone in controlling lateral force due to bad dense zone placement. In the test C (Fig 6c), due to suitable placement of dense zone, it could be observed low liquefaction level and higher stability. Suitable placement of dense wall is like constructing strong sufficient column in the right place of structure. Photographs A, B and C (Fig6a-c) provide sufficient evidence at the time of embankment breakdown at any second. Referring to Figs (7a1- c2) and Tab.1, it could observed that the maximum level of stress appeared below the embankment and the minimum level of stress occurred far from the embankment. This phenomenon is due to subsoil pressure caused by the weight of the embankment.
The model C (with maximum level of stress applied on the model), due to suitable installation of dense zone, resulted significantly controlling lateral force, deformation and creep deformation in the subsoil and increased time stability of dense zone and embankment. Easy collapsing of embankment during earthquake is due to any reason could accelerate excess pore water pressure and placing system in the great danger. The immediate collapse of embankment, pressurizing more subsoil, due to dynamic falling weight of embankment on subsoil, could increases seismic force. The ability of seismic forces upon model is the results of a model characteristic. Arranging dense zone with proper material reduces speed of collapsing of embankment as as well as creep deformation and settlement of whole model. Here it could be observed vertical dynamic force created in the model. Embankment satiability is dependent of subsoil strength and deformation during vibrating model by seismic force. Intensity of displacement, deformation, stress, pore water pressure and liquefaction as well as restricting seismic force in the embankment models are results of selecting accurate place of dense wall.
Liquefied soil exerts higher pressure on retaining walls, which can cause theirs 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 [9]. The lateral shear forces developed under the embankment should be compared with the shear strength of the subsoil [10]. The improvement of soil strength with geotextile material depends on the soil grading. The effect is significant for soil with more fine percent [11]. The liquefaction potential of a soil mass during an earthquake is dependent on both seismic and soil parameters [12].

Test name	At the below of embankment (kPa)	At the away from the embankment (kPa)
A	1.22	1.1
B	1.622	0.47
C	3.13	1.95

Table 1: Maximum Stresses at Each Test

CONCLUSIONS

- The construction of any embankment needs to consider soil foundation behavior with accurate interpretation of the results.
- The results of three experiments have been carried out. They indicated the possibility of understanding behavior of embankment when it is under dynamic loading.
- Placement of dense wall in suitable location of subsoil is like constructing strong sufficient column in the right place of structure.
- Suitable placement of dense zone can more control pore water pressure and lateral force in the system and reducing of settlement and creep deformation of the subsoil and embankment as well as increases time stability of embankment during the earthquake.
- Easy collapsing of embankment during earthquake could accelerate excess pore water pressure.
- Collapsing of embankment has effect on neighboring area of the subsoil of embankment in term of increasing deformation, stress and excess pore water pressure.
- All ability of seismic force activity in the system is result of model characteristics.

TEST A

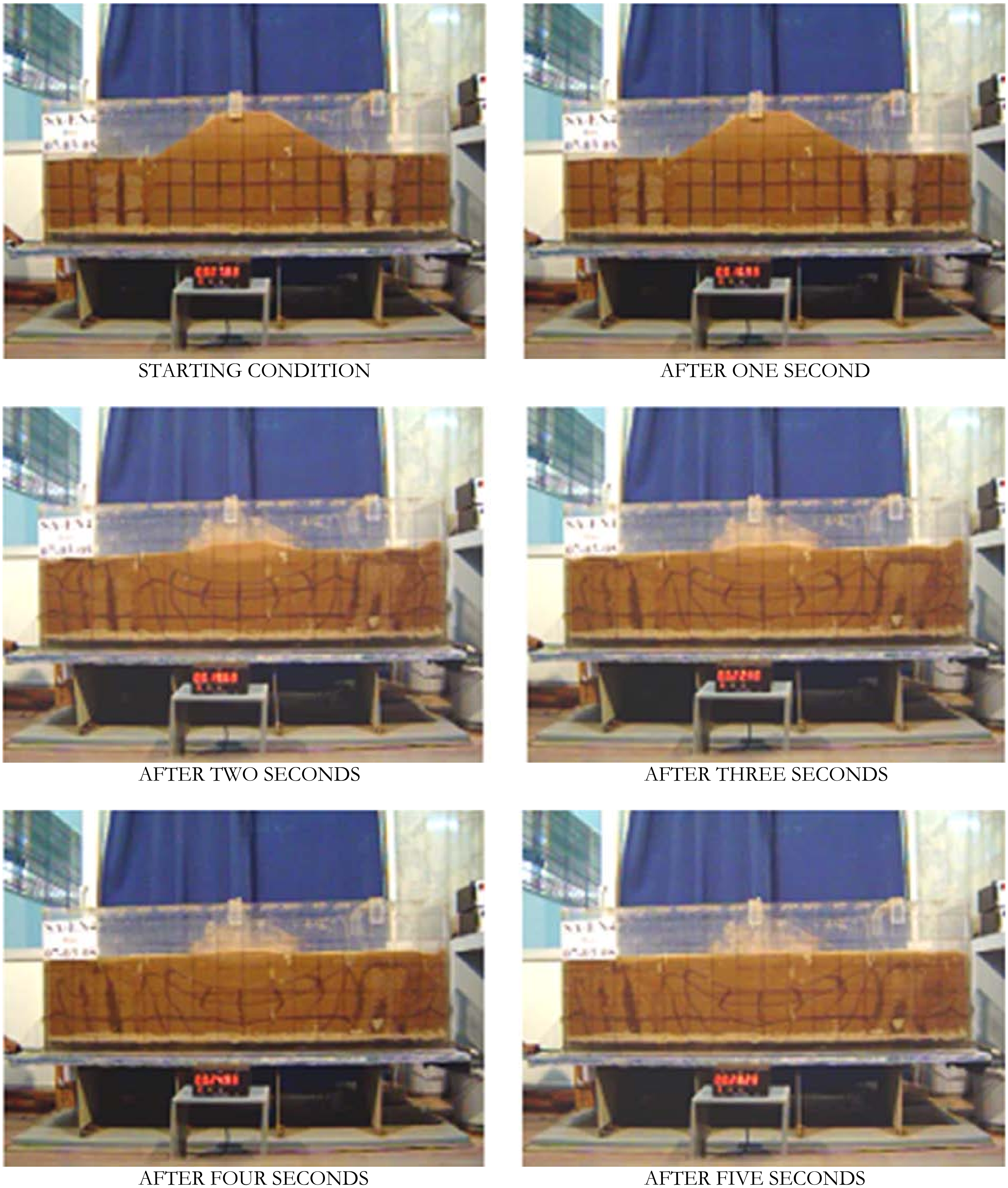
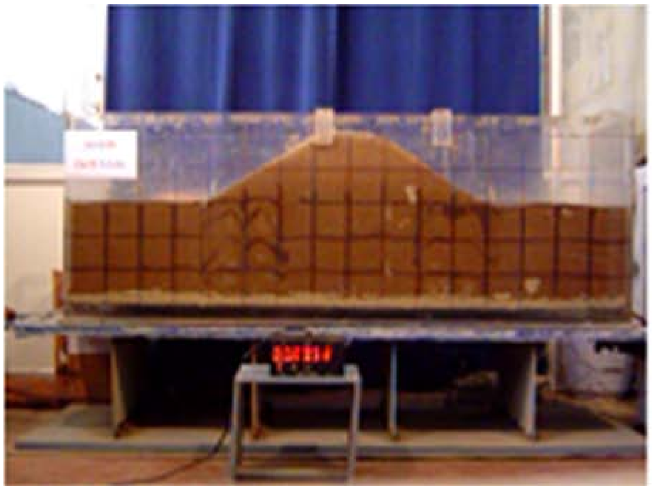
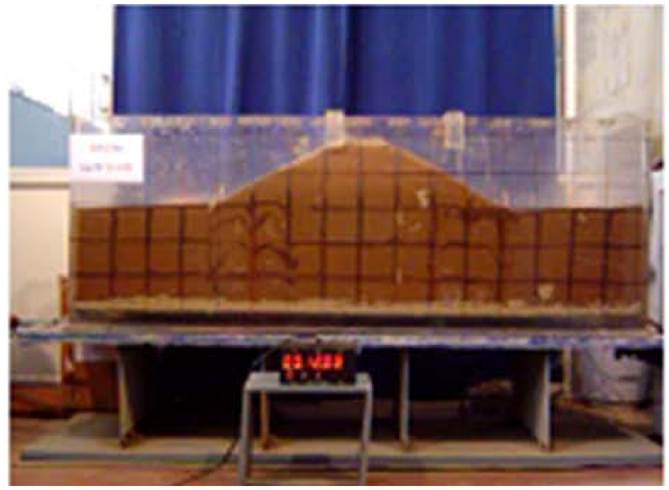


Figure 6a: Deformation shape of embankment subsoil (up to five seconds, Test A).

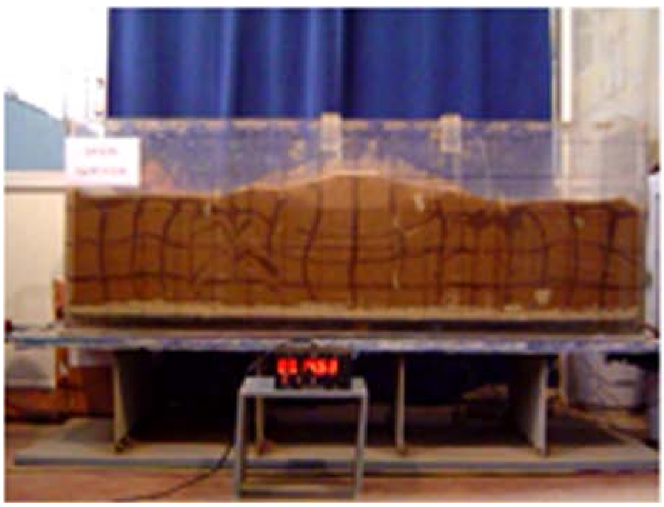
TEST B



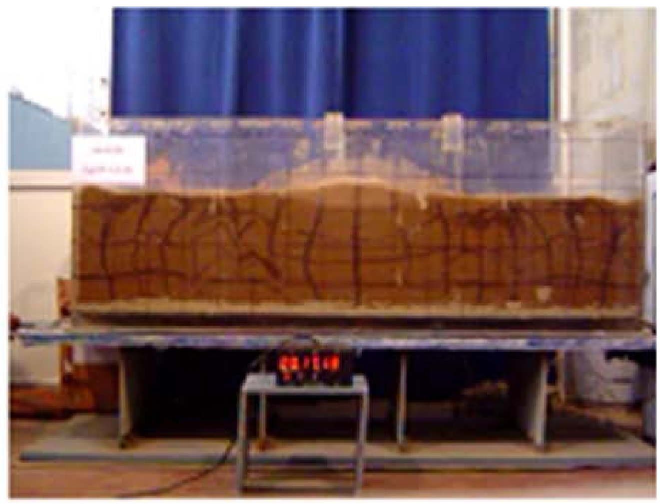
STARTING CONDITION



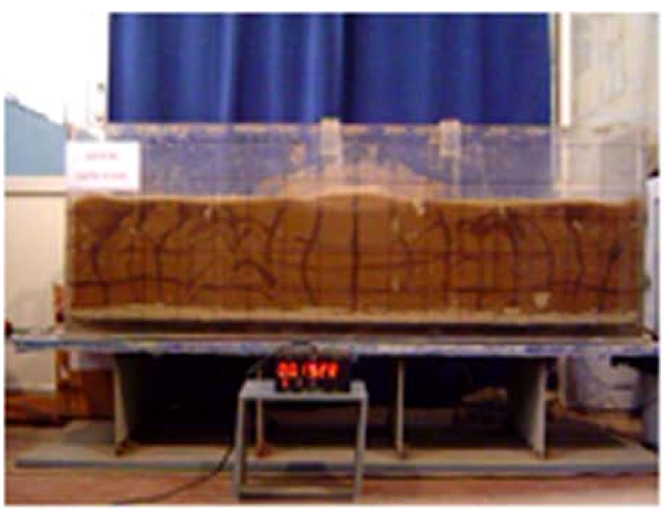
AFTER ONE SECOND



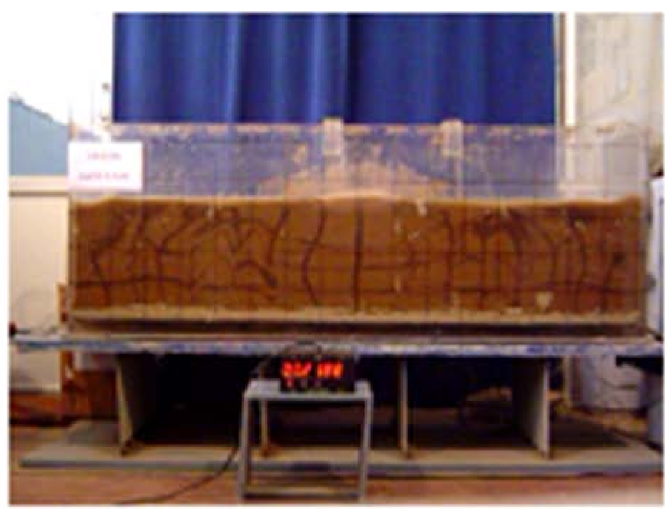
AFTER TWO SECONDS



AFTER THREE SECONDS



AFTER FOUR SECONDS

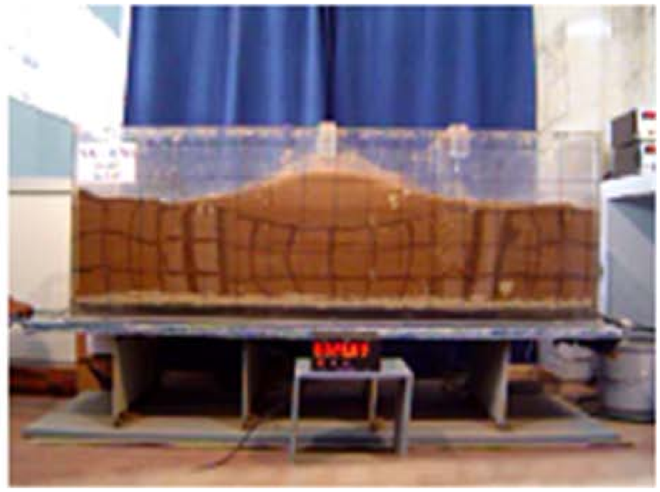


AFTER FIVE SECONDS

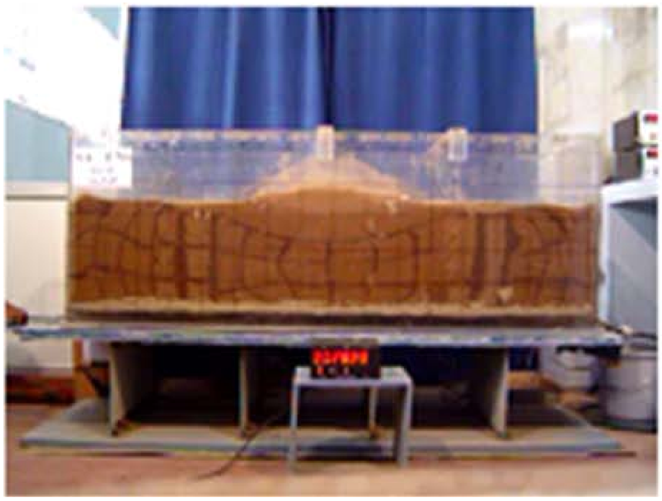
Figure 6b: Deformation shape of embankment subsoil (up to five seconds, Test B).

TEST C

STARTING CONDITION



AFTER ONE SECOND



AFTER TWO SECONDS

AFTER THREE SECONDS

AFTER FOUR SECONDS

AFTER FIVE SECONDS

Figure 6c: Deformation shape of embankment subsoil (up to five seconds, Test C).

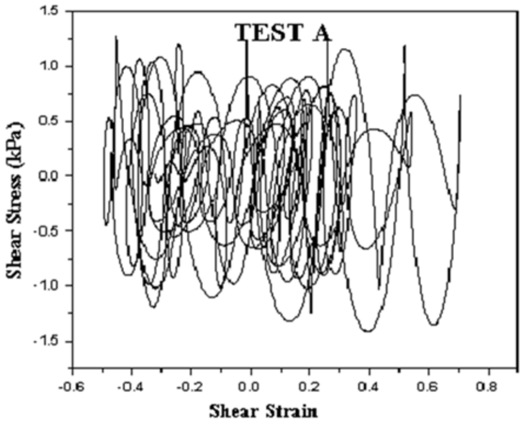


Figure 7a1: Stress strain history in the subsoil away from the embankment (Test A).

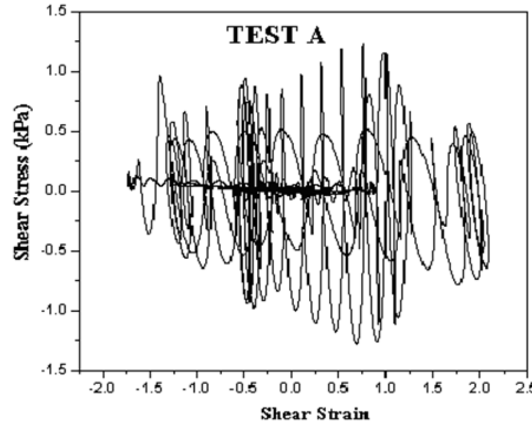


Figure 7a2: Stress strain history in the subsoil below the embankment (Test A).

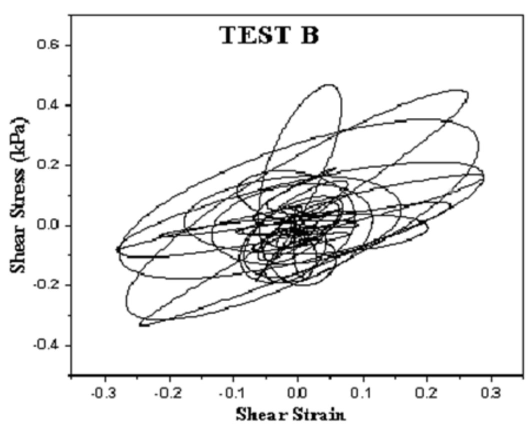


Figure 7b1: Stress strain history in the subsoil away from the embankment (Test B)

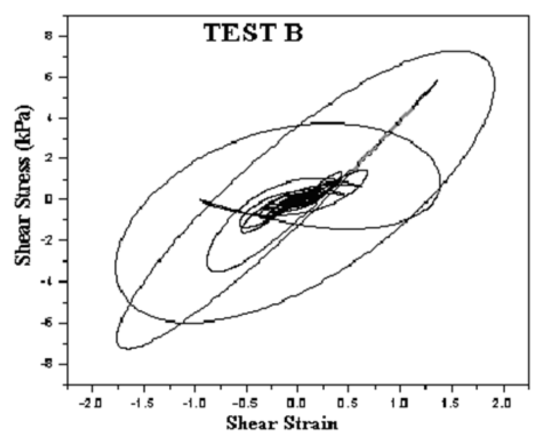


Figure 7b2: Stress strain history in the subsoil below the embankment (Test B).

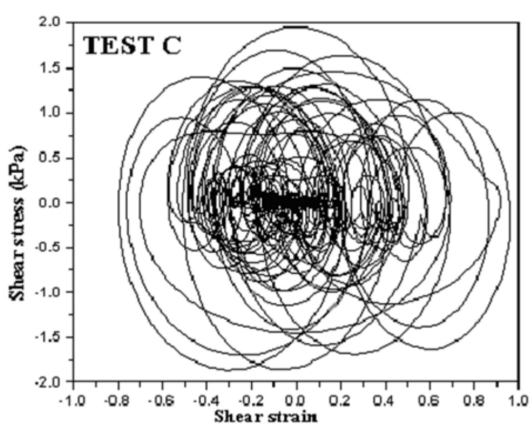


Figure 7c1: Stress strain history in the subsoil away from the embankment (Test C)

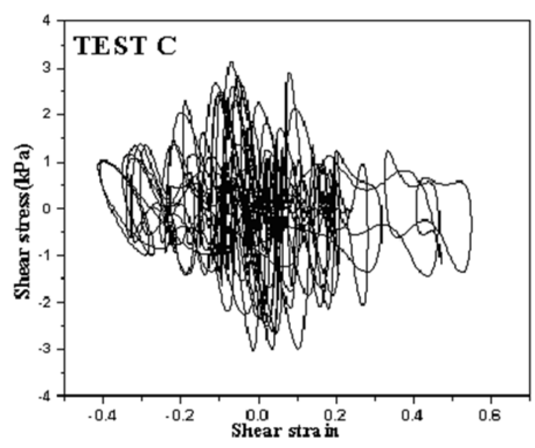


Figure 7c2: Stress strain history in the subsoil below the embankment (Test C).

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