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Centrifuge Model Tests for Investigation of Fiber Reinforced Soil Walls

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ABSTRACT

The centrifuge model tests were used to evaluate the geotechnical properties of fiber reinforced soil walls. The reduced-scale centrifuge models were built and the clay barrier was prepared using kaoline amended silty soil. The unreinforced soil barrier was found to lose their water-tightness and integrity at lower distortion levels compared to fiber reinforced soil barrier. The silty soil used in the centrifuge models, frequently considered as having negligible creep, did not ultimately found to prevent the development of time-dependent deformations. Thus, the significant time-dependent deformations could be occurred in geotechnical structure of fiber reinforced soil walls wall systems. The long-term behavior of reinforced soil walls structures was investigated under stress levels using centrifuge model.

Key words: Fiber, Centrifuge Model; Silty Soil, Geotechnical Properties.

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1. INTRODUCTION

In recent decade, researchers have been studied the structure of reinforced soil walls in earth retention projects (1-3). However, the main challenge of projects is the time-dependent behavior under sustained load. Therefore, development of time-dependent deformations in the geotechnical properties of reinforced soil walls under constant loading is necessary. The time-dependent behavior reinforced soil walls is a key factor for the design of reinforced soil structures with respect to the high deformations and even creep failure of reinforced soil (4, 5). Furthermore, the creep tests conducted on geotechnical specimens are identified to investigate the long-term behavior of a reinforced soil structure (6). The creep tests have been almost used to accelerate the preparation of time-dependent behavior. But, there are a little study about the interaction between the reinforcement and the confining soil affected on the long term deformation of reinforced soil walls (7-10). The reduced scale model used for reinforced soil walls in the centrifuge model is an alternative approach for investigation of interactions between soil and reinforcements (11). To investigate the long-term behavior of reinforced soil walls, the design of full-scale instrumented walls plays an important role. However, in most of reported studies, the full scale of walls did not consider for long-term behavior of reinforced soil walls. The full scaled walls provide the sufficient information about the significant deformations of reinforced soil walls over time (12-14). The strain rate in these walls, during a special time intervals can be predicted by conventional creep tests. But a little information is available on the time-dependent deformations of reinforced soil walls. Costa et al. (6) in geotextile-reinforced walls, a centrifuge test was used to evaluate time-dependent deformation changes. They detected that this going practice of penalizing the reinforcement ultimate tensile strength using considerable creep decrease factors may not be as overly stuffy as sometimes speculated. Allen and Bathurst (7) measured creep rates in full-scale walls and compared them to creep rates measured in-isolation. They found that reinforcement was initially exhibited the creep, with minor stress relaxation. However, in the long-term, there is a trend toward reinforcement stress relaxation. Furthermore, the long-term behavior observed in the full-scale walls indicates that the reinforcement loads are well below values required to cause creep rupture over the design life of the structures (15). In the present study, the centrifuge model tests were used to investigate time-dependent interaction between silty soil and fibers in reinforced soil walls. The long-term tests involved models monitored during time under constant acceleration to evaluate the time-dependent response of the reinforced soil walls under sustained loading. The centrifuge model was utilized to identify time-dependent interaction mechanisms between soil and reinforcement. The long-term behavior of reinforced soil walls structures was also investigated under stress levels using centrifuge model.

2. CENTRIFUGE MODEL

The centrifuge models were built using kaoline amended silty soil as backfill and interfacing fabrics as reinforcement zone. A transparent Plexiglas plate lined with a Mylar sheet was used as one of the side walls of the box (200 mm × 400 mm × 300 mm). The other walls of the strong box consisted of aluminum plates. The schematic diagram of the box is illustrated in Figure 1. The tests were carried out using centrifuge at Tehran University (Iran). The used instrument was beam type centrifuge with a suspending basket which consisted of suspending basket, centrifuge boom, adjustable counterweight, fluids rotary joint, electrical slip ring, driver system, aerodynamic covering, and automatic balancing system. There was relative density of 60% in the zoon of reinforces soil and of 100% in the foundation layer. Models C1 to C4 involved decreased scale walls subjected to stable accelerations elected to be alike to 25, 40, 60 and 80% of the g-level tests.

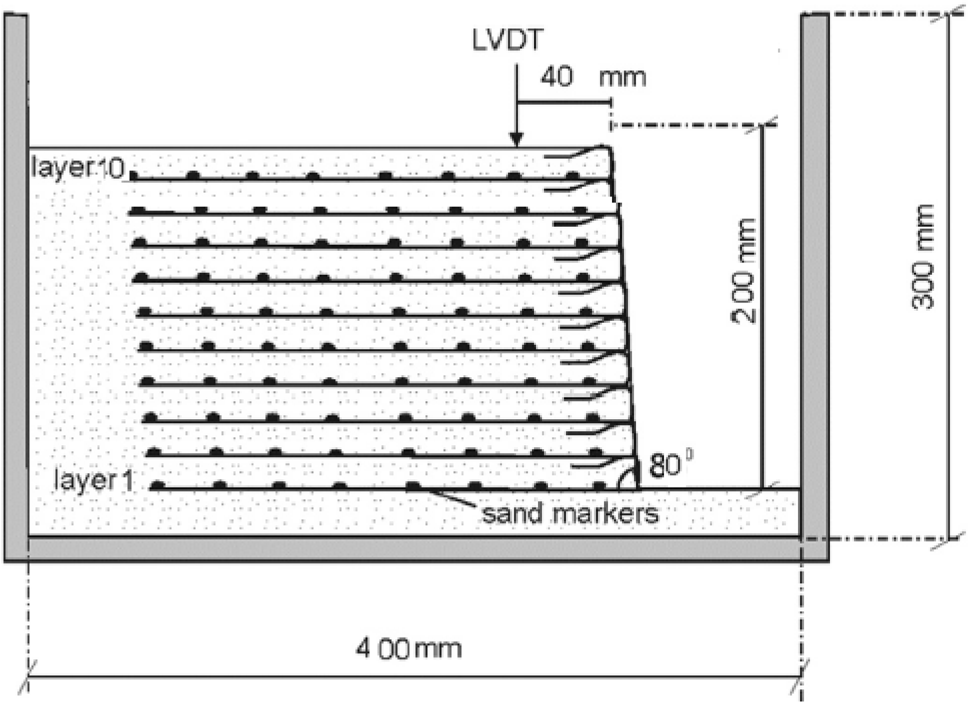

Figure 1. Schematic of centrifuge model (6)

3. MATERIALS

The blend of kaolin and sand in the ratio of 4:1 by dry weight was used for barrier material. Polyester fibers (PET) with equivalent diameter of 40 μm and elongation strain of 19.25% strain were used as discrete fiber reinforcement. In the case of fiber reinforced soil barriers, fibers were hand-mixed at desired fiber content and length with the soil after adding with half of the desired amount of water. The fiber used in the present study is illustrated in Figure 2. The properties of used PET and kaolin are listed in Table 1 and Table 2.

Figure 2. Polyester fibers in this work

Table 1. Properties of used PET fibers

D (μm)	*SG (g/cm³)*	*E (GPa)*	*UTS (MPa)*
49	1.12	19.25	480

Table 2. Properties of used kaolin

CEC (mgEq/100 g)	*pH_{PZC}*	*SSA (m²/g)*	*Metal concentrations (mg/kg)*			
			Fe	Zn	Pb	Cd
16.50	4.60	16.20	1180.0	75.0	16.1	9.8

4. RESULTS

The tensile tests with the tensile tests with a mean final tensile stability of 0.033 kN/m in the cross-machine direction is illustrated in Figure 3. The applied load levels were 25%, 40%, 60%, and 80% of the material ultimate tensile strength. As shown, a comparatively sharp increase in strain rate was observed by the increasing applied load levels. The conventional creep tests conducted without soil confinement in accordance with ASTM D5262 (2012) are presented in Figure 4. Tests were repeated three time for the highest load level to improve the characterization of the creep failure conditions. The samples loaded to 80% of its telic tensile strength displayed a time to crawl failure ranging from 1.0 to 2.5 h.

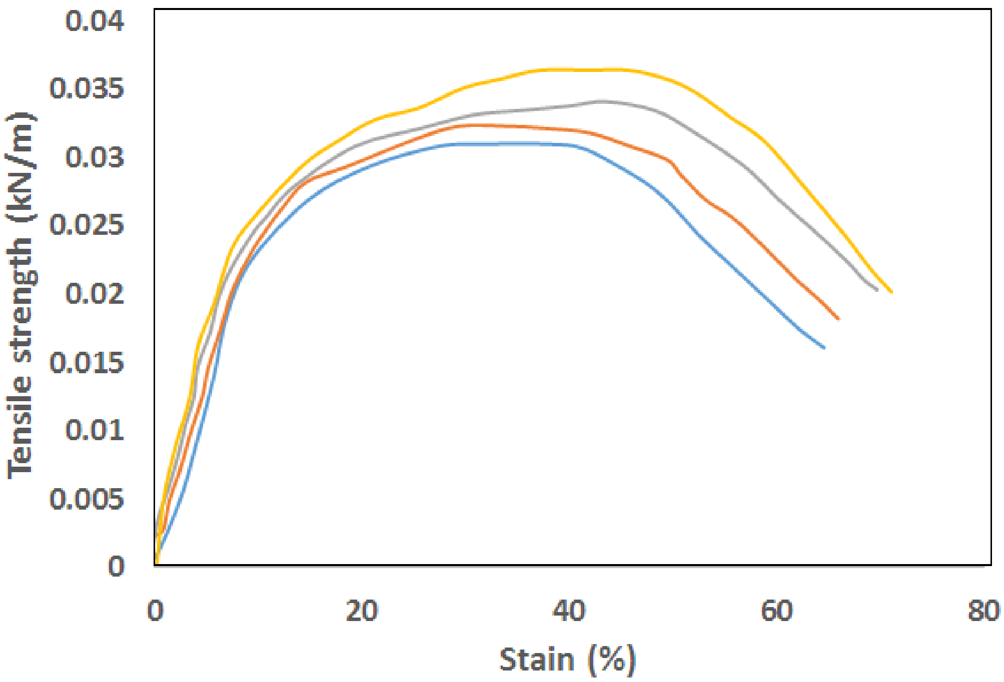

Figure 3. Tensile tests conducted in the cross-machine direction

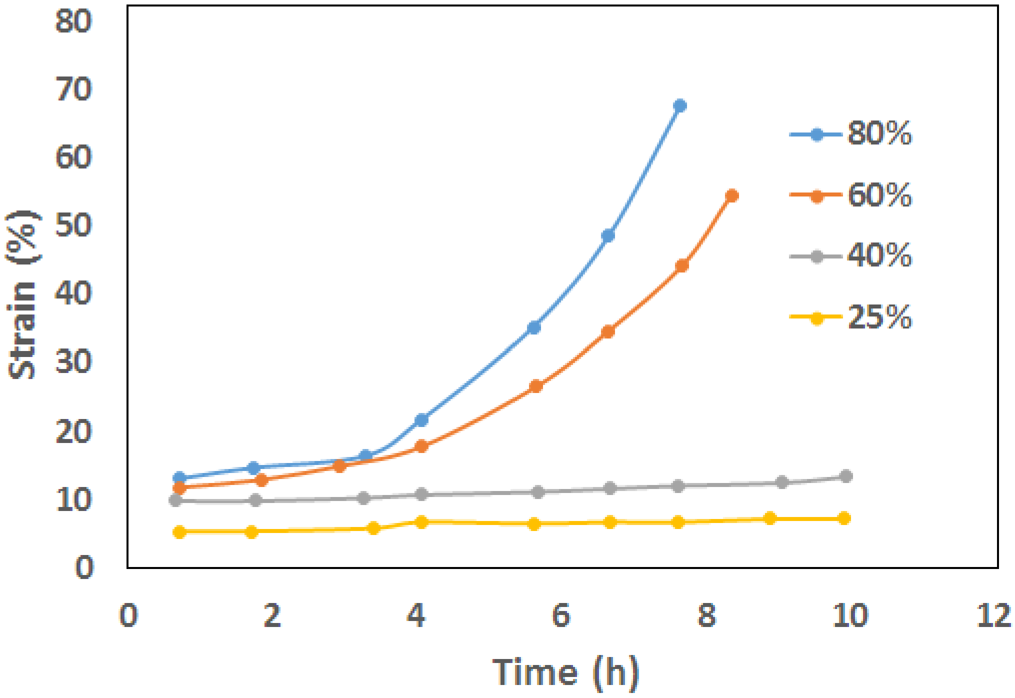

Figure 4. Conventional creep test of samples

Figure 5 shows the time-dependent settlements established at the top of walls built using PET support. The long-term conduct of the walls under stable centrifugal haste was evaluated within 10 h. The time in the figures was the passed time after having reached the objective acceleration in tests. As shown in the Figure 5, time-dependent settlements were observed to occur in all the tests in this series, by increasing settlement rate for increasing acceleration values. The obtained results revealed that the time-dependent specs of the reinforcements affected the overall time-dependent efficiency of the reinforced soil walls.

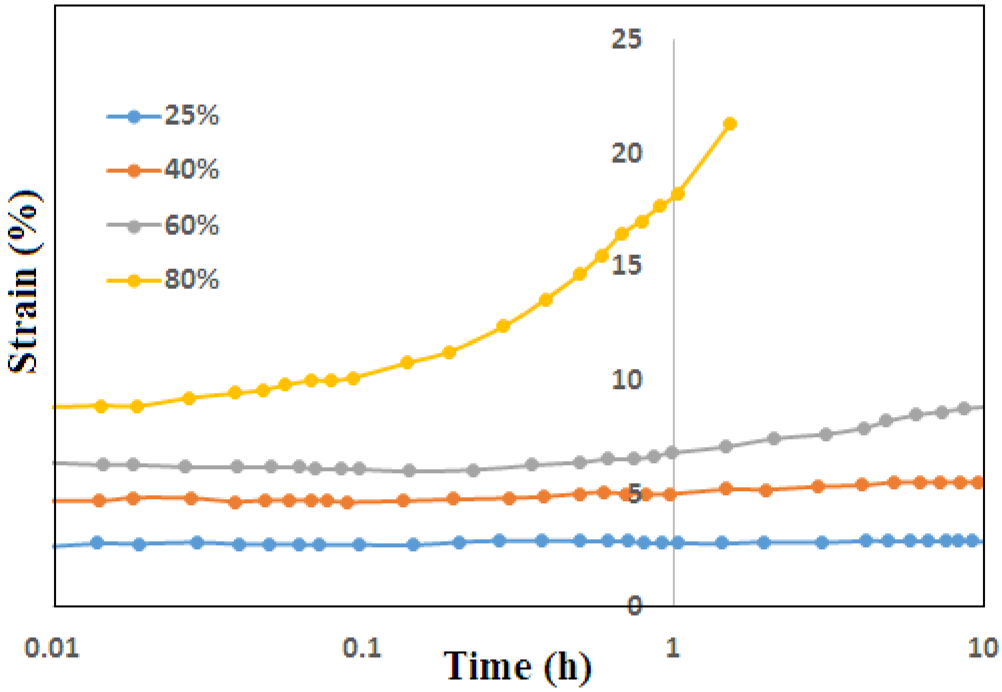

Figure 5. Time-dependent settlements obtained at the crest of models

The reinforcement strains obtained in models C4 for Long-term" tests are illustrated in Figure 6. The tests were conducted under target centrifuge acceleration (N) values corresponding to 80% of the g-level at failure. Figure 6 show the time histories of strains obtained from unconfined creep tests conducted using the same geotextile. As previously mentioned, the scaling factor for time in creep evaluations of centrifuge testing was considered equal one. The magnitude of initial strains for the different layers was in the range of 7.8% to 9.8%. Similar range (7.9-9.7%) is observed for the initial strains for different unconfined tests. The creep strain rates for different geotextile reported in the technical literature are illustrated in Figure 7. The curves were obtained using conventional creep tests results in which each curve correspond to a different geotextile specimen subjected to constant load. As shown, the creep strain rates of the geotextile simulants used as reinforcement in the centrifuge models are consistent with those reported in the literature for geotextile used in reinforced soil structures.

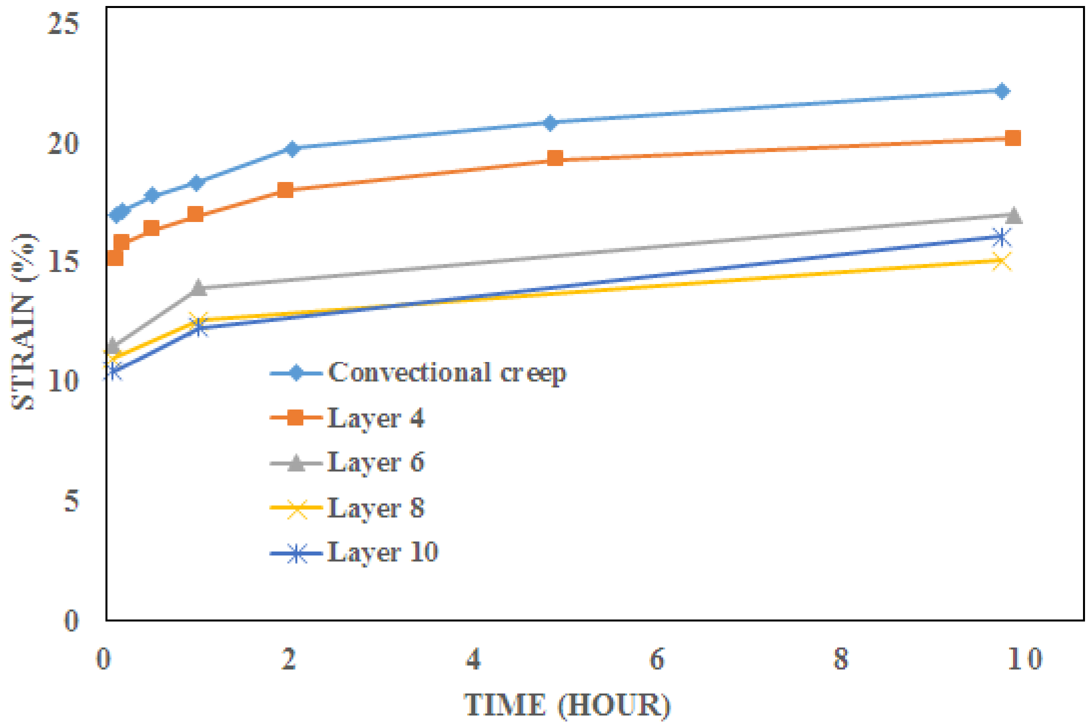

Figure 6. Time-dependent strains from model C4

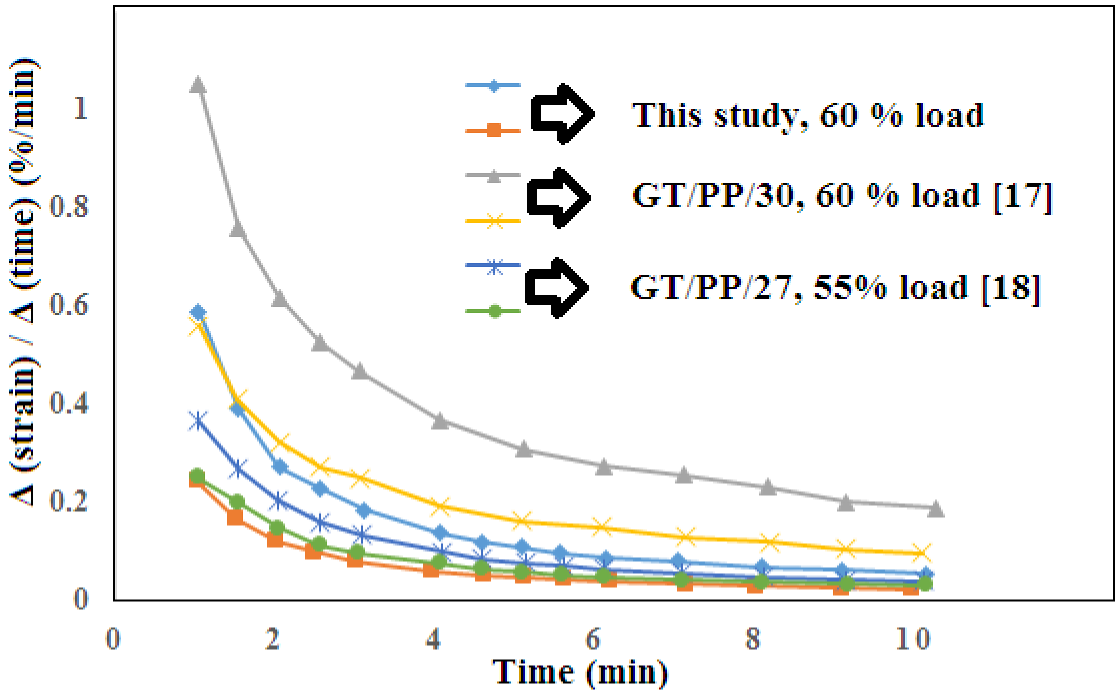

Figure 7. Creep strain rate for geotextile reported in literature, (GT: geotextile, and PP: polypropylene (16, 17))

5. CONCLUSION

The results of the centrifuge tests indicated that the magnitude of time-dependent creep strains developed in the centrifuge models, was similar to that obtained from conventional creep tests. This behavior could be attributed to comparatively high levels of soil shear stress. The comparison of the creep strain rates of soil and reinforcement showed the comparatively low tension levels in the reinforcement but comparatively high stress levels in the soil. Similar trend is obtained by Allen and Bathurst (18). The soil creep results presented in the Figure 5 indicated that the strain rates showed a linear logarithmic trend. The Long-term tests results indicated the time-dependent deformations at the crest of the long-term models and time-dependent strains in the reinforcements. The time-dependent strain rates in centrifuge models were found to be similar to the time-dependent strain rates in unconfined samples from conventional creep. The centrifuge results indicated that the creep behavior of geotextiles may even lead to creep failure of geosynthetic reinforced walls.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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