

# Centrifuge model tests for investigation of fiber reinforced soil walls

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## Abstract

In this study, 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 barriers. The silty soil used in the centrifuge models, frequently considered as having negligible creep, was ultimately found not to prevent the development of time-dependent deformations. The obtained results revealed the significant time-dependent deformations could be occurred in geotechnical structure of fiber reinforced soil walls wall systems.

## 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 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 tested in isolation are identified to investigate the long-term behavior of a reinforced soil structure [6]. The creep tests were almost used to accelerate the preparation of time-dependent behavior. But, the interaction between the reinforcement and the confining soil affected on the long term deformation of reinforced soil walls [7-10].

Using of reduced scale models 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. [15] were used centrifuge tests to evaluate the time dependent deformations in geotextile-reinforced soil walls. They indicated that the current practice of penalizing the reinforcement ultimate tensile strength using significant creep reduction factors may not be as overly conservative as sometimes speculated. Allen and Bathurst [7] measured creep rates in full-scale walls and compares them

to creep rates measured in-isolation. They found that reinforcement was initially exhibiting creep, with minor stress relaxation. However, in the long-term, there was a trend toward reinforcement stress relaxation. Furthermore, the long-term behavior observed in the full-scale walls indicated that the reinforcement loads were well below values required to cause creep rupture over the design life of the structures [16].

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.

## 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). There was relative density of 60% in the reinforced soil zone and of 100% in the foundation layer.

Models C1 to C4 involved reduced scale walls subjected to constant accelerations selected to be equal to 25, 40, 60 and 80% of the g-level tests.

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## 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  $\mu\text{m}$  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 tensile tests with an average ultimate tensile strength 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.

The conventional creep tests conducted without soil confinement in accordance with ASTM D5262 (2012) are presented in figure 4. The specimens loaded to 80% of its ultimate tensile strength showed a time to creep failure ranging from 1.0 to 2.5 h.

Figure 5 shows the time-dependent settlements obtained at the top of walls constructed using PET reinforcement. The long-term behavior of the walls under constant centrifugal acceleration was evaluated within 10 h. The time in the figures was the time elapsed after having reached the target acceleration in each test. 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 characteristics of the reinforcements affected the overall time-dependent performance of the reinforced soil walls.

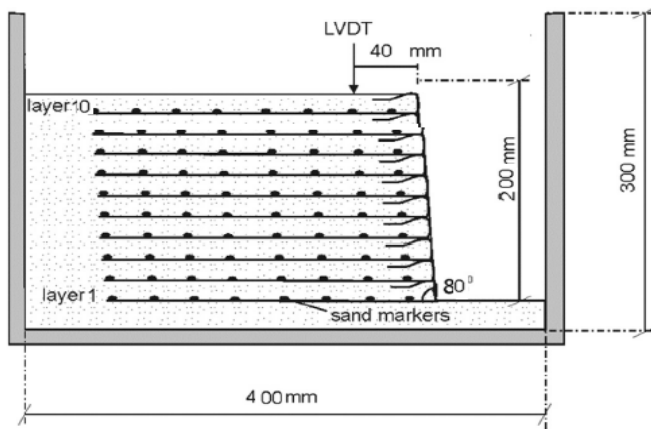


Figure 1. Schematic of centrifuge model



Figure 2. Polyester fibers in this work

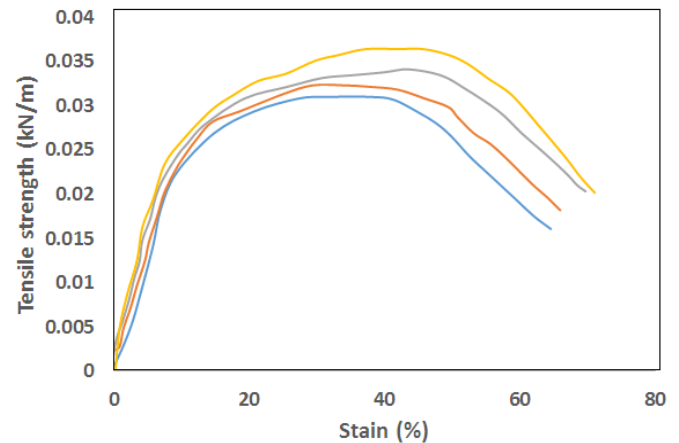


Figure 3. Tensile tests conducted in the cross-machine direction

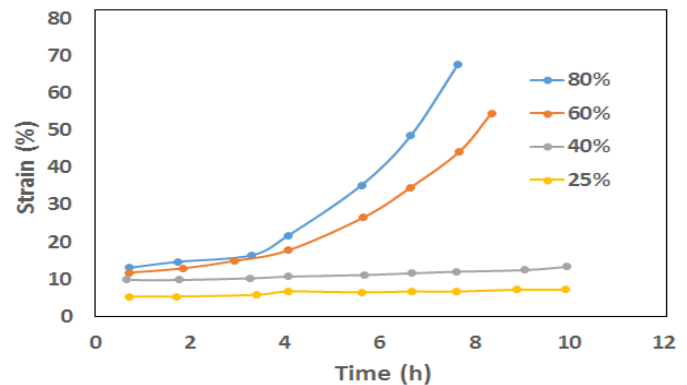


Figure 4. Conventional creep test of samples

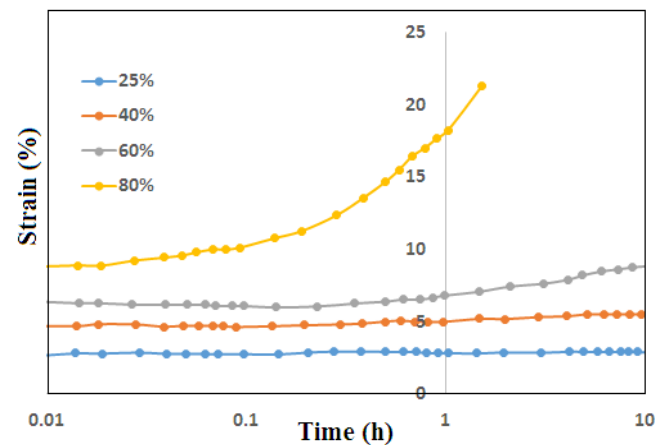


Figure 5. Time-dependent settlements obtained at the crest of models

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.

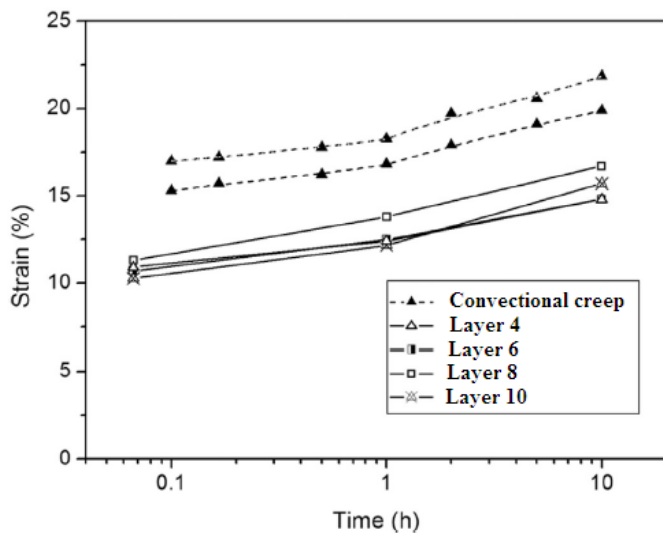


Figure 6. Time-dependent strains from model C4

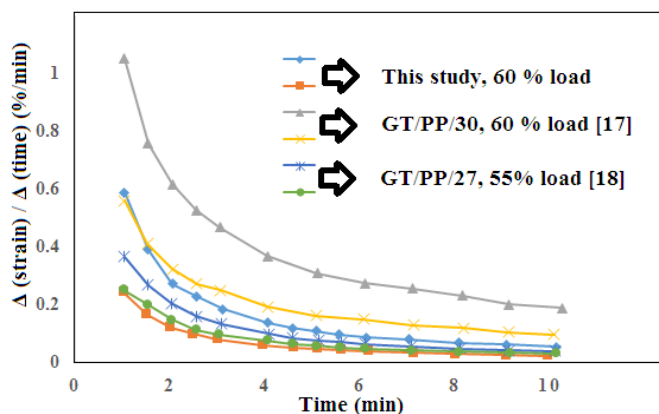


Figure 7. Creep strain rate for geotextile reported in literature, (GT: geotextile, and PP: polypropylene)

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.

## Conclusion

In this research, centrifuge tests were used to evaluate the time dependent deformations in fiber reinforced soil walls. The centrifuge model was tested built using PET fibers as reinforcement elements and kaoline amended silty soil as backfill material. The models were subjected to a constant acceleration and their time-dependent deformations were carried out in long term tests.

Long-term tests 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.

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