# TRANSMISSIVITY BEHAVIOR OF SHREDDED SCRAP TIRE DRAINAGE LAYER IN LANDFILL COVER SYSTEM*

**Krishna R. Reddy†, Aravind Marella and Prasanth Ala**
University of Illinois at Chicago, Department of Civil and Materials Engineering
842 West Taylor Street, Chicago, Illinois, USA

**ABSTRACT:** A three-layer cover system consisting of a barrier layer, drainage layer, and a cover layer is commonly used to cap abandoned landfills, and it was hypothesized that shredded scrap tires could serve as an effective drainage media for such systems. To evaluate the transmissivity (flow capacity per unit cross sectional area in the lateral direction) of a shredded scrap tire drainage layer in a landfill cover system, laboratory transmissivity tests were performed using two different size tire shreds, large (TS1) and small (TS2), that were subjected to simulated landfill cover conditions. The effects of normal stress and the use of a geotextile at the top, bottom, or at both interfaces of the three layer-simulated cover system were investigated. The transmissivity was high and remained almost the same in the tests when the geotextile was used at both the interfaces. In the case when there was no geotextile at the top interface, however, the amount of soil migration into the voids of the tire shreds from the cover soil layer was high. The absence of the geotextile at the bottom interface had a minimal effect on the transmissivity, but the absence of the geotextile at this interface may cause the protrusion of shredded scrap tires into the barrier layer. Based on the results and observations in this study, the presence of a geotextile at the interfaces, irrespective of the tire shred size and stress conditions, prevented a reduction in the performance of the drainage layer.

**KEYWORDS:** Scrap tires, recycling, landfills, cover, drainage

## INTRODUCTION

Transmissivity refers to the drainage capacity in the lateral direction, and this hydrologic property must be evaluated for tire shreds before they can be considered for use as the drainage layer in a landfill cover system, as shown in Figure 1. The transmissivity is measured in terms of the flow rate per unit cross sectional area, $Q_T$. The main source of water that flows through the drainage layer is the water that infiltrates through the overlying cover soil layer from precipitation. Soil particles from the overlying cover soil layer may migrate along with the infiltrating water into the void spaces of the drainage layer, partially clogging the drainage layer. Marella (2002) recently evaluated this type of clogging. In addition, as a result of water draining in the lateral direction, some soil erosion may occur from the soil layers on either side of the drainage layer, so, in the present study, this type of erosion was investigated.

The main objective of this laboratory research was to assess the transmissivity of different size tire shreds, with and without the presence of a geotextile, and to study the migration of soil particles into the void spaces of the tire shreds from either the soil layer above

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† Corresponding author, e-mail: kreddy@uic.edu

or below the drainage layer. Four series of experiments were conducted, with each series consisting of four separate tests, to determine the transmissivity of the tire shred drainage layer under various landfill cover system configurations and conditions. In some experiments, a geotextile was used at the different interfaces, above and below the drainage layer, to minimize soil clogging and erosion.

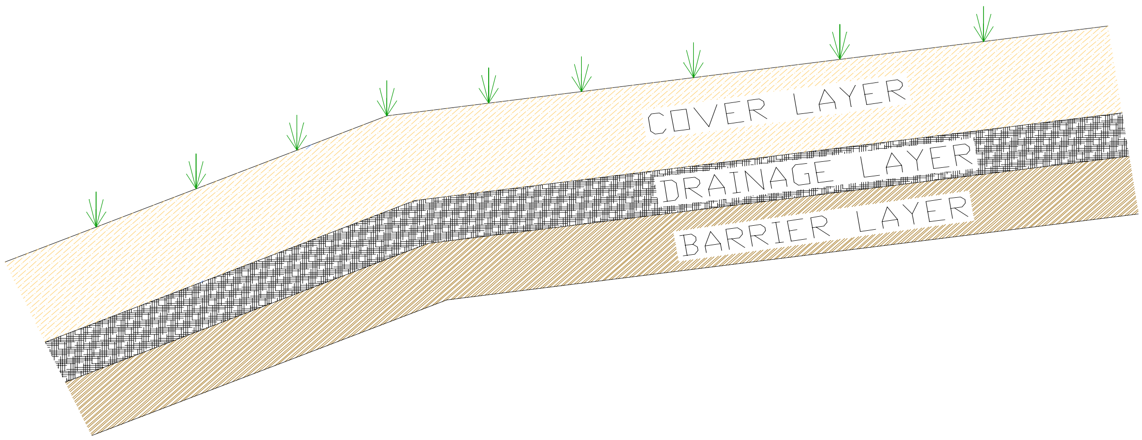


**Figure 1. Typical cover system for abandoned landfills**

## EXPERIMENTAL METHODOLOGY

Figure 2 shows the schematic of the test setup that was used in this study. The test setup consisted of a rectangular-shaped plexiglass open-top box with the dimensions 24" x 10"x 14" (L x W x H). This box had two openings, one inlet and one outlet, which were connected to control valves. The two openings were located at a height of 8 inches from the base of the test setup. The box was divided into three compartments using two perforated plates that were wrapped with a geotextile and placed 16 inches apart. These plates were used as screens to prevent soil from eroding into the inflow (reservoir-1) and outflow (reservoir-2) compartments and to retain the simulated landfill cover system. The simulated landfill cover system was located in the center compartment, and various configurations were used for the different experiments, but, as seen in Figure 2, the main components of the system included the cover and barrier soil layers, which were placed above and below the drainage layer, respectively. The inlet valve was connected to a water source that provided a constant inflow, and the outflow, which gave the transmissivity value, was measured using a flow meter.

Two types of tire shreds, named as TS1 and TS2 with average sizes of 6.5 inches and 3.5 inches, respectively, were used as the drainage material in this study, and the size distribution, unit weight, and hydraulic conductivity of these tire shreds were provided in Marella (2002). A silty clay soil obtained from a landfill site in Carlinville, Illinois, was used to simulate both cover soil layer and barrier soil layer, and the specific gravity, Atterberg limits, grain size distribution, hydraulic conductivity, and the moisture-density relationship of this soil were also given in Marella (2002). In some of the experiments, an 8 oz/yd$^2$ nonwoven geotextile was used at the interface between the tire shred drainage layer and the cover soil layer and/or at the interface between the tire shred drainage layer and the barrier soil layer, and the purpose of the geotextile was to reduce the clogging potential of the tire shreds and to maintain a high transmissivity for long-term conditions.

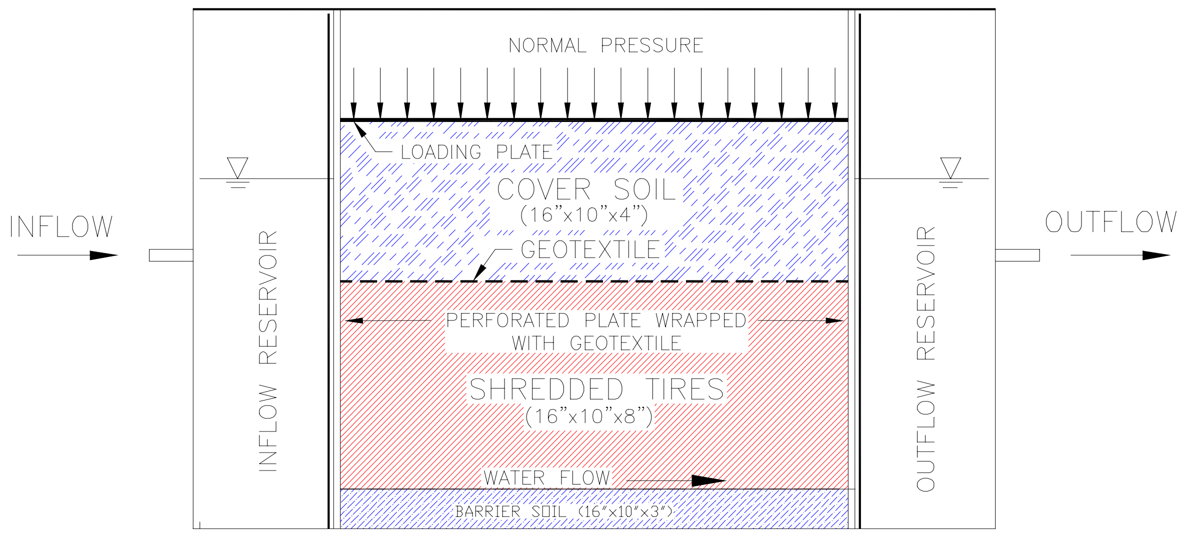


**Figure 2. Schematic of transmissivity test set-up**

Four series of experiments (I, II, III, & IV) were conducted to assess the clogging potential of the tire shreds as a result of soil erosion from the cover and/or barrier soil layers, and each series of experiments was composed of four separate tests with the variables shown in Table 1. Initially, the transmissivity test apparatus was placed on a level surface. Then the inlet was connected to a constant water supply source using flexible PVC tubing, and another flexible PVC tube was used to connect the outlet control valve to a drain. The amount of soil required to create a three-inch thick soil layer in the test setup was calculated. This soil was then measured and subsequently mixed with water to result the predetermined optimum moisture content of the soil. The moist soil was then placed in small layers in the center compartment, and each layer was tamped lightly until the layer thickness was three inches. Based on the particular test program in Table 1, a geotextile was placed over the barrier soil layer. The dry weight of the geotextile was measured before placing it in the test setup so that the dry weight of the geotextile could be measured after testing to determine the amount of soil that had been clogged in the interstices of the geotextile. Approximately seven kilograms of tire shreds, which was sufficient to create a eight-inch thick tire shred layer, were taken and placed randomly over the bottom layer, and the tire shreds were placed without any compaction. Depending on the testing program in Table 1, a geotextile was then weighed and placed over the tire shred layer. Finally, a 3-inch thick cover soil layer was placed over the tire shred layer in the same manner that was used for the barrier soil layer.

After the simulated landfill cover system was configured, water was allowed to enter through the inlet into the reservoir-1, and the starting time of the experiment was recorded. The water level in reservoir-1 was maintained at 12 inches from the base of the test apparatus. The 12-inch water level was provided to saturate the bottom soil layer, the entire drainage layer, and the bottom inch of the cover soil layer. This water level was used to simulate a high amount of infiltration from precipitation and the worst-case scenario erosion conditions for the cover soil. The outflow from reservoir-2 was measured periodically, and the measured outflow volume in a

**Table 1. Testing program to study transmissivity of tire shreds**

| Experimental Series | Experiment Number | Tire Shreds | Geotextile at the top interface $Oz/yd^2$ | Geotextile at the bottom interface $Oz/yd^2$ | Normal Stress (psf) |
|---|---|---|---|---|---|
| **I** | 1 | TS-1 | No | No | 0 |
| | 2 | TS-1 | No | 8 | 0 |
| | 3 | TS-1 | 8 | No | 0 |
| | 4 | TS-1 | 8 | 8 | 0 |
| **II** | 1 | TS-1 | No | No | 120 |
| | 2 | TS-1 | No | 8 | 120 |
| | 3 | TS-1 | 8 | No | 120 |
| | 4 | TS-1 | 8 | 8 | 120 |
| **III** | 1 | TS-2 | No | No | 0 |
| | 2 | TS-2 | No | 8 | 0 |
| | 3 | TS-2 | 8 | No | 0 |
| | 4 | TS-2 | 8 | 8 | 0 |
| **IV** | 1 | TS-2 | No | No | 120 |
| | 2 | TS-2 | No | 8 | 120 |
| | 3 | TS-2 | 8 | No | 120 |
| | 4 | TS-2 | 8 | 8 | 120 |

specified time period was used to calculate the flow rate. At the end of the experiment, top cover soil layer was removed and dried, and its dry weight was measured. The geotextile, if used, was also removed, dried, and weighed. The tire shreds from the drainage layer were then removed and dried, as was the soil and/or geotextile from the bottom layer. The dry weights of the individual components were used to calculate the amount soil erosion that occurred and to determine the amount of soil that had been clogged in the geotextile interstices.

## RESULTS AND DISCUSSION

The measured outflow values during each experiment were used to calculate the flow rates in cubic feet per second (cfs). The flow rate was then converted to the flow rate per unit cross sectional area ($Q_T$) with units cfs/sq.ft, where the cross sectional area is the flow area in the transverse direction. The $Q_T$ was plotted versus the elapsed time (hours), and the flow pattern was studied for each of the tests. The magnitude of the flow rate was not a major concern in these experiments because the conditions simulated the worst-case scenario, and saturated conditions such as these are unlikely to occur in a typical landfill cover system. The experimental results, however, provided the drainage performance of the tire shreds under these critical conditions. The flow pattern observed for each test was compared to the flow patterns for the other tests within the same experimental series, and the results of each experimental series were then compared.

The final dry weight of the cover soil layer, after completing each experiment, was used to calculate the amount of soil that had been infiltrated and/or eroded from the top and bottom soil layers, and it was expected that that there would be a significant amount of soil loss in the experiments when the geotextile was absent because of the vertical migration of soil particles into the drainage layer (tire shred) void spaces. All four experiments conducted in Series I can be compared based upon their $Q_T$ values and the amount of soil infiltration and/or erosion that occurred as shown in Figures 3(a) and 3(b). From Figures 3(a), it is evident that there was very little difference in the flow rates of each of these tests when compared to one another. As expected though, Figure 3(b) shows that the amount of soil loss was greater in tests 1 and 2 compared to the other two tests that possessed a geotextile at the top interface. Based on visual observations, it was found that the presence of a geotextile at the bottom interface in tests 2 and 4 prevented the intrusion of the tire shreds into the barrier soil layer. This is advantageous because the barrier soil layer integrity needs to be protected to maintain its low permeability. The percentage of soil loss from the barrier layer was low for all the experiments compared to the soil loss from the cover soil layer. The reason for high amount of cover soil loss was attributed to the high rate of inflow, which, as stated earlier, would be rare under typical field conditions. Based on calculations, it was determined that the amount of soil loss from the cover soil or barrier soil layer would not signify any threat of instability to the cover system as a whole. From visual observations, it was found that when a geotextile was used, it had a significant amount of soil that adhered to its surface, and this soil contributed to its increase in weight after each experiment.

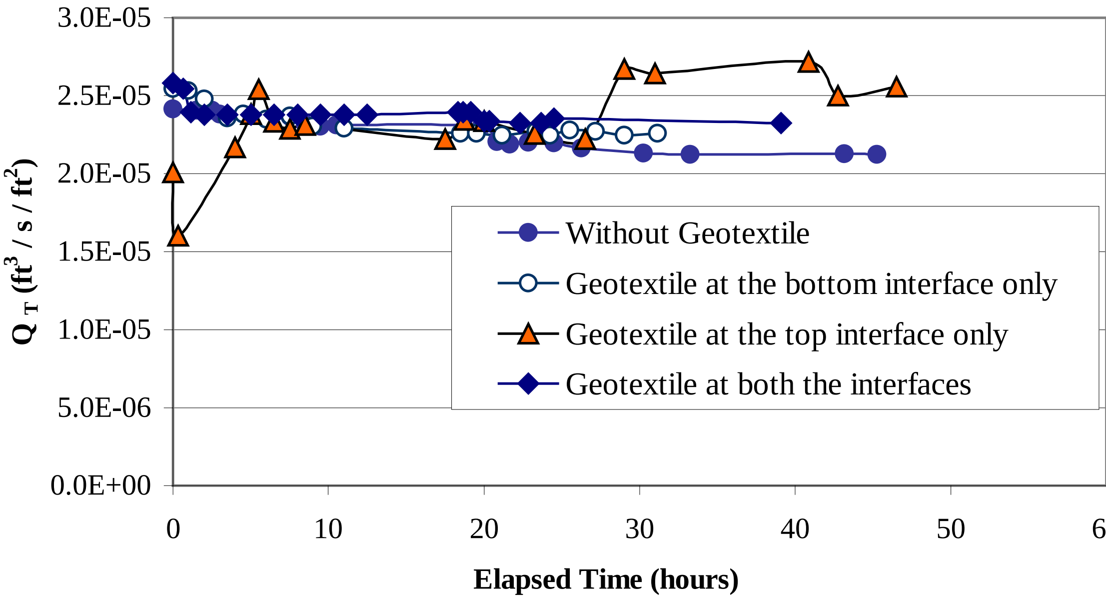


**Figure 3(a). Transmissivity of test series-I results using tire shreds TS-1 and no normal stress**

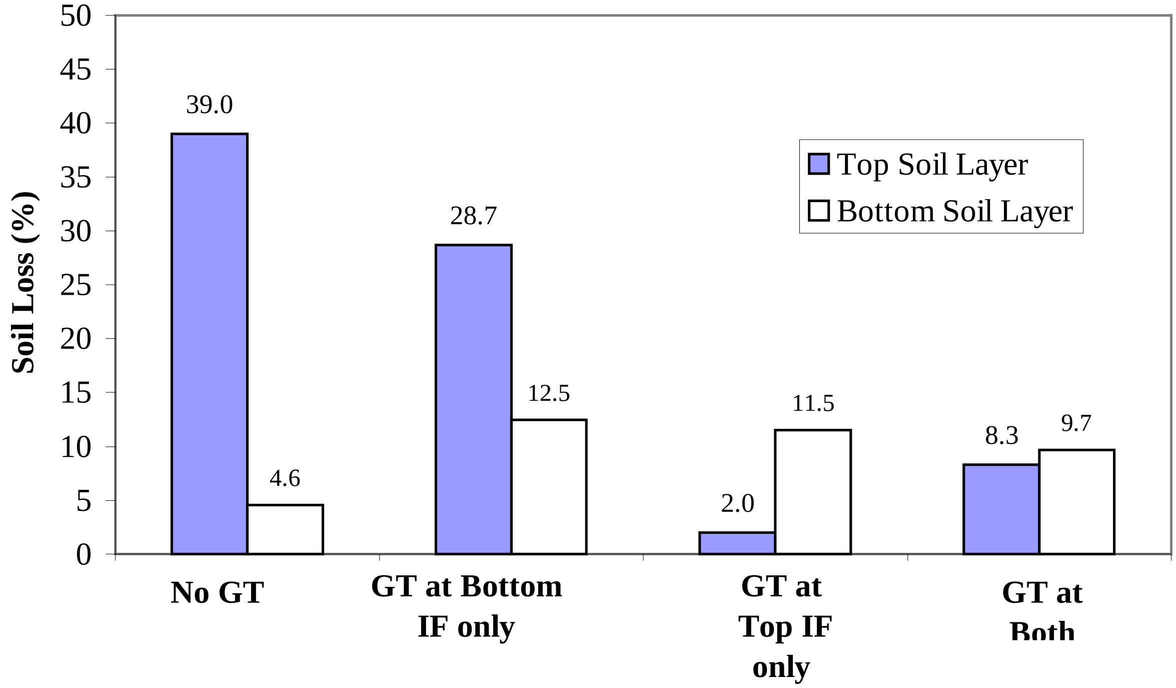


**Figure 3(b). Transmissivity test series-I results using tire shreds TS-1 and no normal stress**

Figures 4(a) and 4(b) show the results of the four tests preformed in Series II, which were subjected to a normal stress of 120 psf. This stress includes the self-weight of the cover soil layer in addition to an applied normal stress that simulated a one-foot thick cover soil layer. Compared to the tests conducted in Series I, shown in Figure 3(a), it is clearly evident that the normal stress contributed to reducing the flow rate in the Series II tests. The flow rates in the tests 1 and 2 were lower than the flow rates in the tests 3 and 4, and this was attributed to clogging of the drainage layer (tire shreds) due to soil erosion. It was expected that there would be a reduction in void space due to the migration of the soil particles from the cover soil layer into the shredded tire drainage layer, but it was not as evident until the porosity was reduced by applying a normal stress. As observed earlier in the Series I tests, the Series II tests showed that the presence of the geotextile at the top interface in tests 3 and 4 prevented soil infiltration and erosion from the cover soil, and, based on visual observations, it was found that the presence of the geotextile at the bottom interface in tests 2 and 4 protected the barrier soil layer from the intrusion of tire shreds.

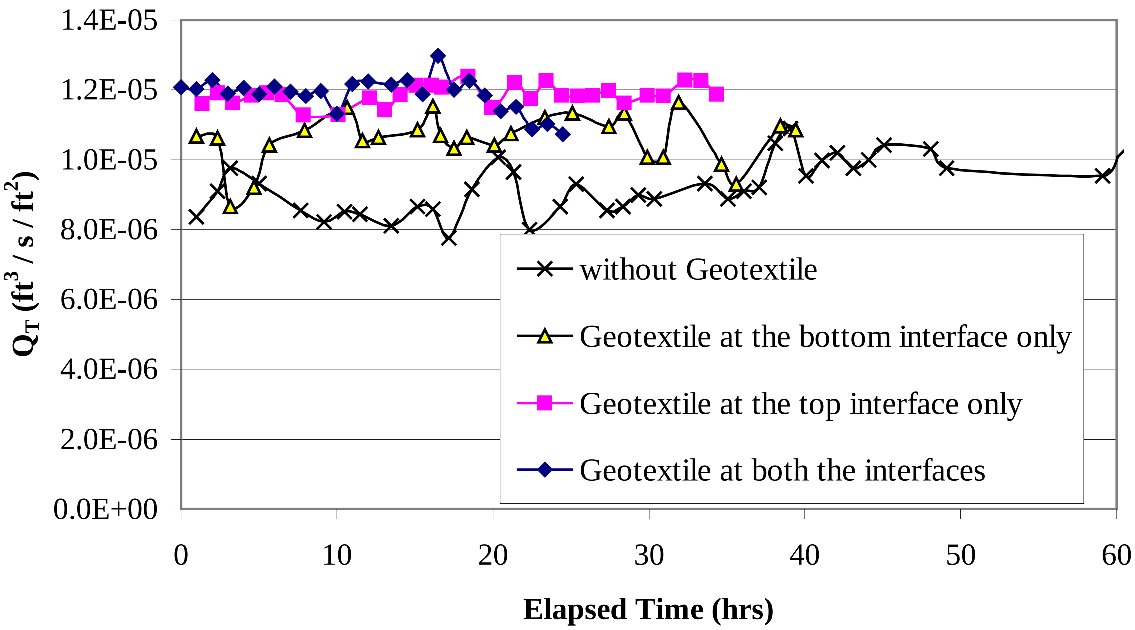


**Figure 4(a). Transmissivity test series-II results using tire shreds TS-1 and 120 psf normal stress**

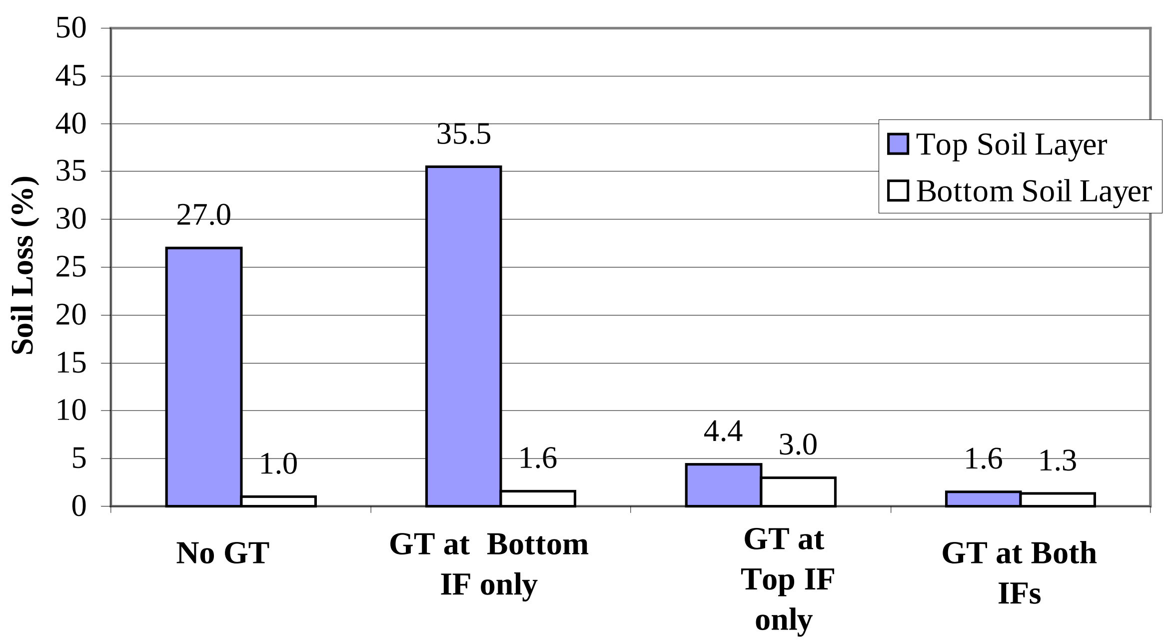


**Figure 4(b). Transmissivity test series-II results using tire shreds TS-1 and 120 psf normal stress**

Figures 5(a) and 5(b) show the results from the Series III tests. As seen in Table 1, these four tests were conducted with the smaller size tire shreds possessing an average size of 3-4 inches, and they were performed without the added normal stress. Similar to Figure 3(a) from Series I, Figure 5(a) shows that there was very little difference in the flow rate for each of the tests. Figure 5(b) also shows results that were similar to the earlier series in that the amount of soil loss was greater for tests 1 and 2 because these simulated cover systems did not possess a geotextile at the top interface. Moreover, the results from Series III verified the conclusions from the previous two series that using a geotextile prevents cover soil infiltration and erosion and protects the barrier soil layer from tire shred intrusion.

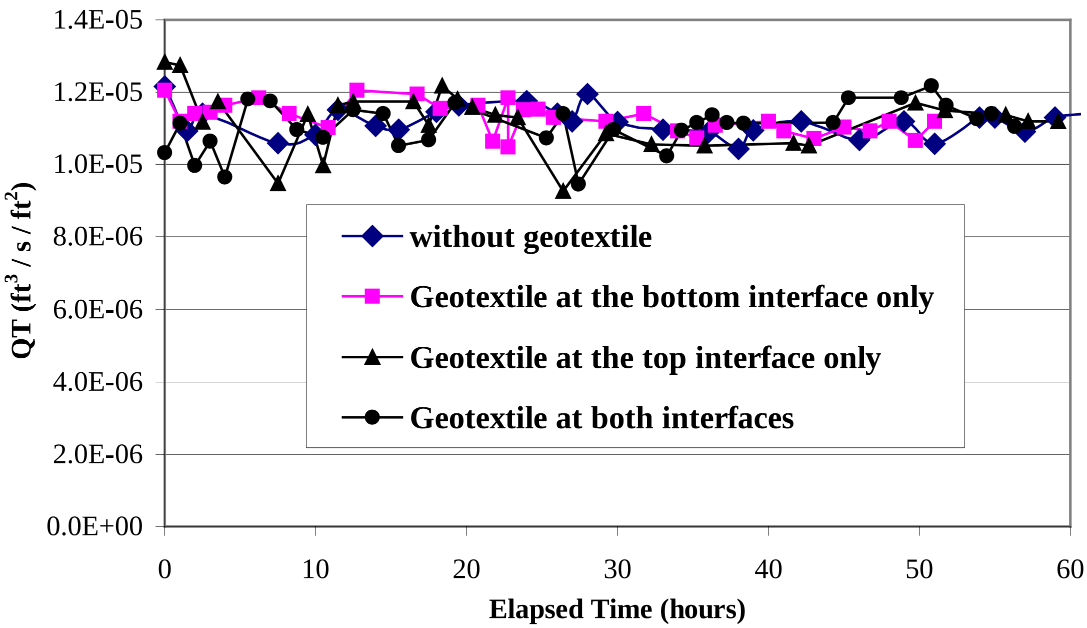


**Figure 5(a). Transmissivity test series-III results using tire shreds TS-1 and no normal stress**

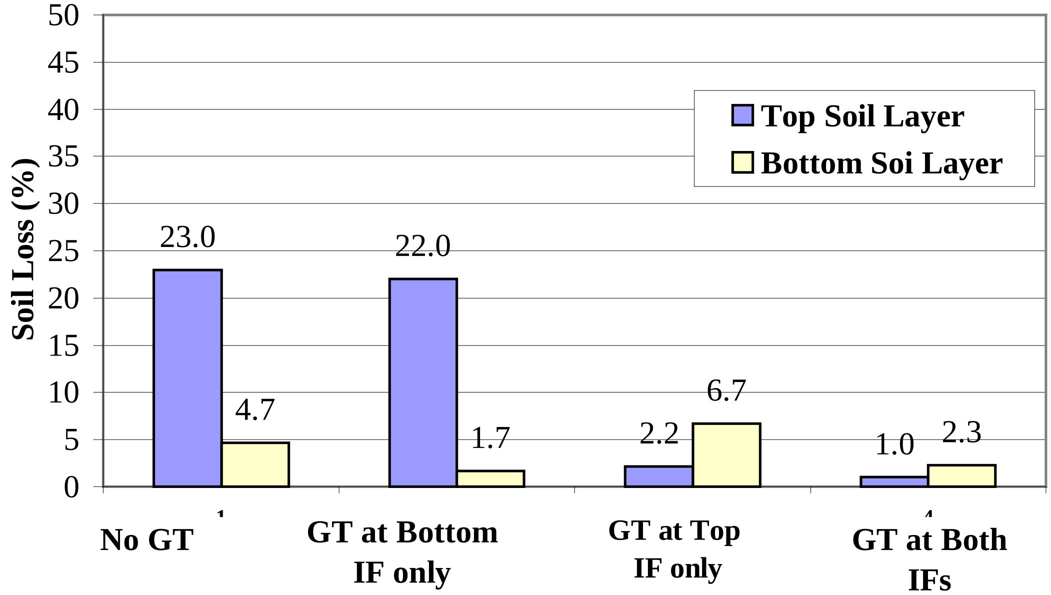


**Figure 5(b). Transmissivity test series-III results using tire shreds TS-1 and no normal stress**

The results from Series IV are shown in Figures 6(a) and 6(b), and, as seen in Table 1, these tests used the smaller size tire shred along with an additional normal stress of 120 psf. Unlike the results from Series II, which employed the 120 psf normal stress and the larger size tire shreds, the application of the normal stress did not significantly reduce the flow rate compared to the tests in Series III. In addition, as seen in Figure 6(a), the flow rates for all the experiments in Series IV were nearly the same. As illustrated in Figure 6(b), there was a large amount of soil loss in tests 1 and 2 from the cover soil layer, but, as seen in Figure 6(a), the flow rate per unit area was almost equal to that of tests 3 and 4. These results verify the earlier conclusion that the presence of the geotextile at the top interface in tests 3 and 4 prevents soil infiltration and erosion from the cover soil.

## SUMMARY AND CONCLUSIONS

Transmissivity tests were conducted using various simulated cover systems that incorporated one of two different sized tire shreds as the drainage layer to examine the changes in the flow rate mainly caused by soil infiltration and/or erosion. Four experimental series were conducted, where each series consisted of four tests that used different normal stress conditions and different cover system configurations with or without the presence of an 8 oz/yd$^2$ nonwoven geotextile at the cover soil layer/drainage layer and/or drainage layer/barrier soil layer interfaces.

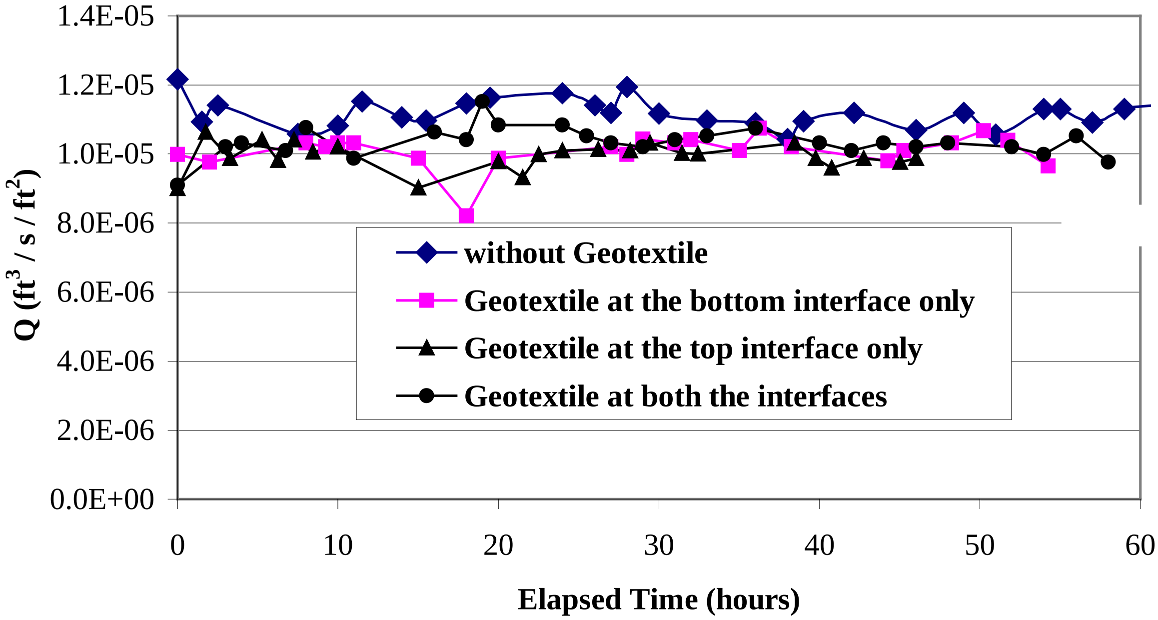


**Figure 6(a). Transmissivity test series-IV results using tire shreds TS-2 and 120 psf normal stress**

The results from these experiments indicated that when the cover system was placed under an additional normal stress application, the larger sized tire shreds compressed, reducing their porosity and the transmissivity. The compressive effects of normal stress, however, were reduced when the smaller size tire shreds were employed. Moreover, it was evident from the results of all the experimental series that providing a geotextile at the interface between the cover soil layer and the drainage layer reduces soil infiltration and/or erosion. Furthermore, providing a geotextile at the interface between the drainage layer and the barrier cover soil was observed to be beneficial for protecting the barrier soil layer and reducing the intrusion of tire shreds. Overall, in spite of the significant soil erosion and some clogging, both sizes of the tire shreds performed as an effective drainage media and allowed high transmissivity as a result of their high porosity. Apparently, the soil only partially clogged and reduced tire shred porosity, and this reduction was not significant enough to reduce the flow.

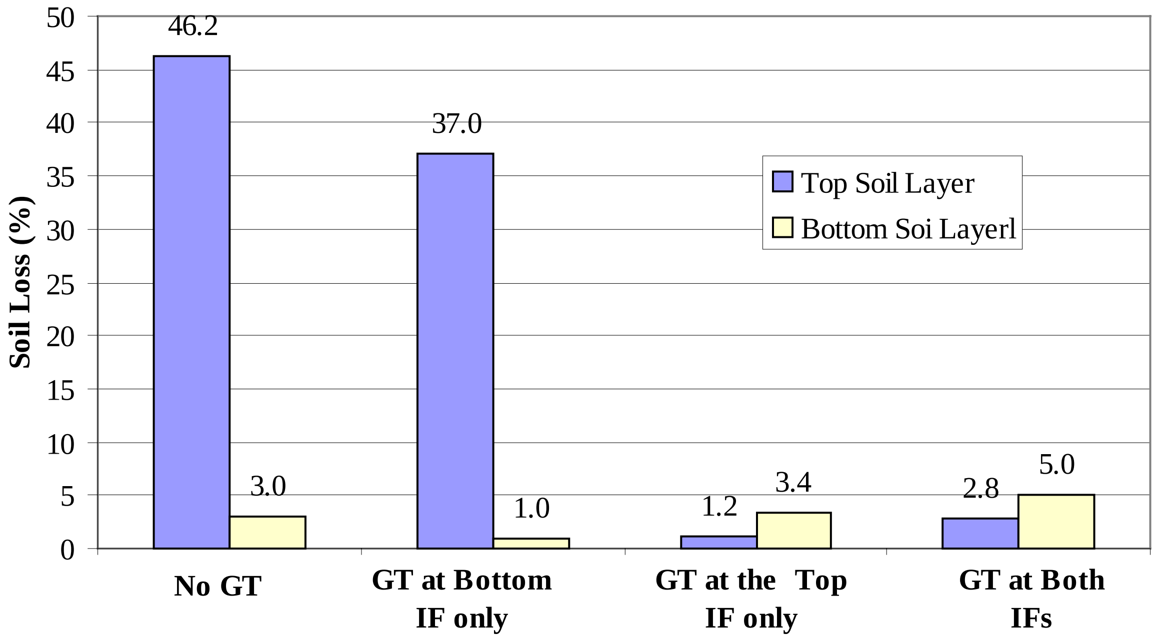


**Figure 6(b). Transmissivity test series-IV results using tire shreds TS-2 and 120 psf normal stress**

In summary, based on the experimental results and visual observations from all the transmissivity test series, it can be concluded that the use of shredded scrap tire as a drainage material in a landfill cover system would be efficient. Moreover, the use a the geotextile at the top interface and the bottom interface of the shredded tire drainage layer irrespective of the thicknesses of different layers in the final cover system would be beneficial for drainage layer performance.

## REFERENCES

1. Reddy, K.R. and Saichek, R.E., (1998), "Characterization and Performance Assessment of Shredded Scrap Tires as Leachate Drainage Material in Landfills", Proceedings of the Fourteenth International Conference on Solid Waste Technology and Management, Philadelphia, PA.
2. Reddy, K.R., and Saichek, R.E., (1998), "Assessment of Damage to Geomembrane Liners by Shredded Scrap Tires", Geotechnical Testing Journal, Vol.21, No.4, pp. 307-316.
3. Reddy, K.R., and Marella, A.,(2001), "Properties of Different Size Tire Shreds: Implications on Using as Drainage Material in Landfill Cover Systems," Proceedings of the Seventeenth International Conference on Solid Waste Technology and Management, Philadelphia, PA.
4. Marella, A., (2002), "Use of Shredded Scrap Tires as Drainage Material in Landfill Covers," M.S. Thesis, University of Illinois at Chicago, Chicago, IL.