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The Identification of Dynamic Behavior with Three Variables in Fine Grained Soil

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ABSTRACT

In this study, cyclic triaxial test experiments were made on samples prepared by the slurry deposition method and the effect of fines and clay content of the dynamic behavior of the soil was examined. From the obtained two variable graphs, the finding where dynamic behavior is controlled by three or more variables created the idea where they will be represented on three variable surfaces in stead of two variable graphs. As a result, in this study, the dynamic behavior of soils having different fines and clay content were examined and the effect of cyclic stress ratios CSR, fines and clay content on dynamic behavior. From the three variable graph results it can be understood that number of cycles required to reach ±2.5% double amplitude strain increases due to decrease in CSR and increase in fines and clay content.

Keywords: Fines content, Clay content, Cyclic stres ratio, Double amplitude strain.

INTRODUCTION

Studies regarding dynamic behaviors of soils and their results were especially made on liquefaction sandy soils after Niigata-Japan and Alaska-USA earthquakes in 1960. Few of the studies were made on silty sand. Together with 1975 Haicheng and 1976 Tangshan earthquakes, liquefaction of silts began to be researched. Especially in 1995 Hyogoken-Nanbu earthquake it was observed that silts became liquefacted. However the uncertainty about the liquefaction of silty soils still continues today. In the studies made in the past, the results stated that increasing silt content will increase liquefaction resistance, shear resistance will decrease or until the clay ratio reaches to a limit value the liquification resistance will decrease and the resistance will increase after that.

The liquefaction skills of the fine grained soils are usually determined according to the liquefaction criteria depending usually on physical properties. Initially Wang [1] determined liquefaction according to clay content, liquid limit and natural water content. Seed and Idriss [2] determined according to clay content, liquid limit and natural water content. Andrews and Martin [3] determined the liquefaction of a fine grained soil according to liquid limit and clay content values. However the difference of this criterion from the others, they also mentioned the situations where laboratory experiments are required, other than liquefaction evaluation of the soils. Perlea et al. [4] stated that initial liquefaction is rarely observed in soils with cohesion although important deformations occur, that the resistance against liquefaction increases with the increasing fines content, that the plasticity of the fines effect the liquification in silty clays or silts with clay, that the I_P values of the soil samples which have the lowest resistance are between 4 and 5 and that the I_P values are 14 in soils where no liquefaction is observed.

Niu [5] and Liang et al. [6] stated in their experiments that clay content is the main factor effecting the liquefaction property of silt and that the critical clay content is 9%. Sunitsakul [7] emphasized that silt content is important in soils with high sand content. From the cyclic triaxial test experiment results he determined that in contrary of sandy soils, silty soils are effected from loading frequency and magnitude. Bray and Sancio [8] determined the liquefaction criteria according to plasticity index, liquid limit and natural water content in their cyclic triaxial test experiment where effective consolidation pressure. Generally the dynamic behavior of the fine grained soils is either determined

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according to physical properties or the determination is made by the evaluation of the experiment results through two variable graphs.

MATERIAL PROPERTIES

The soil sample used in the experiments is taken from 3-4 m depth and is silt with 10% clay content. Before the experiment, the dry sample is mixed the sample with water. The weight of water is 10 times of the sample. The thin part of the suspension is taken by vacuum in order to obtain soil samples with different clay contents. Therefore soil samples with same mineralogy but different clay contents were obtained. The clay obtained from washing was added to the sample with 10% clay to obtain samples with 12%, 13%, 15% and 18% clay contents. Therefore eight different soil samples with different clay content were obtained without changing the mineralogical structure of the soils. Grain size distribution, specific gravity and consistency limits of the soil were measured initially and were shown in Table 1.

Tablo 1. *The physical properties of the mixtures used in testing*

Mixture	w_L	w_P	I_P	G_S	%C	%M	%S	%F
54%FC+4%C	27	-	-	2.73	4	50	46	54
51%FC+6%C	28	-	-	2.72	6	45	49	51
71%FC+9%C	31	-	-	2.69	9	62	29	71
67%FC+10%C	30	-	-	2.70	10	57	33	67
73%FC+12%C	32	-	-	2.69	12	61	27	73
63%FC+13%C	29	-	-	2.70	13	50	37	63
75%FC+15%C	29	19	9	2.71	15	60	25	75
82%FC+18%C	30	21	10	2.69	18	60	22	82

PREPARATION OF THE EXPERIMENT SAMPLES

When laboratory experiments will be made with disturbed samples, the most important question is "Which is the best method that represents the soil properties most properly?" Thre answer of this question is very important in means of the reliability of the experiments. When we look at the literature, dry pluviation, wet tamping, sedimenting in water and slurry deposition are methods used for sample preparation. In this study, slurry deposition method is selected as it is similar to the slurry deposition method in nature. This method is arranged according to the void ratio which was determined earlier. The void ratio of the samples in this study were taken between 0.75 and 0.80. Accordingly, distilled water was added to dry sample so as to increase the water content up to 1.5 times of the liquid limit. The sample was kept waiting for 24 hours so it will absorb the water completely and reaches equilibrium. The mixture was placed in a cell made of transparent plastic with 10cm inner diameter and 22cm height. At this stage it was kept waiting before loading for 24 hours under its own weight as it is very soft and starting from the next day loading started gradually so as to reach the foreseen consolidation pressure in 10 steps. Consolidation process with radial drainage finished in 1 week and then the sample was placed in the freezer and after the sample was kept waiting in the freezer for 4 hours it was placed into the experiment cell.

EXPERIMENT RESULTS

In this study, initially Monterey no.0 standard sand was used for the calibration of the cyclic triaxial test device where the experiments are conducted. This sand is uniform with light brown color and the D_{50} maximum and minimum void ratios are the same as the values in literature. The results of this study are in accordance with the results of the previous studies made with Monterey standard sand (Polito [9], Sancio [10], Silver et al [11]).

For the cyclic triaxial test, samples with 100mm diameters were prepared and experiment was conducted on cylindrical samples which were placed in the cyclic triaxial test cell. The failure criteria was selected as □2.5% double strain amplitude reached at N=15 cycles representing an earthquake of magnitude Mw= 7½ suggested by Seed and Idriss [2].

For the soils having different fines contents at different CSR values between Fig. 1 and 12, the relations between excess pore water pressure ratio - number of cycles and axial strain – number of cycles were given. These graphics can do for all of the experiments with different fine and clay content. At the end of the comparison, it was observed that excess pore water pressures increase with the CSR increase and the necessary number of cycles for 2.5% double amplitude strain decreases. It was also observed that excess pore water pressures decrease with the number of cycles required to reach 2.5% double amplitude strain with increasing fines content and the number of cycles required to reach 2.5% double amplitude strain increase with increasing fines content. It was also observed that excess pore water pressure ratios and strains decrease with increase of clay content.

Tablo 1. *The physical properties of the mixtures used in testing*

Mixture	w_L	w_P	I_P	G_S	%C	%M	%S	%F
54%FC+4%C	27	-	-	2.73	4	50	46	54
51%FC+6%C	28	-	-	2.72	6	45	49	51
71%FC+9%C	31	-	-	2.69	9	62	29	71
67%FC+10%C	30	-	-	2.70	10	57	33	67
73%FC+12%C	32	-	-	2.69	12	61	27	73
63%FC+13%C	29	-	-	2.70	13	50	37	63
75%FC+15%C	29	19	9	2.71	15	60	25	75
82%FC+18%C	30	21	10	2.69	18	60	22	82

As seen in the graphs, the finding where dynamic behavior is controlled by three or more variables created the idea where they will be represented on three variable surfaces instead of two variable graphs. In three variable graphs, the relation between fines content, CSR and number of cycles; clay content, CSR and number of cycles, and sand content, fines content and excess pore water pressure. These were multiplied by 100 so that CSR values were better observed.

In Fig. 13, the axis show the fines content, CSR and number of cycles required to reach 2.5% double amplitude strain. From the graph, it can be observed that number of cycles required to reach 2.5% double amplitude strain increases when CSR decreases and fines content increases. In Fig. 14, clay content, CSR and number of cycles required to reach 2.5% double amplitude strain is shown with N. From the graph, it can be observed that number of cycles required to reach 2.5% double amplitude strain increases when CSR decreases and clay content increases. In Fig. 15, sand content, fines content and excess pore water pressure value in 2.5% double amplitude strain. From the graph, it can be observed that excess pore water pressure value increases at the number of cycles required to reach 2.5% double amplitude strain when fines content decreases and sand content increases.

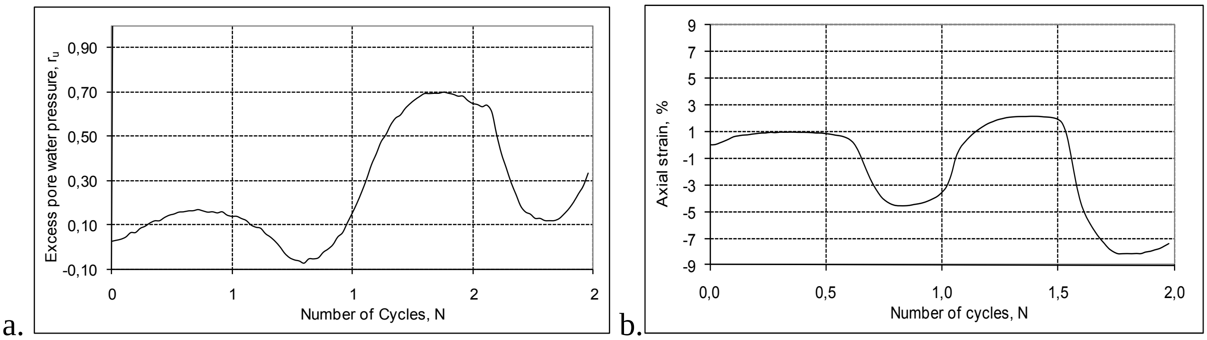

Figure1. *Test result of 54% Fines and 4% Clay containing samples for CSR=0.373 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

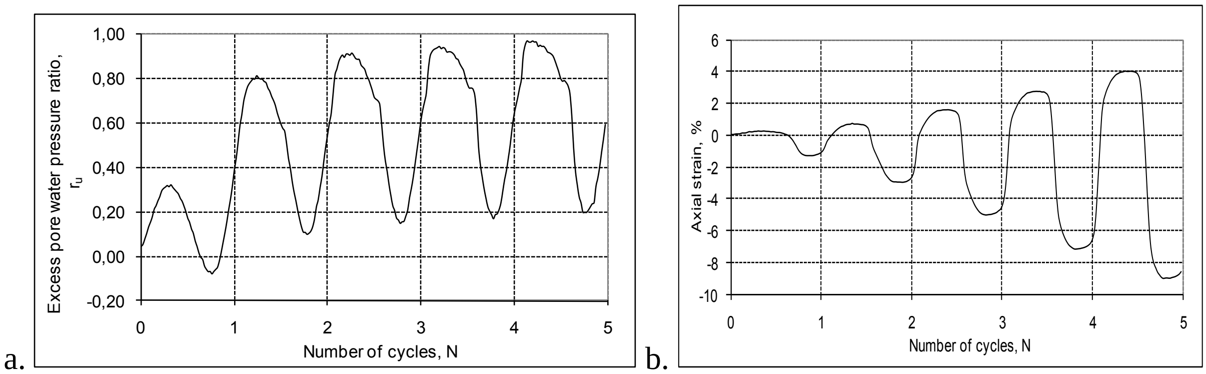

Figure2. *Test result of 54% Fines and 4% Clay containing samples for CSR=0.251 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

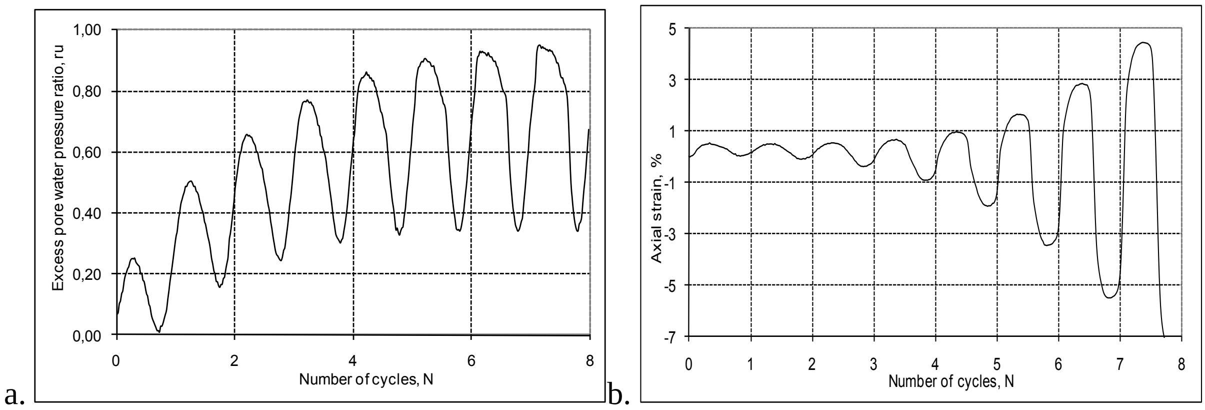

Figure3. *Test result of 54% Fines and 4% Clay containing samples for CSR=0.200 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

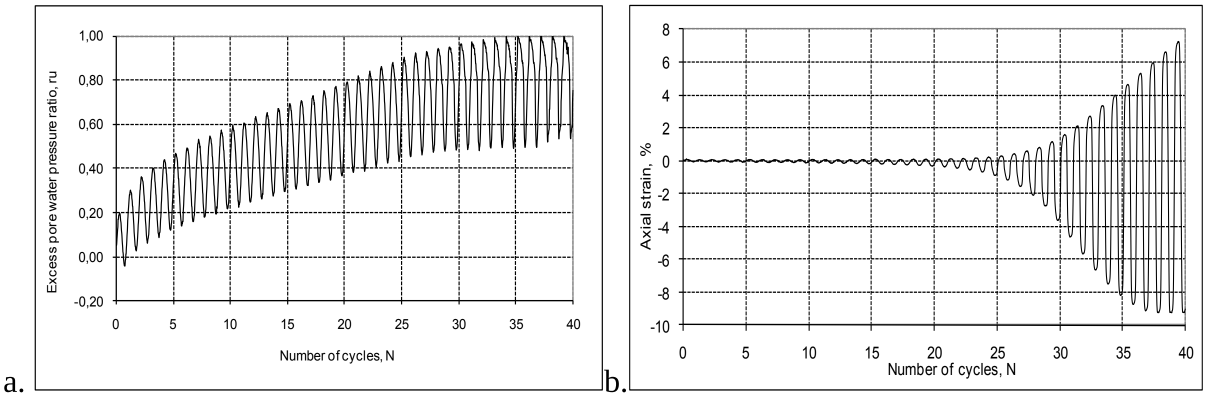

Figure4. *Test result of 54% Fines and 4% Clay containing samples for CSR=0.157 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

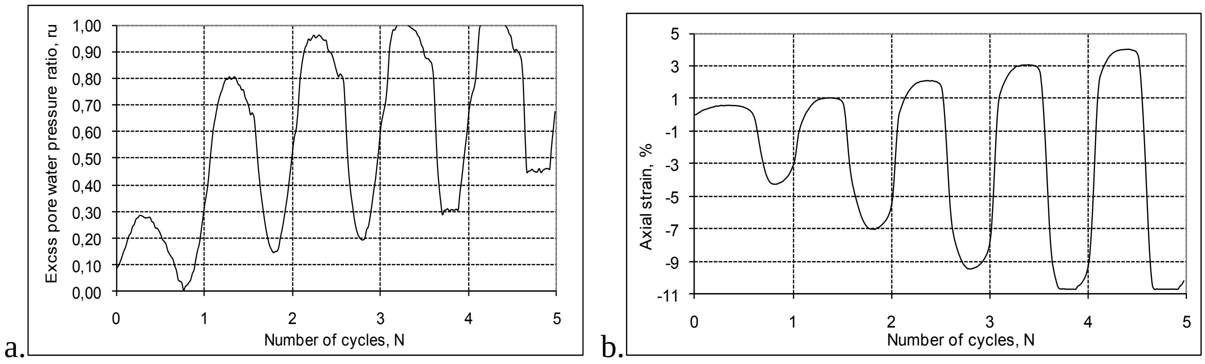

Figure5. *Test result of 51% Fines and 6% Clay containing samples for CSR=0.365 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

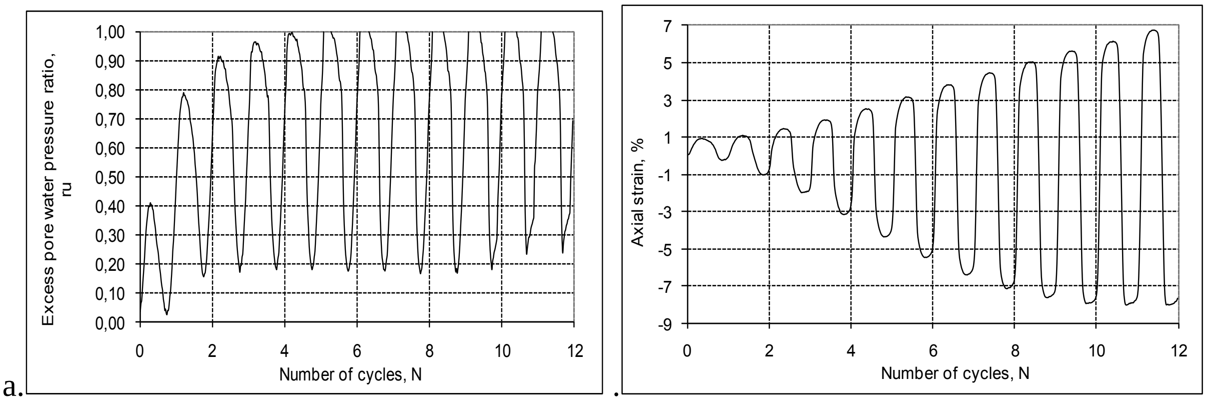

Figure6. *Test result of 51% Fines and 6% Clay containing samples for CSR=0.246 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

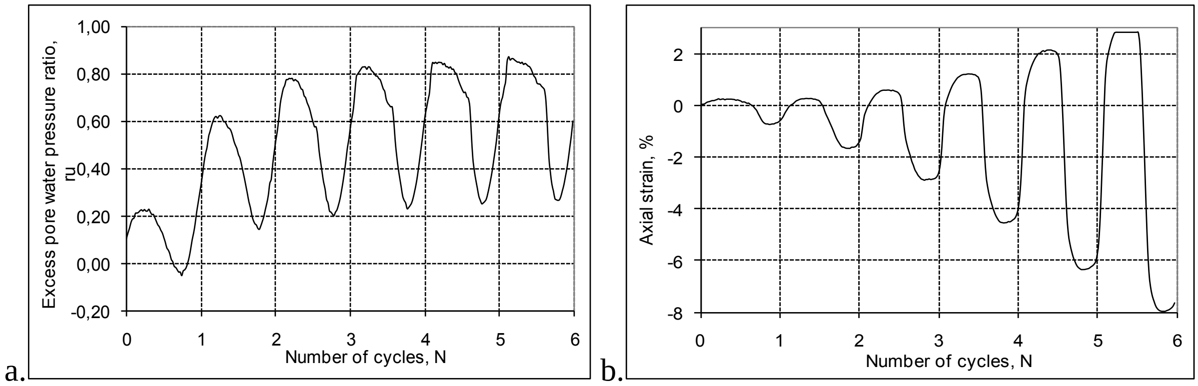

Figure7. *Test result of 51% Fines and 6% Clay containing samples for CSR=0.196 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

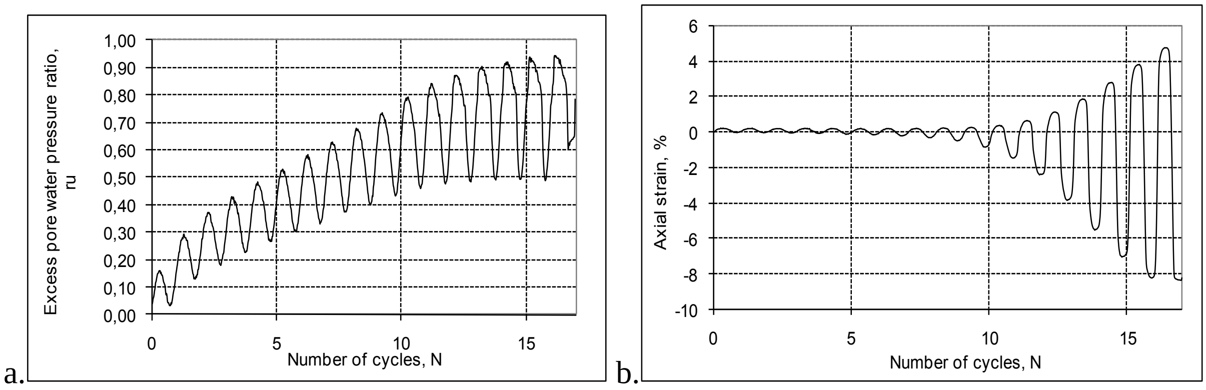

Figure8. *Test result of 51% Fines and 6% Clay containing samples for CSR=0.152 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

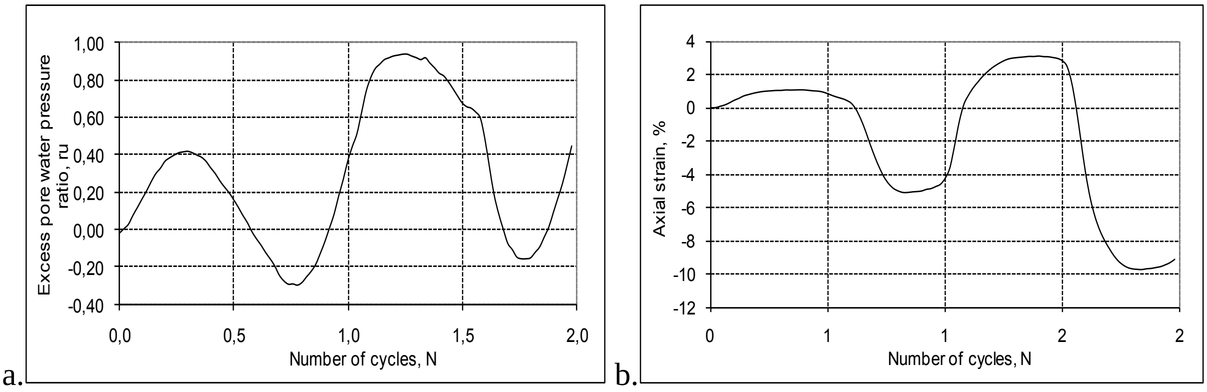

Figure9. *Test result of 71% Fines and 9% Clay containing samples for CSR=0.364 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

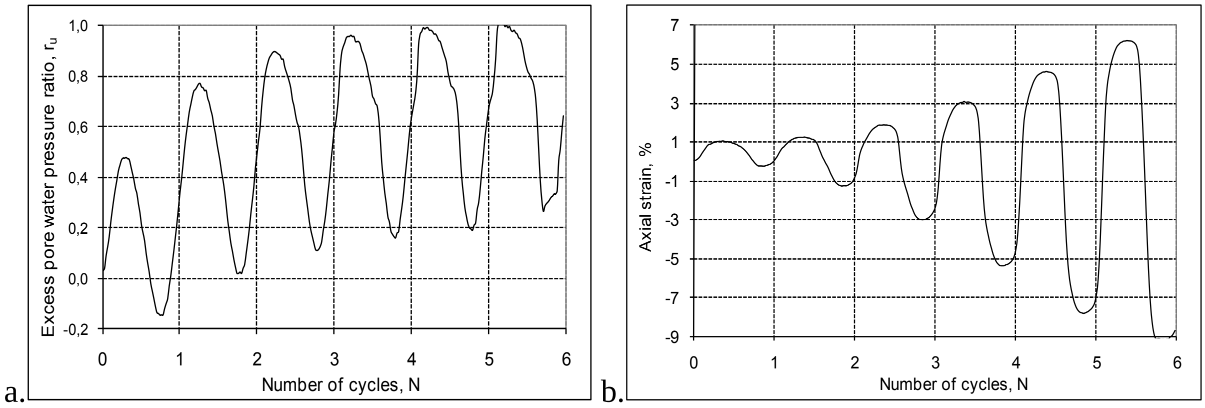

Figure10. *Test result of 71% Fines and 9% Clay containing samples for CSR=0.254 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

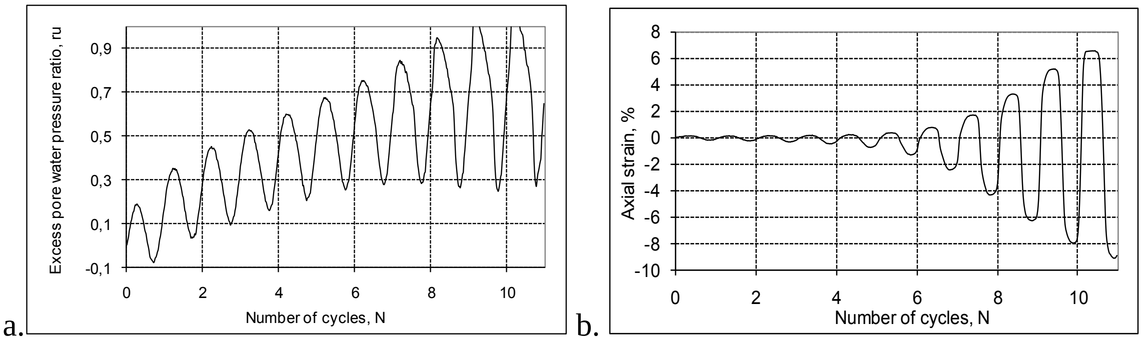

Figure11. *Test result of 71% Fines and 9% Clay containing samples for CSR=0.199 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

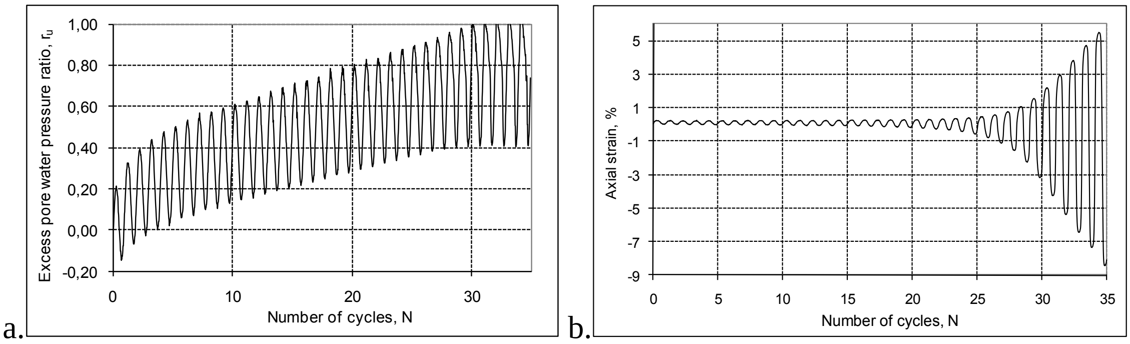

Figure12. *Test result of 71% Fines and 9% Clay containing samples for CSR=0.152 a. Excess pore water pressure ratio- Number of cycles, b.Axial strain- Number of cycles.*

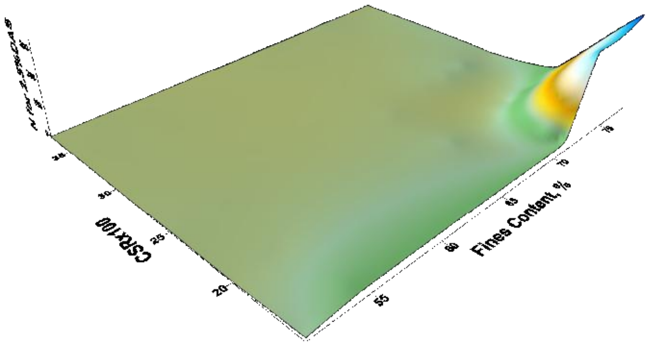

Figure13. *Fines content, CSR and number of cycles relationship*

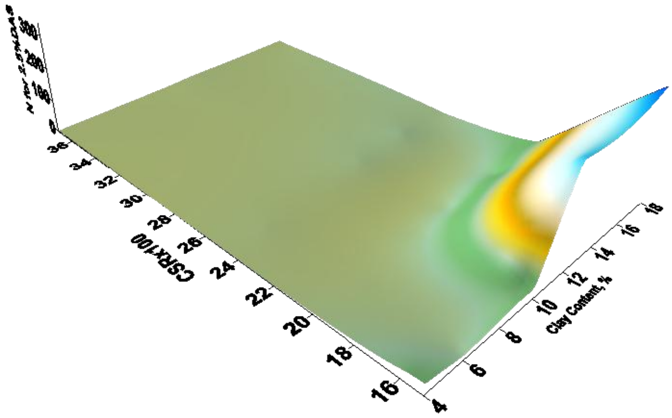

Figure14. *Clay content, CSR and number of cycles relationship*

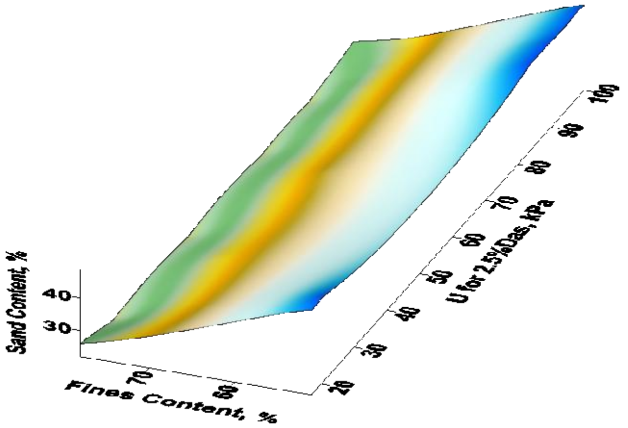

Figure14. *Sand content, Fines content and pore pressure relationship*

CONCLUSION

In this study, the dynamic behaviors of soils with different fines content and different clay content and the effect of CSR, fines and clay content on dynamic behavior was examined. In the three variable graphs, graphs representing fines content, clay content, CSR and number of cycles required to reach 2.5% double amplitude strain. From the obtained graphs, it was observed that number of cycles required to reach 2.5% double amplitude strain increases when CSR decreases and fines content increases, number of cycles required to reach 2.5% double amplitude strain increases when CSR decreases and clay content increases and excess pore water pressure value increases at the number of cycles required to reach 2.5% double amplitude strain when fines content decreases and sand content increases. In situations like dynamic behavior of soil which is effected from many factors, the usage of three variable graphs should be used instead of two variable graphs in order to ease the interpretation of the results.

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