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STABILITY ANALYSIS OF THE EMBANKMENT MODEL

BY

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Abstract. In analysis of embankment model affected by dynamic force, employment of shaking table is a scientific way in assessment of earthquake behavior. This work focused on saturated loose sandy foundation and enbankment. The results generated through the pore pressure sensors indicated pore water pressure playing main role in creation of liquefaction and stability of the system, and also revealed deformation, settlement, liquefaction intensity and time stability of system in direct correlation with the strength and characteristics of soil. One of the economical methods in stabilization of soil foundation is improvement of some part soil foundation.

Key words: embankment; sand, shaking table; liquefication.

1. Introduction

Earthquake is the most catastrophic natural phenomenon, which cannot be predicted. It is characterized by shaking of 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 effect of earthquake with some understanding and findings.

Developments in earthquake geotechnical engineering, which include understanding group behavior during shaking, effects of earthquake on geotechnical facilities, site amplification studies, etc. [1]. It is a research work using Random-field theory and geostatistics tools to model soil properties and earthquake shaking intensity for present of potential extent of liquefaction [2]. There is presented the earthquake response analysis of the soil liquefaction. It considered effect of excess pore water pressure on stress analysis, and proposes a method to predict changes in the pore water pressure with simplified conditions for analysis, based on the cumulative damage concept [3]. An investigation has been performed regarding the liquefaction in silty soil during earthquake and considering of onshore and offshore structures. Investigation was performed for cohesive soil and lead to liquefaction [4]. This paper deals with understanding of pore water pressure behavior in the system when seismic force applied up on model, which is fully saturated, and seismic force created by shaking table in one direction. The impact analysis and mitigation of seismic force applied on loose sandy saturated embankment and subsoil are investigated.

2. Methodology and Experiments

The experimental set up (manual-shaking table) developed in the Earthquake Engineering laboratory, Sri Jayachamaraja College of Engineering, Mysore, was used to carryout the experiments [5]. The acceleration and excess pore water pressure developed during dynamic loading were measured through sensors $A1\ldots A3$ and $P1\ldots P4$ connected to signal conditioners respectively (Fig. 1).

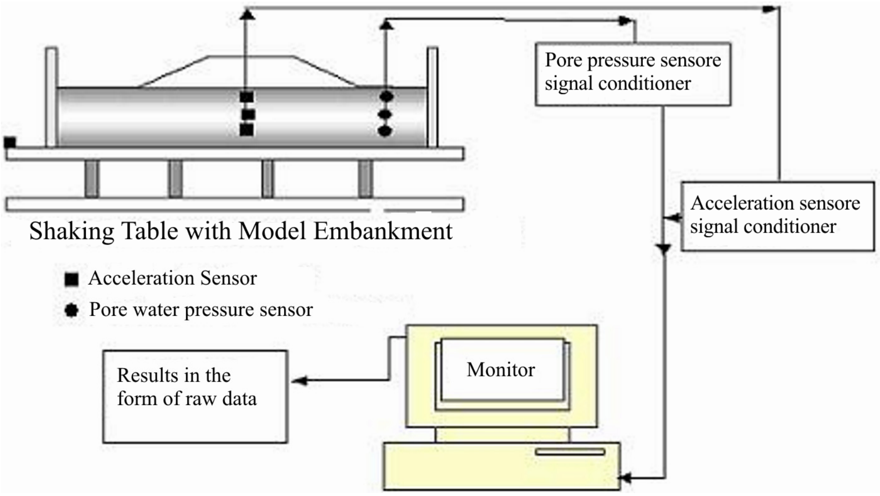


Fig. 1 – Schematic diagram of shaking table with model embankment.

In the present investigation five types of embankment experimental models are considered (Figs. 2 *a*...*e*). The first one is without dense zone. The remaining types are of dense zone placed in the subsoil of the model embankment with one outside the toe and the second inside the toe of embankment. Fig. 3 shows the cross section of ground level with sand, water level and positions of pore pressure and acceleration transducers [6].

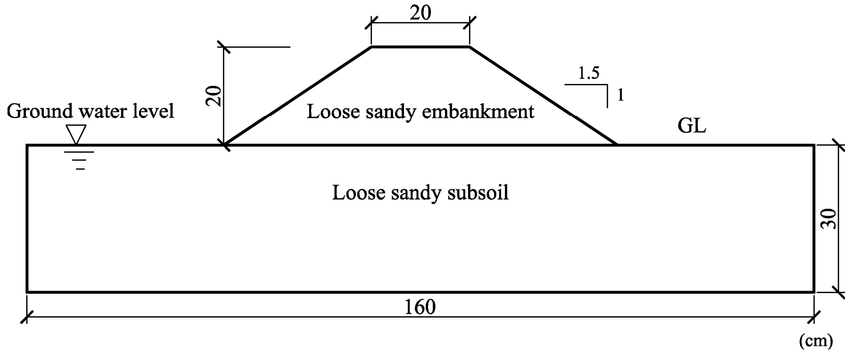


Fig. 2 *a* – Model one: loose sandy embankment and saturated loose sandy subsoil without any mitigation [6].

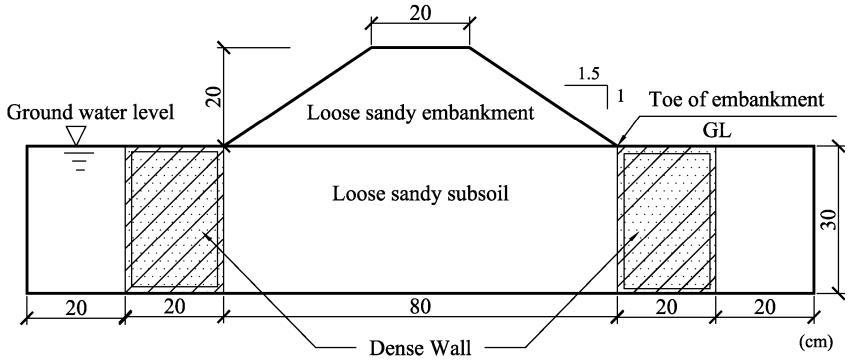


Fig. 2 *b* – Model two: saturated loose sandy subsoil with dense zone confined in geo-textile, installed outside the toe of loose sandy embankment [6].

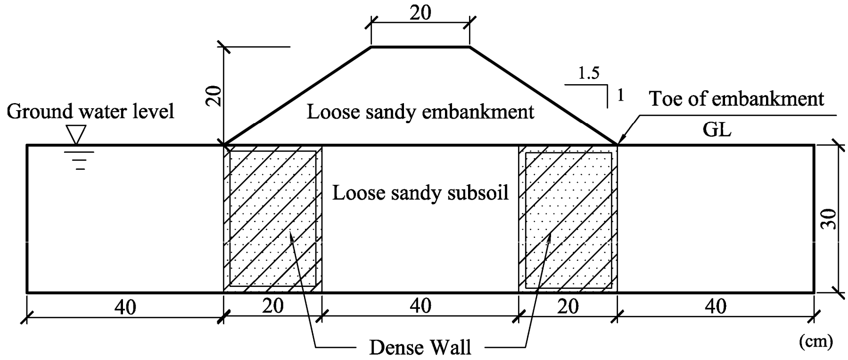


Fig. 2 *c* – Model three: saturated loose sandy subsoil with dense zone confined in geo-textile, installed inside the toe of loose sandy embankment [6].

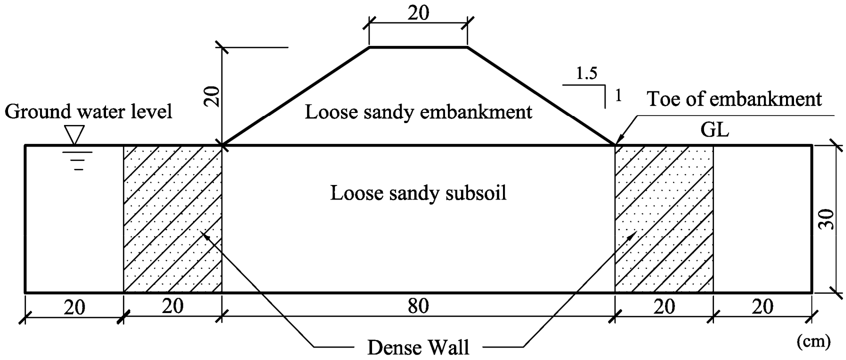


Fig. 2 *d* – Model of loose embankment and loose subsoil fully saturated with dense sandy wall 20 cm thick in subsoil on the outside the toe of embankment.

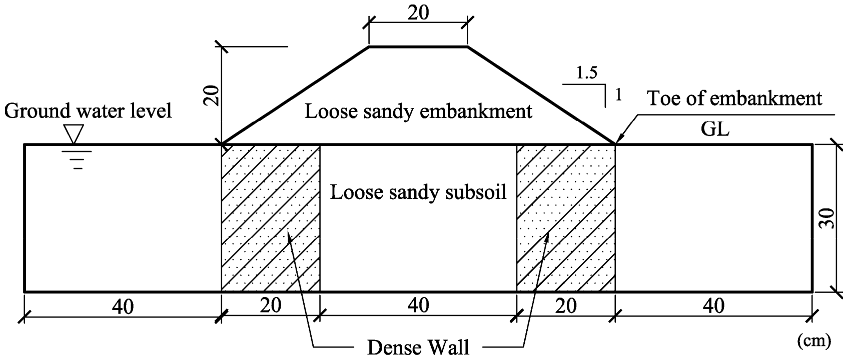


Fig. 2 *e* – Model of loose embankment and loose subsoil fully saturated with 20 cm thick dense sandy wall in subsoil inside of toe of embankment.

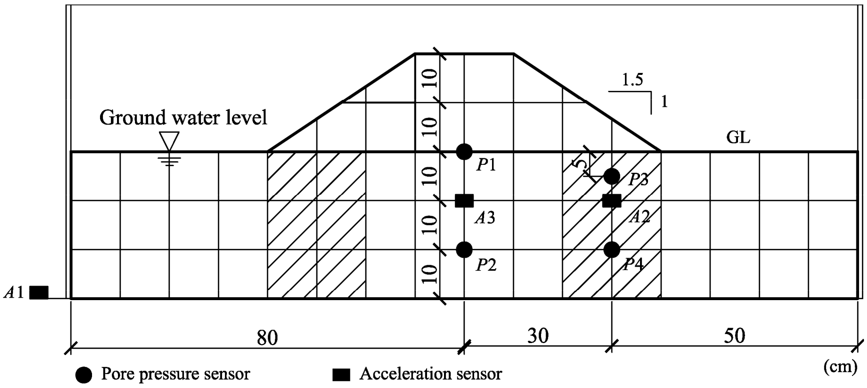


Fig. 3 – Position of transducer..

3. Results and Discussion

The shaking table tests were conducted at normal gravitational environment. The acrylic box was subjected to harmonic shaking by applying 1…3 Hz frequency with 0.5 gravitational level of acceleration. 750 N force has been applied on all models for a period of 12 s to smoothing, is accomplished by removing Fourier components with frequencies higher than $1/(n\Delta t)$, where n is the number of data points considered at a tome and Δt – the time spacing between two adjacent data points. In the present study, the cutoff frequency for pore pressure sensor data is fixed at 20 Hz. The number of data points considered at a time is 25 and spacing between two adjacent points is 0.002 s. The Band Pass Filter Acceleration recording is being made to eliminate noise above and below a specified frequency range (band pass filter) in the active dataplots.

The results of the experiments recorded through the pore pressure (P) and acceleration sensors (A) of the five models are illustrated in Tables 1 and 2 and corresponding graphs of pore pressure, acceleration and shear stress strain highlighted in Figs. 4 *a…e*, 5 *a…e* and 6 *a…e*, respectively. The intensity of stress applied in these experiments has played a main role in embankment stability analysis. The strength of ground directly depends on the placement of the dense walls and its sustainability. Structure without dense wall was more susceptible for seismic force applied and observed less time stability. Dense wall confided in the geo-textile has less susceptible for seismic force applied and more effective up on system stability compared to dense wall dose not confide in geo-textile. Among the all models the model in which the dense wall confide in geo-textile and placed inside the toe of embankment system shown best stability. The dense wall confined in geo-textile placed inside the embankment behaved like a structure with enough flexibility and hence possesses sufficient resistance against dynamic and seismic forces during shaking, which would reduce the magnitude of shear stress and resulting in a reduction the differential settlement of the embankment [5]. 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 [7]. Deformation during cyclic loading will depend on the density of the soil, the magnitude and duration of the cyclic loading, and amount of shear stress reversal [8]. Effective stress is not the unique 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 lets the understanding of soil volume change behavior [9]. Dense zone confided in geo-textile installed inside the toe of embankment will mitigate liquefaction.

In the present investigation model *c* has less affected by liquefaction compared to all models due to the position and characteristics of dense wall.

Table 1

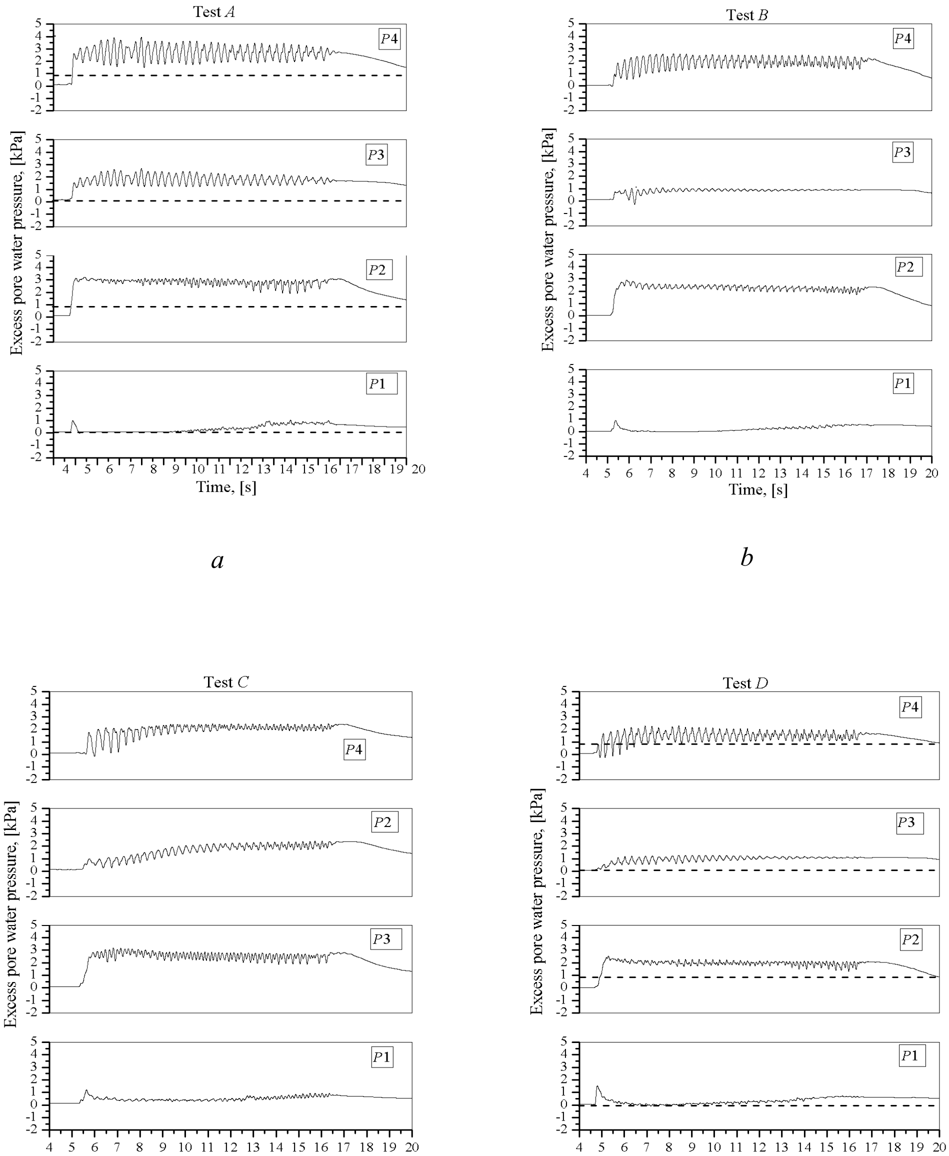
Results of Pore Water Pressures

Sensor No	Minimum pore water pressure, [kPa]					Maximum pore water pressure, [kPa]				
	Test *A*	Test *B*	Test *C*	Test *D*	Test *E*	Test *A*	Test *B*	Test *C*	Test *D*	Test *E*
*P*1	0	0	0	0	0.25	1.00	1.00	1.00	1.5	1.78
*P*2	1.95	0	0.2	1.2	1.07	3.25	2.95	2.4	2.54	3.05
*P*3	1.30	0.5	0	0.51	0.18	2.70	1.00	3.1	1.25	1.16
*P*4	1.45	0	0.1	0.28	0.37	3.95	2.55	2.5	2.23	2.66
	Average pore water pressure, [kPa]					Rate of increase of pore water pressure, [kPa]				
*P*1	0.5	0.50	0.50	0.75	1.02	0.1	5.75	3.35	12.8	6.78
*P*2	2.6	1.48	1.20	1.87	2.06	3.2	3.53	0.52	4.44	10.6
*P*3	1.5	0.75	1.55	0.88	0.67	1.2	0.66	4.50	0.74	0.66
*P*4	2.7	1.28	1.30	1.255	1.52	1.92	1.53	2.22	1.19	2.09
	Rate of dissipation of pore water pressure, [kPa]									
*P*1	0.13	0.02	0.34	0.03	0.14					
*P*2	0.75	0.67	0.39	0.45	0.52					
*P*3	0.18	0.20	0.53	0.26	0.24					
*P*4	0.39	0.50	0.34	0.23	0.51					

Table 2

Results of Accelerations

Sensor No	Predominant frequency, [Hz]					Amplification factor, [Hz]				
	Test *A*	Test *B*	Test *C*	Test *D*	Test *E*	Test *A*	Test *B*	Test *C*	Test *D*	Test *E*
*A*1	3.21	3.42	3.23	3.38	3.54	1.00	1.00	1.00	1	1
*A*2	3.07	3.3	3.22	3.21	3.55	0.24	0.98	2.40	0.5	0.84
*A*3	3.06	3.3	3.22	3.41	3.58	0.97	0.59	1.25	0.5	1.28
	Peak acceleration, [m/s^2]					Time of occurrence of peak acceleration, [Hz]				
*A*1	10.3	17.60	10.0	9.9	12.5	8.0	11.2	9.0	8.35	7.2
*A*2	2.5	17.30	24.0	4.9	10.5	13.2	16.3	15.1	15.85	6
*A*3	10.0	10.45	12.5	4.95	16	14.6	16.4	15.3	6.5	15.1



a *b*

c *d*

Fig. 4 – Time histories of excess pore water pressure.

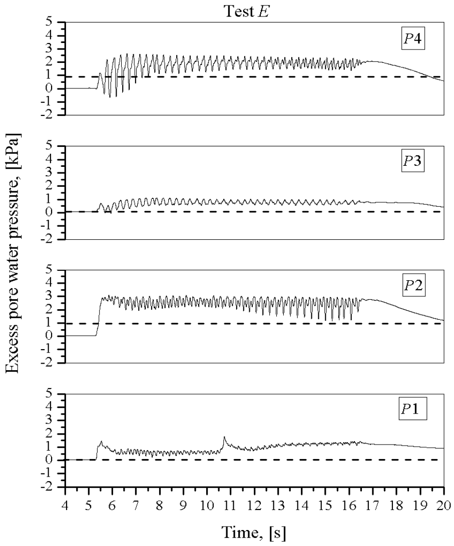
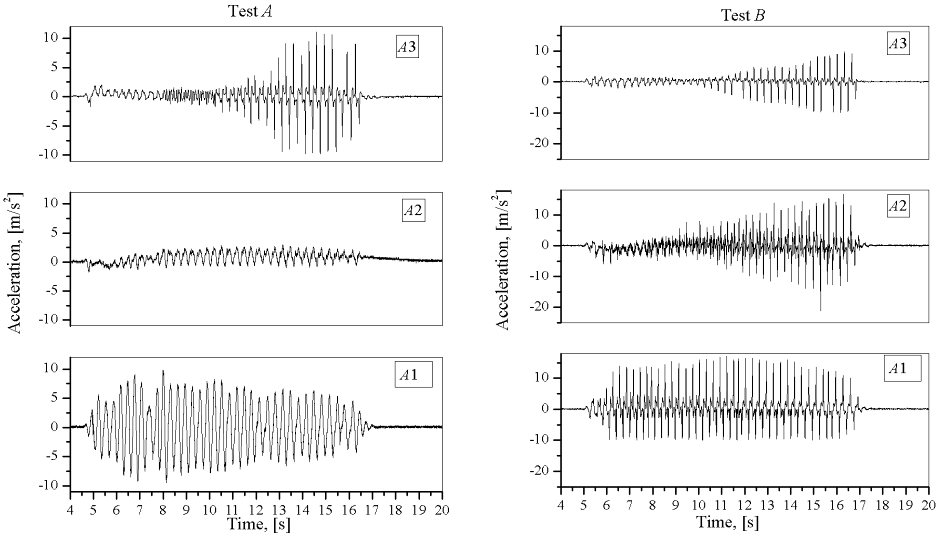
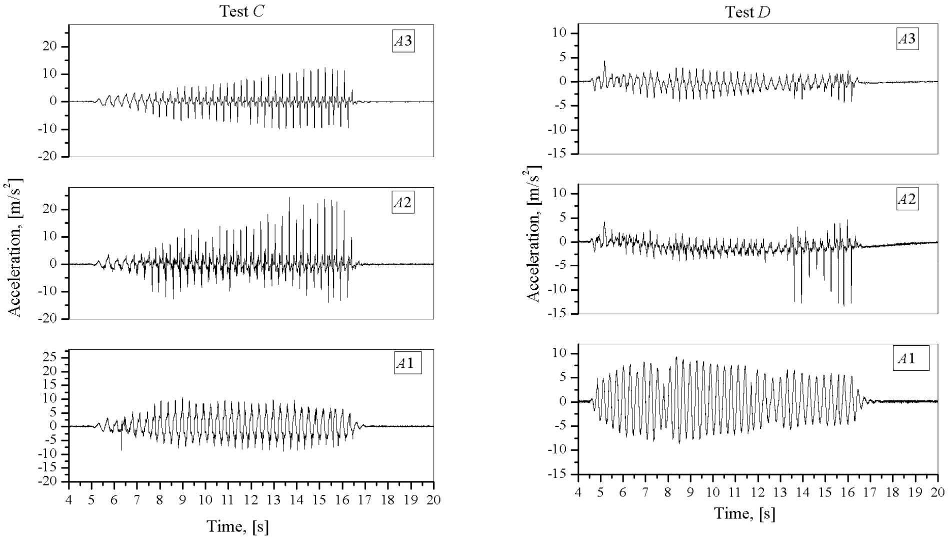


Fig. 4 *e* – Time histories of excess pore water pressure.

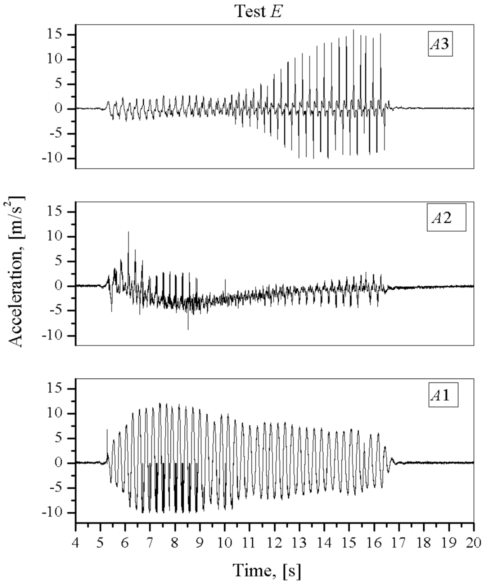


a *b*

Fig. 5 – Acceleration time history.

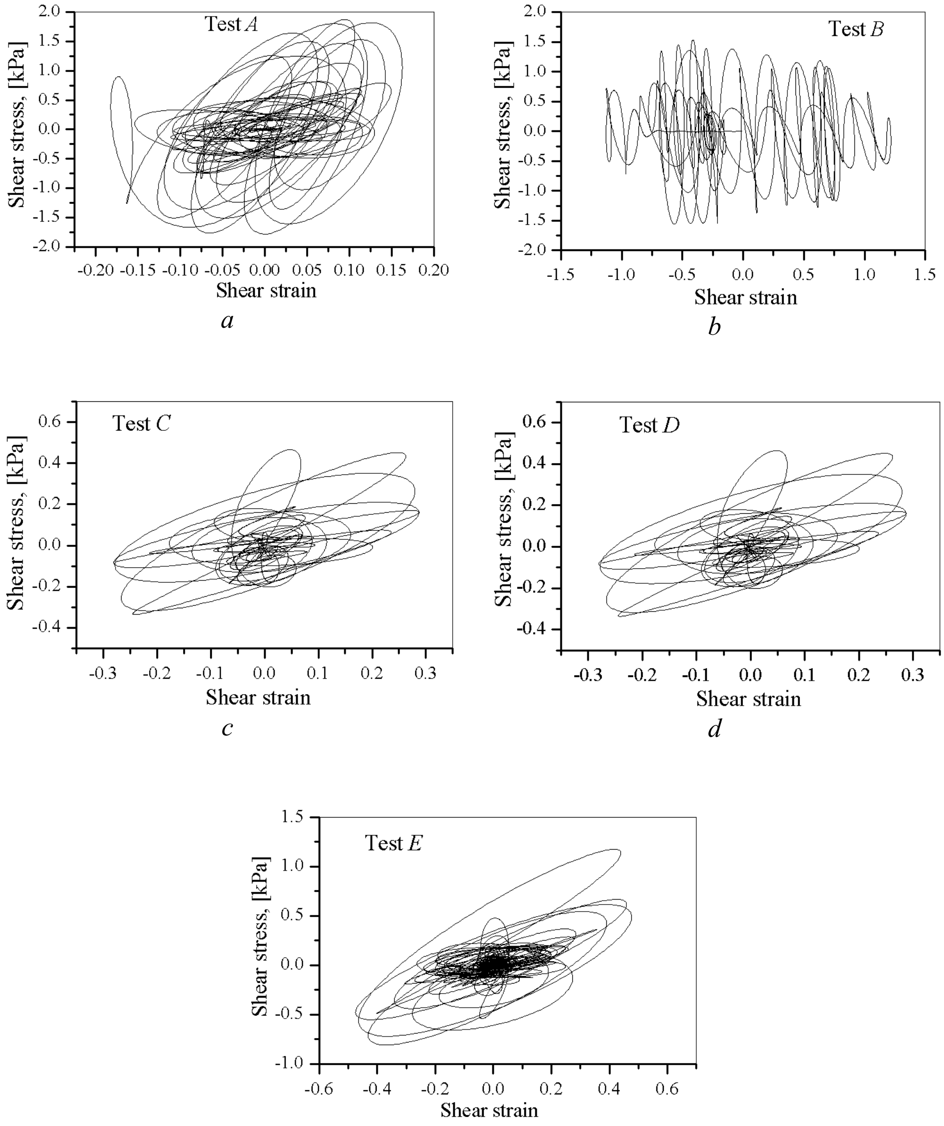


c *d*



e

Fig. 5 – Acceleration time history.



a *b* *c* *d* *e*

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

4. Conclusions

The embankment under non-linear stress is one of the complicate structures in design and analysis. Prevision of dense zone confined in geotextile inside the toe of the embankment decreases lateral force up on structure considerably; it increases stability of the ground, resulting a reduction of unsustainable deformation and differential settlement. It also reduces the creep deformation of foundation. Best way of increasing soft soil foundation bearing capacity is an economical improvement of the subsoil, in some part of soil foundation.

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ANALIZA STABILITĂŢII UNUI MODEL DE TERASAMENT

(Rezumat)

În analiza unui model de terasament supus unei forţe dinamice, folosirea masei vibrante este o modalitate ştiinţifică de evaluare a comportării seismice. Această cercetare este realizată pe terenuri de fundare nisipoase saturate. Rezultatele obţinute prin senzori ai presiunii apei din pori indică importanţa acesteia în declanşarea

lichefierii sau a stabilității sistemului. Aceste rezultate prezintă corelații directe ale deformației, tasării, intensității fenomenului de lichefiere şi timpului de stabilitate al sistemului cu rezistența şi alte caracteristici ale pământului. Una din cele mai economice metode de stabilizare a terenului de fundare este cea de îmbunătățire a caracteristicilor acestuia pe o zonă limitată.