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SEISMIC EVALUATION OF SANDY EMBANKMENT MODEL

BY

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Abstract. Understanding of seismic force and its activity on embankment model by use of shaking table is one of the scientific method in controlling earthquake ability. In this work three types of subsoil under embankment have been constructed and in all models characteristics of embankments are constant and subsoil are created with three types of dense zone. The obtained results revealed types and time of collapse has direct correlation with dense zone and subsoil characteristics and if it is well arranged more controlled seismic force and lateral movement during the shaking of the system and it could be best, economic and shortest way of increasing embankment model stability.

Key words: Embankment model; seismic force; horizontal dense zone; vertical dense zone.

1. Introduction

Embankment represents constructed or natural soil, material in construction of embankment could be imported from another place or replaced from another portion of the project. Dense zone in the embankment is one of the important elements in the embankment and subsoil composition. It influences all systems behavior, creation of suitable dense zone in subsoil and is a method to achieve safety of the system.

There is investigation on application of a nonlinear energy sink (NES) that is locally attached to a main structure, with the purpose of passively absorbing a significant part of the applied seismic energy, to locally confine it and then to dissipate it in the smallest possible time. Alternatively, the overall goal will be to demonstrate that it is feasible to passively divert the applied seismic energy from the main structure (to be protected) to a preferential nonlinear substructures (the NES), where this energy is locally dissipated in a time scale fast enough to be of practical use for seismic mitigation [1]. An investigation has also been performed on liquefaction in silty soil during earthquakes with consideration of onshore and offshore structures [2]. It is reported, using FLAC 2D software, double sand lenses liquefaction mechanism and soil deformation due to applying cyclic loading has been studied [3]. There is presented the results of a research concerning saturated loose sand, tested under bi-directional cyclic loading to characterize liquefaction and cyclic failure, by using an advanced soil static and dynamic universal triaxial and torsional shear apparatus [4]. In a scientific research was reported a series of laboratory model tests to investigate the using of shredded waste tires as reinforcement to increase the bearing capacity of soil [5]. There was research activity on ultimate bearing capacity of surface strip foundations on geo-grid-reinforced sand and un-reinforced sand [6]. It is reported conducting experiment on embankment model by shaking table to evaluating behavior of embankment when it is under seismic loading [7].

In this investigation shape, size and material of dense zone were main factors and effect of that on improvement of bearing capacity, deformation, settlement and liquefaction evaluated.

2. Method and Material

To evaluate the seismic force on sandy embankment model three types of dense zone which first type is dense zone installed in subsoil and second type made up from composite material confined in geo-textile and third type is with dense lower layer rested under loose sandy saturated subsoil in the system have been created, in all three types the manual-shaking table has used to vibrate in one direction (Figs. 1,…,3 *a*...*c*). The shaking table consisted of two wooden panels with steel plates between them for producing harmonic vibration and approximately force on model. Two types of transducer (acceleration sensors ($A1,\ldots,A3$) and pore pressure sensor ($P1,\ldots,P4$)) (Figs. 4 *a*...*c*) were used to measure the acceleration and pore pressure and its results integrated to draw pore pressure and shear stress graph.

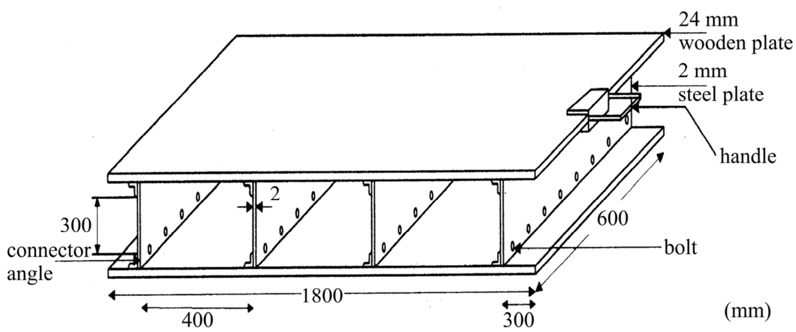


Fig. 1 – Shaking table without acrylic box.

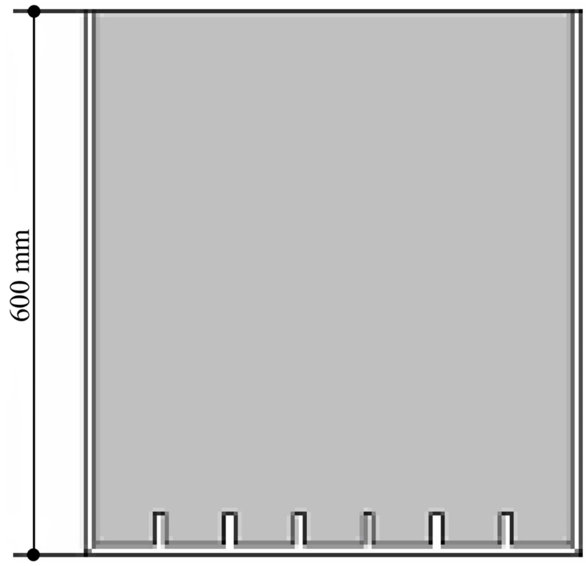


Fig. 2 – Elevation schenatic diagram of transparent acrylic box.

Test procedures of experimental are the followings:

a) the following are the steps involved for preperation of model ground;

b) the filter plates were fixed and sealed on top of baffle walls inside the acrylic box;

c) the aluminium channels were fixed with gum tape inside the acrylic box;

d) the pore pressure sensors were kept and tied to the string at required location inside the acrylic box;

e) signal conditioners of both acceleration sensors and pore pressure sensors were switched on and pore pressure was calibrated to zero reading in signal conditioner;

f) the prepared sand was laid according to the requirement of density;

g) acceleration sensors were placed at required locations, one being kept on the shaking table for measuring the input motion;

h) the coloured sand was laid at very 10 cm height horizontally and at 10 cm vertically in aluminium channels;

i) the water was allowed through baffle walls at very slow rate for saturating the ground; the quantity of water consumed for saturation was noted;

j) readings of pore pressure sensors were set to zero in the corresponding signal conditioner, in order to find out only the excess pore water pressure generated during shaking;

k) maximum displacement during shaking was measured by fixing a pen to the top surface of table against a rigidly held white sheet fitted to a cardboard;

l) the shaking was carried out uniformly for a specified duration (12 s);

m) the results recorded in the computer were saved soon after the completion of experiment.

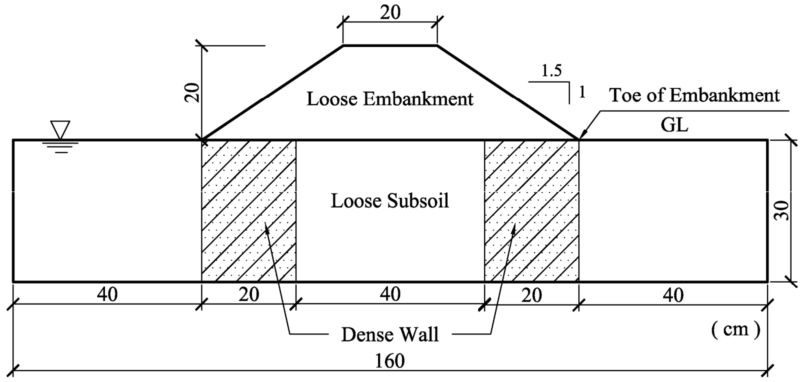


Fig. 3 *a* – Model of loose embankment and loose subsoil fully saturated with 20 cm thick dense sandy wall in subsoil inside of toe of embankment.

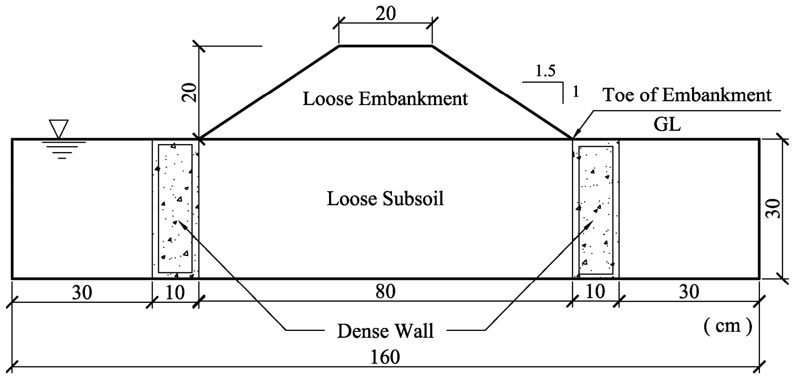


Fig. 3 *b* – Model moist loose embankment and loose subsoil fully saturated and dense wall made from composite (60% sand and 40% gravel) confined in geo-textile placed on the outside of toe of embankment

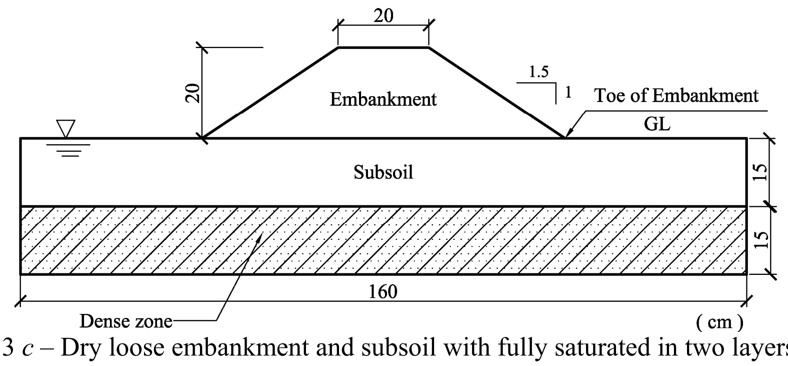


Fig. 3 *c* – Dry loose embankment and subsoil with fully saturated in two layers, dense lower layer (15 cm) and loose upper layer (15 cm).

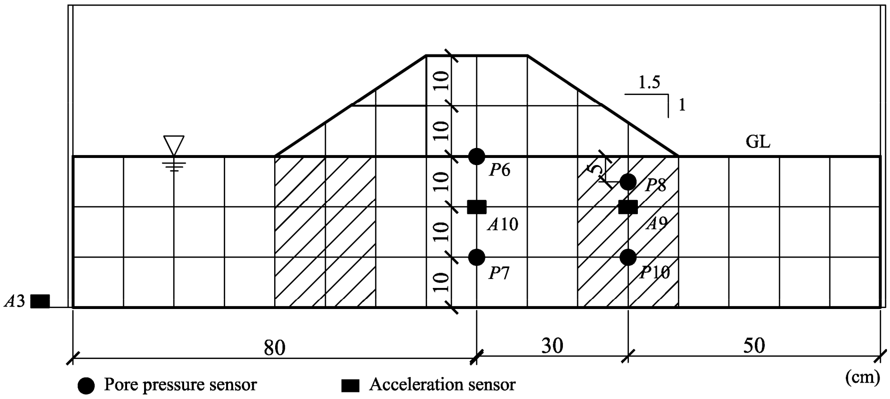


Fig. 4 *a* – Position of transducer in model *A*.

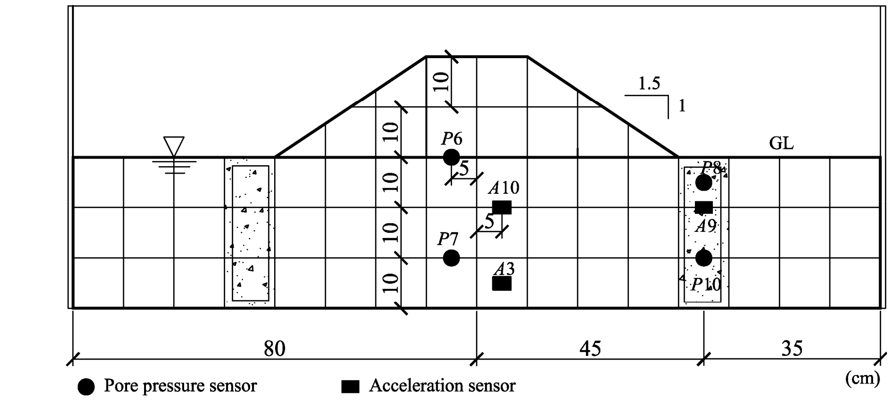


Fig. 4 *b* – Position of transducer in model *B*.

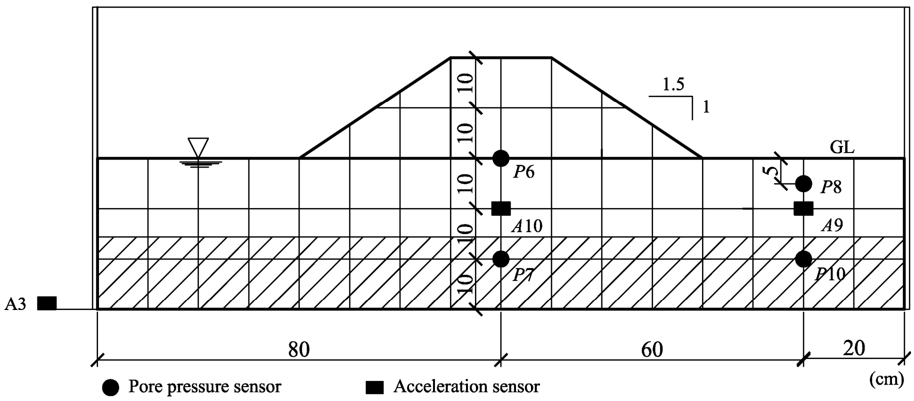


Fig. 4 *c* – Position of transducer in model *C*.

The horizontal shear strain, γ, is obtained from the differential displacement between two adjacent accelerometers, $\gamma = \Delta d/\Delta h$, where, Δd is the differential horizontal displacement between two adjacent points, Δh – distance between the two acceleration points.

The maximum shear stress at a depth h is given by

$$\tau_{\max} = \sum \left\{ \gamma_s \frac{h}{g} \right\} a_{\max} ,$$

where g is the acceleration due to gravity and γ_s – unit weight of soil.

3. Results and Discussion

To increase accuracy in design and construction of embankment foundation, employee of suitable shape of dense zone which consist of acceptable material is a scientific way in development of embankment construction technology [8].

From experiments *A*, *B* and *C* indicated pore water pressure and dynamic stress could not easily damage subsoil if it is equipped by dense horizontal or vertical layer (Figs. 5 *a*...*c* and 6 *a*...*c*). On the model *C* maximum level of stress has been applied (Table 1), due to densification of 15 cm lower layer of subsoil, minimum intensity of deformation in that section observed (Figs. 7 *a*...*c*), availability of dense layer even away of ground surface increased shape stability of subsoil and embankment. The shape of collapse in the models *A* and *B* are very sharp and in the model *C* is moderate (Figs. 7 *a*...*c*). When model *C* has collapsed less deformation effected on the neighboring area.

In the model *B* dense zone confined in geo-textile made up from composite material, due to its less weight even with less stress applied on that could not resist against lateral force properly. Heavy dense zone has more influence on controlling dynamic force compared to when it is light and confinement.

At all cases minimum deformation and maximum pore water pressure under embankment at center of subsoil observed (Table 2), it is occurred due to collapse of embankment, it could deduce effect of dynamic lateral force in the center of subsoil. The embankment submerged by liquefaction before collapsing that under dynamic lateral force. The stability of embankment depends on stability of subsoil, construction of embankment from light material and subsoil from heavy material represents a method of increasing system quality.

The liquefaction occurs in saturated soil [9]. Liquefaction causes the collapse of dams [10]. Deformation during cyclic loading will depend on the magnitude and duration of the cyclic loading, and amount of shear stress reversal [11]. The improvement of soil strength with geo-textile material depends on the soil grading [12].

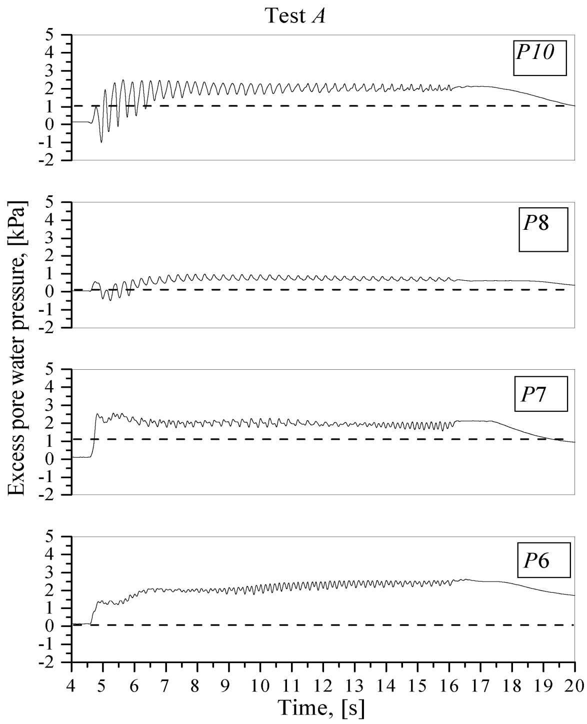


Fig. 5 *a* – Time histories of excess pore water pressure.

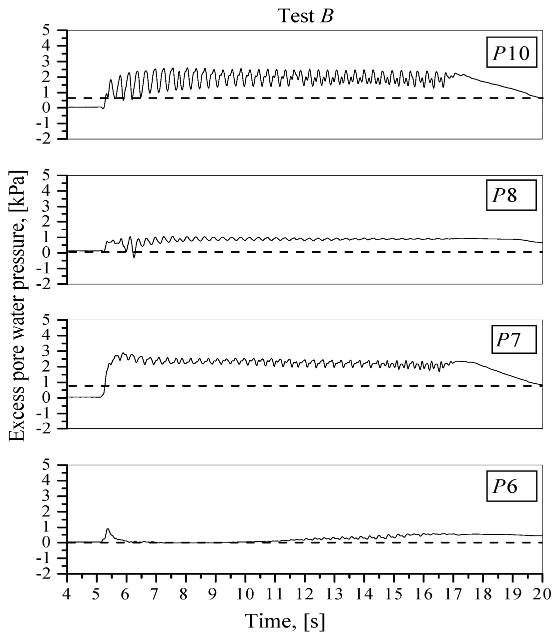


Fig. 5 *b* – Time histories of excess pore water pressure.

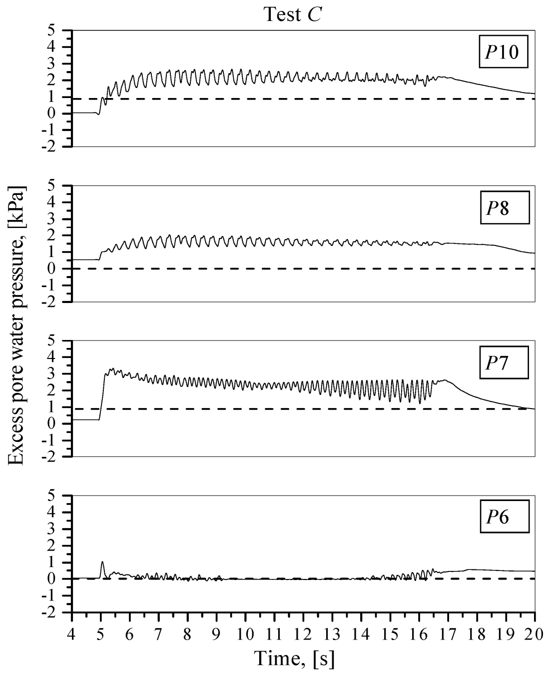


Fig. 5 *c* – Time histories of excess pore water pressure.

Table 1

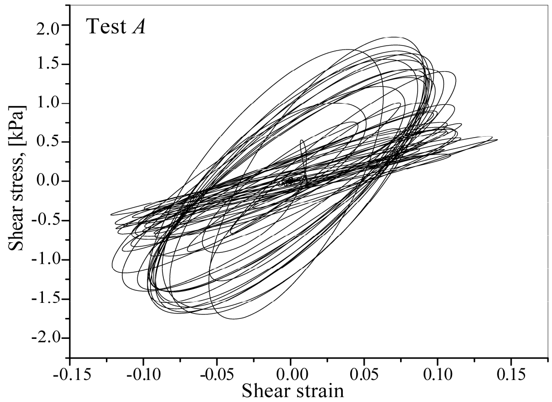
Detail of Pore Pressure Characteristics of Tests A, B, C

Sl. no.	Features	Test	*P*1	*P*2	*P*3	*P*4
1	Maximum pore water pressure, [kPa]	*A*	2.56	2.59	1.02	2.52
		B	0.86	2.91	1.05	2.67
		C	1.06	3.37	2.01	1.69
2	Time of occurrence of maximum excess pore water, [s]	*A*	12.22	5.32	7.66	5.66
		B	5.36	5.89	6.13	8.07
		C	5.08	5.41	7.38	9.53

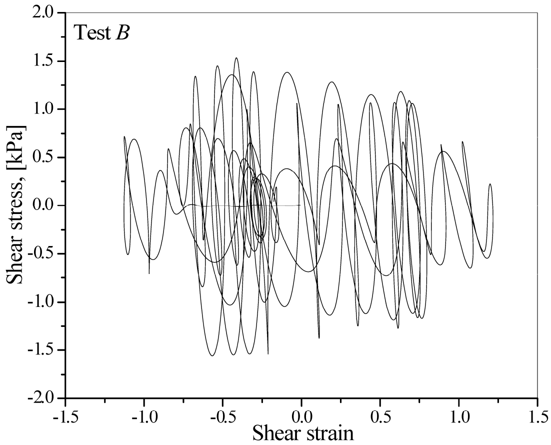
Table 2

Maximum Stress at Each Test

Test	At the below of embankment, [kPa]
A	1.86
B	1.57
C	2



a



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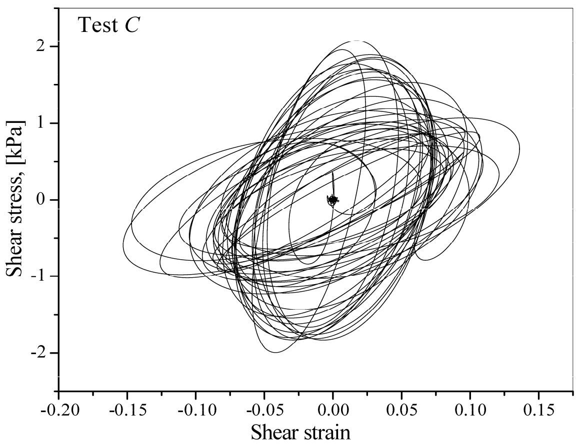
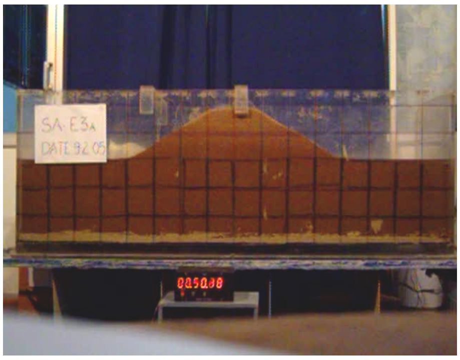


c

Fig. 6 – Stress strain history in the subsoil below of the embankment.

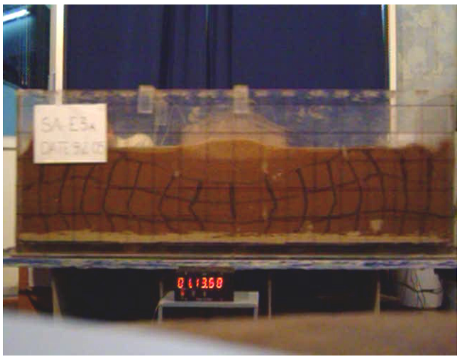
Test *A*



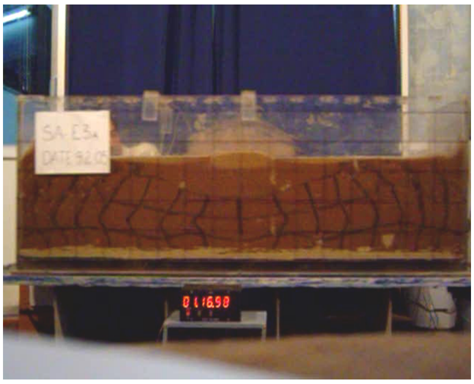
Initial condition

After one second

After two seconds



After three seconds

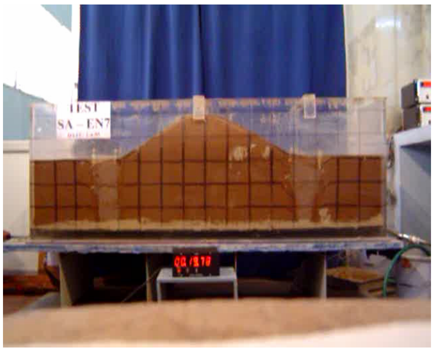


After four seconds

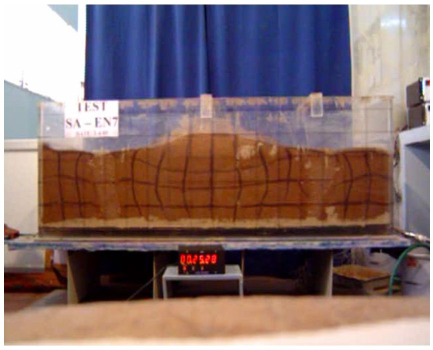
After five seconds

Fig. 7 *a* – Deformation shape of embankment–subsoil system at different instants of time.

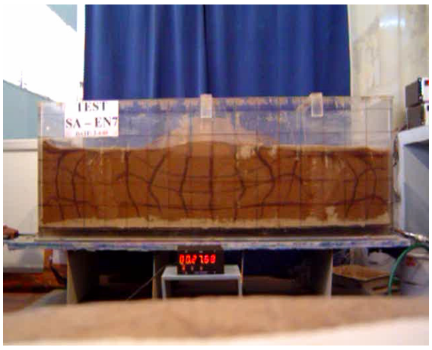
Test *B*



Initial condition



After one second



After two seconds

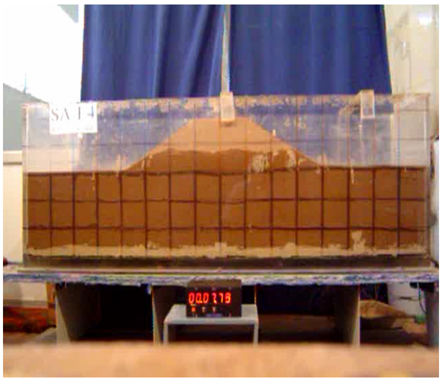
After three seconds

After four seconds

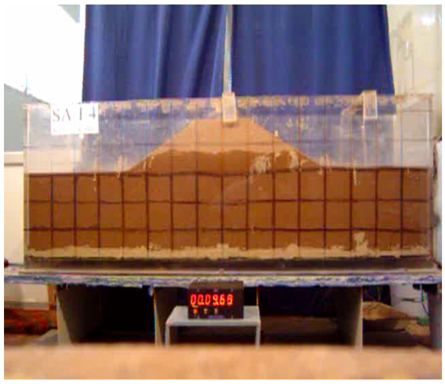
After five seconds

Fig. 7 *b* – Deformation shape of embankment–subsoil system at different instants of time.

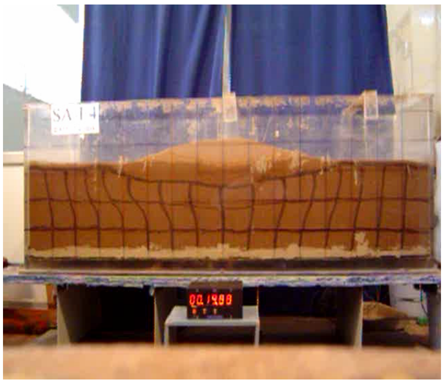
Test *C*



Initial condition



After one second



After two seconds

After three seconds

After four seconds

After five seconds

Fig. 7 *c* – Deformation shape of embankment–subsoil system at different instants of time.

5. Conclusions

1. Reduction of dense zone movement resulted in improvement of system bearing capacity.

2. The stress created liquefaction is responsible for all types of deformation and settlement of the system.

3. The liquefaction submerged embankment before collapsing that by seismic force.

4. At all cases minimum deformation and maximum pore water pressure under the embankment at center of subsoil were observed.

5. Seismic force in the center of subsoil by weight of embankment was controlled.

6. Availability of dense layer under embankment has positive correlation with stability of embankment and neighboring structure.

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EVALUAREA SEISMICĂ A UNUI MODEL DE TERASAMENT DIN NISIP

(Rezumat)

Înțelegerea forței seismice şi a activității sale asupra unui model de terasament prin folosirea masei vibrante este una dintre metodele ştiințifice pentru controlul acțiunii seismice. În această lucrare, s-au construit trei tipuri de teren de fundare sub terasament şi pentru toate modelele, caracteristicile terasamentelor sunt constante şi zonele de sub terasament prezintă trei tipuri de îndesare. Rezultatele au condus la concluzia că tipurile de cedare şi intervalul de timp până la cedare depind în mod direct de caracteristicile terenului de fundare, cu cât acesta este mai îndesat. cu atât se poate limita forța seismică şi deplasarea laterală în timpul vibrației sistemului, şi aceasta poate fi cea mai bună metodă, economică şi de scurtă durată, pentru creşterea stabilității modelului de terasament.