COMPARING PERFORMANCE OF GEOCOMPOSITE FILTER-DRAINS AND GRANULAR FILTERS UNDER CANAL LINING

H.Rahimi and A.A.Khosravi
Department of Irrigation Engineering, Faculty of Soil and Water Engineering., University of Tehran, Karaj, Iran.

ABSTRACT

In many irrigation projects where the groundwater table is high part of the canals may be located below the water table. In this situation groundwater applies uplift pressure to the bottom and side panels of the canal lining. This phenomenon may cause deformation, displacement and or rupture of the concrete panels or other damage which results in high maintenance costs to the project. The most effective way to control the uplift pressure under the canal lining is to provide a filter-drainage system under the lining. Up to the present, granular filters have been the most common material in use. In some cases application of granular materials is not an easy task due to high costs involved and/or environmental impacts. In recent years geosynthetic materials (geocomposites) have been employed as replacement for granular filters. In the present study the behaviour of geocomposite material as a filter drainage layer under canal lining has been investigated using a physical laboratory model. The results of the experiments showed that a geocomposite layer of adequate thickness can fully relieve the uplift pressure and discharge the drained water effectively. Also the efficiency of the filter-drainage under bottom concrete panels only and both bottom and side concrete panels were studied. The results showed that providing a filter under the side panels has no significant effect on the drainage capacity of the system. As the weight of the concrete panel on a geocomposite layer would cause some deformation of the material its effect was also considered in the physical model. The results of this part of the experiments showed that by applying the weight of the concrete lining the effective thickness and thus permeability of the geocomposite is reduced and its effect should be considered in the design of geosynthetic filters.

1 INTRODUCTION

Natural filter-drainage systems are widely being used under the lining of irrigation canals, especially with rigid linings such as concrete. The most extensively used example of these natural materials is granular soil i.e. a mixture of gravel and sand. In recent years geocomposite filter-drains have been introduced as an alternative to granular filters, due to limitations and problems inherent in using granular materials (Siahi and Baghbanzadeh, 2003). These problems and limitations include the high expense of supply and preparation of suitable graded material, the environmental impacts and construction of the system.

The geocomposite drains normally consist of a geonet core sandwiched between two layers of geotextile filters. Water collected under the lining of the canal enters into the system normal to the geotextile filter and drains out via the geonet core. Several studies have been conducted on geocomposite filter-drains (Shukla, 2006). In a laboratory study, Hwu *et al*. (1990) investigated the intrusion of fabric on one side of a geonet drain into the pathways between strands in the geonet core. They found that short-term intrusion could reduce maximum flow capacity by between 39% and 88% fron the original value. Koerner *et al.* (1993) excavated 41 geocomposite sheets installed as “edge drains” beside a highway pavement. The edge drains were installed at a depth of less than 1 metre. The lateral loads on the drain core imposed by heavy trucks which were estimated to be in the order of 140 kPa had no adverse effect on the geocomposites. Koerner *et al.* (1996) carried out some laboratory tests to quantify the *in situ* drainage capacity of the material. No sign of failure was observed by visual inspection of the overall appearance and measuring the mass of soil entrapped in the core. In all cases the cores had not been deformed, but in some samples excessive amounts of soil were judged to have moved through the geotextile into the core. Chang *et al.* (1996) monitored the performance of geocomposite drains installed beneath three building raft foundations at a site with a high groundwater table. The drains were composed of a geonet core with geomembrane on one side and geotextile on the other side. Measurement of the piezometric pressure indicated that the drains were able to reduce the pore water pressure by about 50% with respect to adjacent undrained areas, with no change over a 3-year period. McKean and Inouye (2001) conducted an extensive study on the field evaluation of the long-term performance of geocomposite and concluded that the performance was quite satisfactory. Rahimi *et al.* (2004) investigated the feasibility of using artificial drains as a filter-drainage system under the lining of irrigation canals by computer modelling. Using computer software they modelled seepage of groundwater through the soil into the canal and showed that seepage flow towards the canal can be drained properly by installing a geocomposite layer at the bottom only of the canal. Their study also showed that the flow lines meet each other at the corners of the bottom of the canal. Their findings imply that there is no need to provide filter drains under side walls of the canal.

The main objectives of the present study are to investigate the feasibility of employing geocomposite material as the drainage system under canal lining in a physical model by considering different types of materials, different groundwater levels and the effect of loads imposed by concrete lining.

2 MATERIAL AND METHODS

2.1 PHYSICAL MODEL

The physical model used in the present study was designed to simulate a concrete lined canal under the groundwater table in laboratory conditions. As the first stage, it was necessary to determine the main parameters of experimental model conforming to the natural conditions. The model canal was built in a cubical steel tank. To ensure water supply at a fixed water level, two smaller steel tanks were made and placed on the two sides of the main tank. On each side of the tanks, four taps were installed to allow maintaining water table at four different levels, i.e., 150, 250, 350 and 450 miilimetres above the bottom of the canal. In each experiment, one tap acts as entry valve to the main tank and the other acts as exit valve. In this way, the water table will be maintained at a given level for each experiment. The canal was made of thin aluminium sheet and placed in the middle of the main tank, above the foundation material. The space between the canal and walls of the main tank was filled with the same material as the foundation. Different parts of the physical model and their dimensions are shown on Figure 1. The model canal has a trapezoidal shape, with 200 mm bottom width, 1.44 m length and side slopes of 1:1.5 (vertical: horizontal). The canal was made of a light material for manoeuverability. To measure the hydrostatic pressure next to the canal, several piezometers were installed at one side of the canal. The piezometers were installed at 100 mm intervals both horizontally and vertically. Since the soil under and behind the canal was homogeneous, it was assumed that the seepage pattern was similar on both sides of the canal.

To evaluate the drainage capability of the system, it is necessary to measure the water flowing out of the system. For this purpose, a smaller tank was installed at the outlet of the geocomposite layer and by measuring the volume of collected water it is possible to determine the outflow discharge. Figure 2 shows the physical model used to carry out the laboratory experiments.

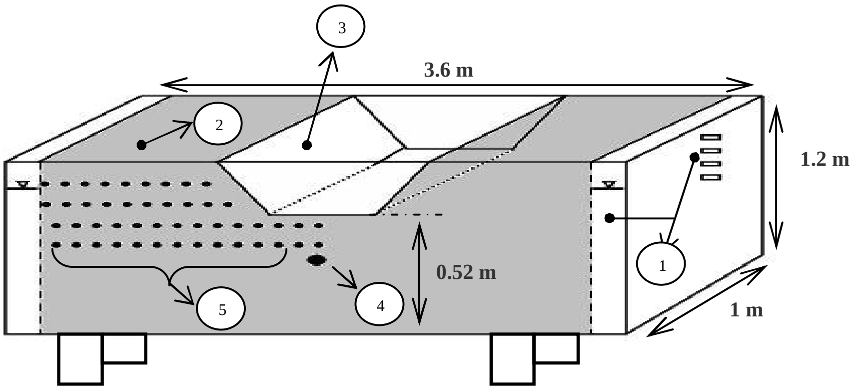

Figure 1: Sketch of physical model and its components

1- Reservoir and outlet valves
2- Foundation soil
3- Aluminum canal
4- Drainage outlet
5- Piezometers

.

Figure 2: Side view of the physical model.

2.2 FOUNDATION SOIL

In order to apply the most critical conditions and decrease the time needed for performing the experiments the porous media (here the foundation soil) should have a relatively high permeability. Such a material will be saturated and come to equilibrium in a short period of time. The texture of the foundation soil should be chosen in a way that isotropic conditions in regard to permeability can be assumed. As a result for the purpose of this study fine, clean sand was chosen, which is also highly susceptible to piping. The physical properties of selected media are given in Table 1.

Table 1: Physical properties of the foundation soil.

$k(\frac{mm}{\sec})$	$k(\frac{mm}{\sec})$	$D_{15}(mm)$	$D_{50}(mm)$	$D_{85}(mm)$	Soil classification
0.14	2.0	0.18	0.286	0.404	SP

The foundation soil was placed in the main tank in horizontal layers 100 mm thick under and around the canal body.. Each layer was compacted by a flat wooden hammer under given compaction effort. The number of blows was determined based on the preliminary tests to achieve a given in-place dry density of 17 kN/m^3. Maximum care was taken to apply a uniform compactive effort and to reach a uniform compaction throughout the material.

2.3 GEOCOMPOSITE FILTER-DRAIN

For the purpose of the present study, four types of geotextiles available in the market were employed as the filter encapsulating a similar geonet core. Some physical characteristics of the geotextiles as measured in accordance with the ASTM Standards or as reported by the manufacturers are given in Table 2. The Geonet cores employed in this study were available in thicknesses of 12 mm and 24 mm.

Table 2: Some physical properties of geotextile filters.

Transmitivity $\psi = \frac{1}{k}\ (s^{-1})$	Permeability $(mm/\sec)$	$O_{90}(mm)$	$O_{95}(mm)$	Thickness (mm)	Unit Weight	Type of Polymer	Geotextile Name
0.414	1.23	0.3	0.37	3	250	PE	GT 250
0.421	1.52	0.307	0.36	3.6	300	PE	GT 300
0.417	1.0	0.195	0.206	2.18	300	PE	Niddle-punched GT
0.434	0.54	0.166	0.19	1.24	150	PP	Thermal GT

2.4 GRANULAR FILTER

One of the objectives of this study was to compare geocomposites with a granular filter-drain. For this purpose some experiments were conducted using a natural or granular filter-drainage system. To perform effectively, the granular filter-drain should have adequate thickness and appropriate grading. The thickness of the granular filter-drain considered for this study was 150 mm. and its grading was determined based on the texture of the subgrade soil using the criteria suggested by Terzaghi (1930). Figure 3 depicts the gradation curve of the granular filter-drain.

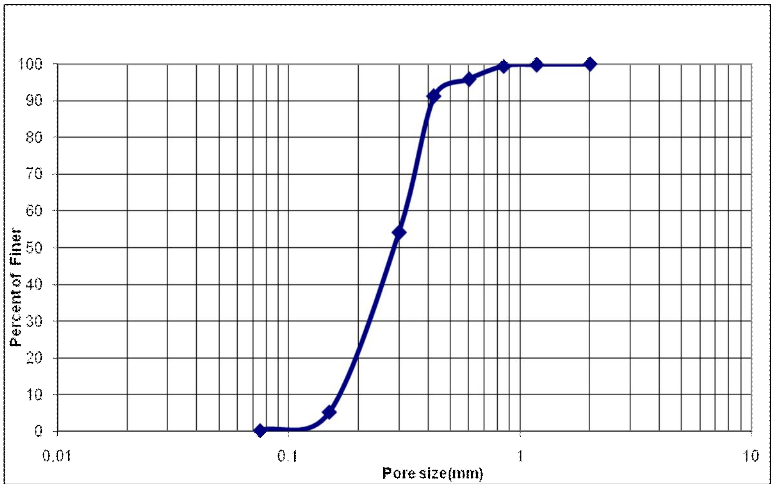

Figure 3: Gradation curve of the granular filter.

2.5 TESTING METHOD

To evaluate the drainage capability of the subgrade soil in its natural condition and to find out whether the base soil needs a drainage system or if it can drain the seepage flow under canal lining without inducing excess pore pressures, some preliminary tests were conducted without using the drainage system. The preliminary experiments were carried out with water levels at 150 mm, 250 mm, 350 mm and 450 mm above the bottom of canal. In each case, the pyrometer readings were recorded and the out flow measured.

In the following steps, layers of different geocomposite, with different thicknesses were placed under the bottom and/or side walls of the canal. For each case the piezometer readings were recorded and the outflow measured. In the final stage a dead load equivalent to the weight of a 100 mm thick concrete lining was applied to the canal and again for each case the piezometer readings were recorded and outflow measured. The results of the experiments are given in the following section.

3 RESULTS AND DISCUSSION

The seepage lines for the first case (no drainage system provided) are shown in Figure 4. The figure shows that the seepage line of the first applied head (150 mm above the canal bottom) is located under the lining, which implies that if groundwater table is at this level, there is no need to provide any filter-drainage system under the canal lining and that the soil has adequate capacity to discharge the excess water around the lining out of the system. This case was not considered in the next experiments when working with granular and artificial filter-drains. In the next step the applied head was increased from 150 mm to 450 mm. As expected the seepage curves rise and intersect the canal lining at second to fourth head (Figure 4). This indicates that the seepage discharge is increasing and that the soil is not capable of safely draining the seeped water. Thus excess hydrostatic pressure (uplift) is applied to the canal both at the bottom and side walls. This is more evident for the highest water level (450 mm). In this condition a filter-drain system under the canal becomes necessary. In the later stages the piezometric heads and discharge flows were measured for cases where different geocomposites of different thicknesses were placed under the bottom and/or the side slopes of the canal. Another case was considered where the drainage layer was not provided under the side slopes of the canal to verify the theoretical results obtained by Rahimi *et al.* (2004). The results of these tests are given in the following sections

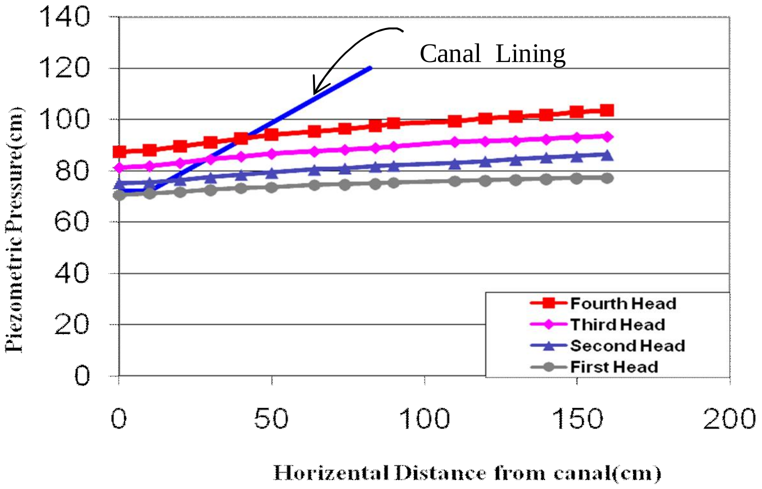

Figure 4: Seepage lines for no drainage system at different heads.

3.1 GEOCOMPOSITE FILTER-DRAIN ONLY UNDER THE BOTTOM OF THE CANAL

In this case four different geocomposites with a 12 mm geonet core were used. The test results are shown in Figure 5. The figure shows that at the highest water level the seepage line for GT300 filter intersects the lining and thus exerts uplift pressure. The GT300 filter has been able to discharge excess water at lower heads. The seepage line for the GT250 filter, which is needle-punched, intersects the canal at the third and fourth heads. For the Thermal-bound filter the seepage line intersects the canal at all water levels. This indicates that this 12 mm geonet core is not capable of draining the excess water from the bottom of the canal and that a thicker core is needed. For the remainder of the experiments a thicker core (24 mm) was used. Using 12 mm thick core at the bottom of the canal the discharge of the drained water increased by 180% to 220% when compared to the condition with no filter-drain.

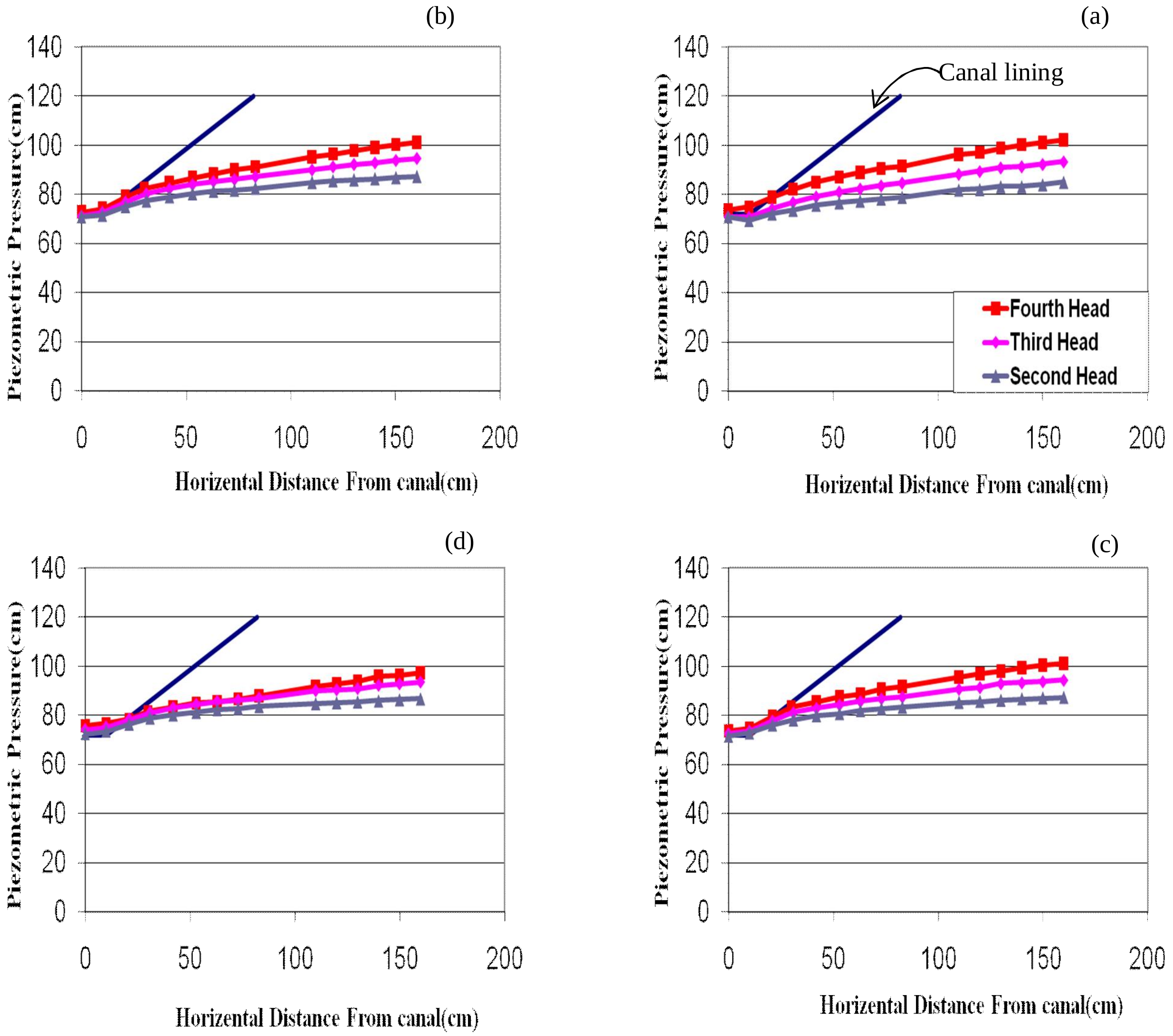

Figure 5: Seepage lines for 12 mm thick geonets located at bottom of the canal only
a) GT300, b) GT250 , c) Needle-punched GT , d) Thermal GT.

In the second series of the experiments, 24 mm thick geonet cores were used under the same conditions. Figure 6 shows the results of these experiments where the seepage lines are all located lower than the canal bottom. In this situation no uplift is imposed to the canal lining and the drainage system is able to safely discharge the excess water from the bottom of the lining. The measured discharge of drained water, using 24 mm thick core has increased by 100% to 120% in comparison with the 12 mm-thick core.

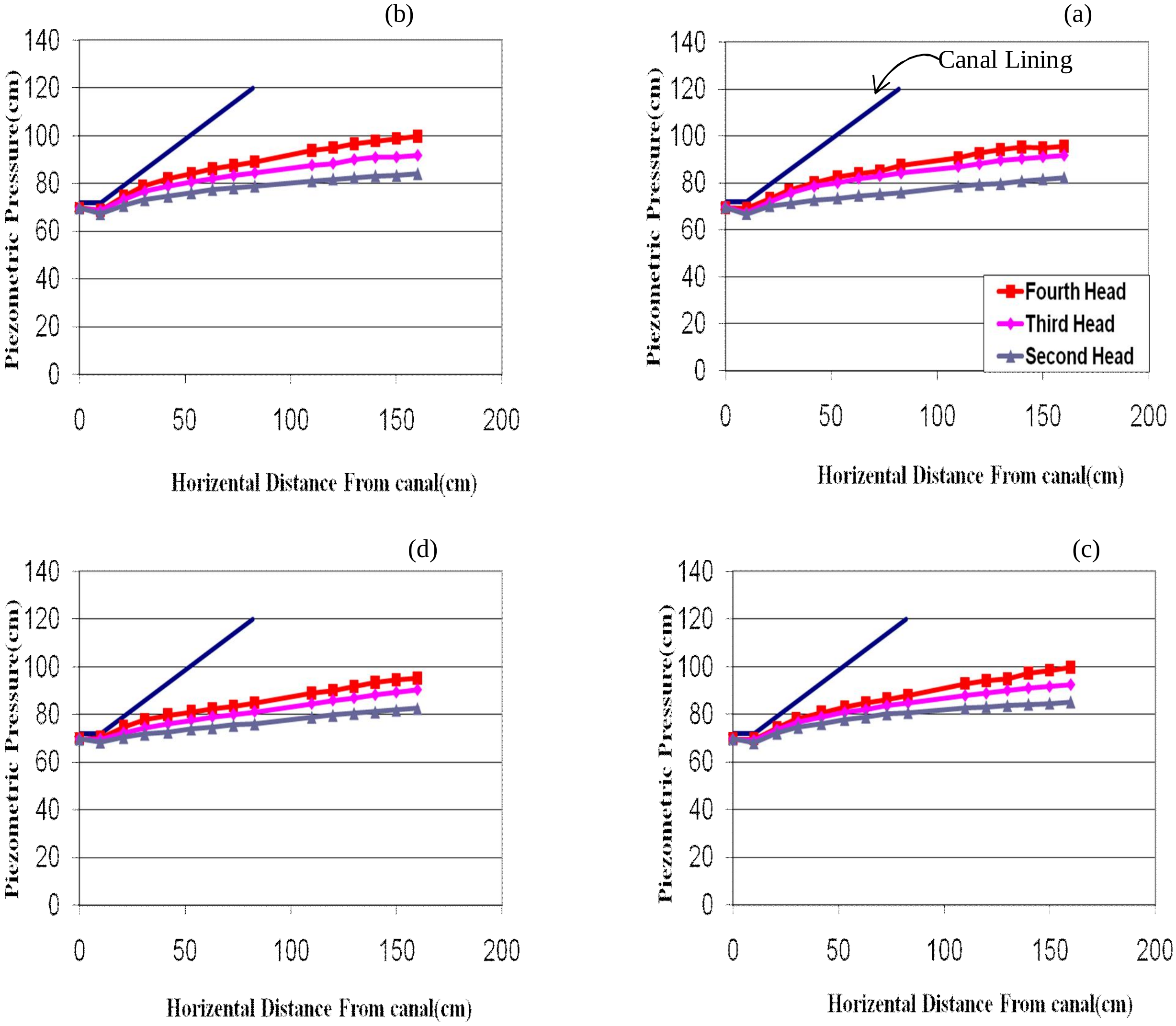

Figure 6: Seepage lines for 24 mm thick geonets placed at the bottom of canal only
a) GT300, b) GT250 , c) Needle-punched GT , d) Thermal GT.

3.2 GEOCOMPOSITE FILTER-DRAIN UNDER BOTTOM AND SIDE SLOPES OF THE CANAL

Similar experiments were carried out where a geocomposite layer with thickness of 12 mm and 24 mm were placed under both the bottom and the side slopes of the canal and the results compared with the case where geocomposite was only placed at the bottom of the canal. Figures 7 and 8 show the results of this part of the experiments.

Comparing the results of the two sets of experiments shows that there is no significant difference between the two cases. Measurement of the outflow discharge shows the same results. The percent increase in the outflow discharge rate is given in Table 3. Based on these results it is concluded that filter-drains employed under the side slope of the canal have no significant effect in lowering the uplift pressure or increasing the outflow discharge.

Table 3: Percent increase in discharge capacity of drainage layer placed under both bottom and sides of the canal in comparison with the case of placing only under the bottom.

Core Thickness		Geotextile Type
24 mm	12 mm	
0.3-2.5 %	1.3-1.5 %	GT300
1-1.5 %	0.4-2.5 %	GT250
0.7-0.9 %	1.4-1.8 %	Needle-punched GT
0.35-0.8 %	0.8-1.1 %	Thermal GT

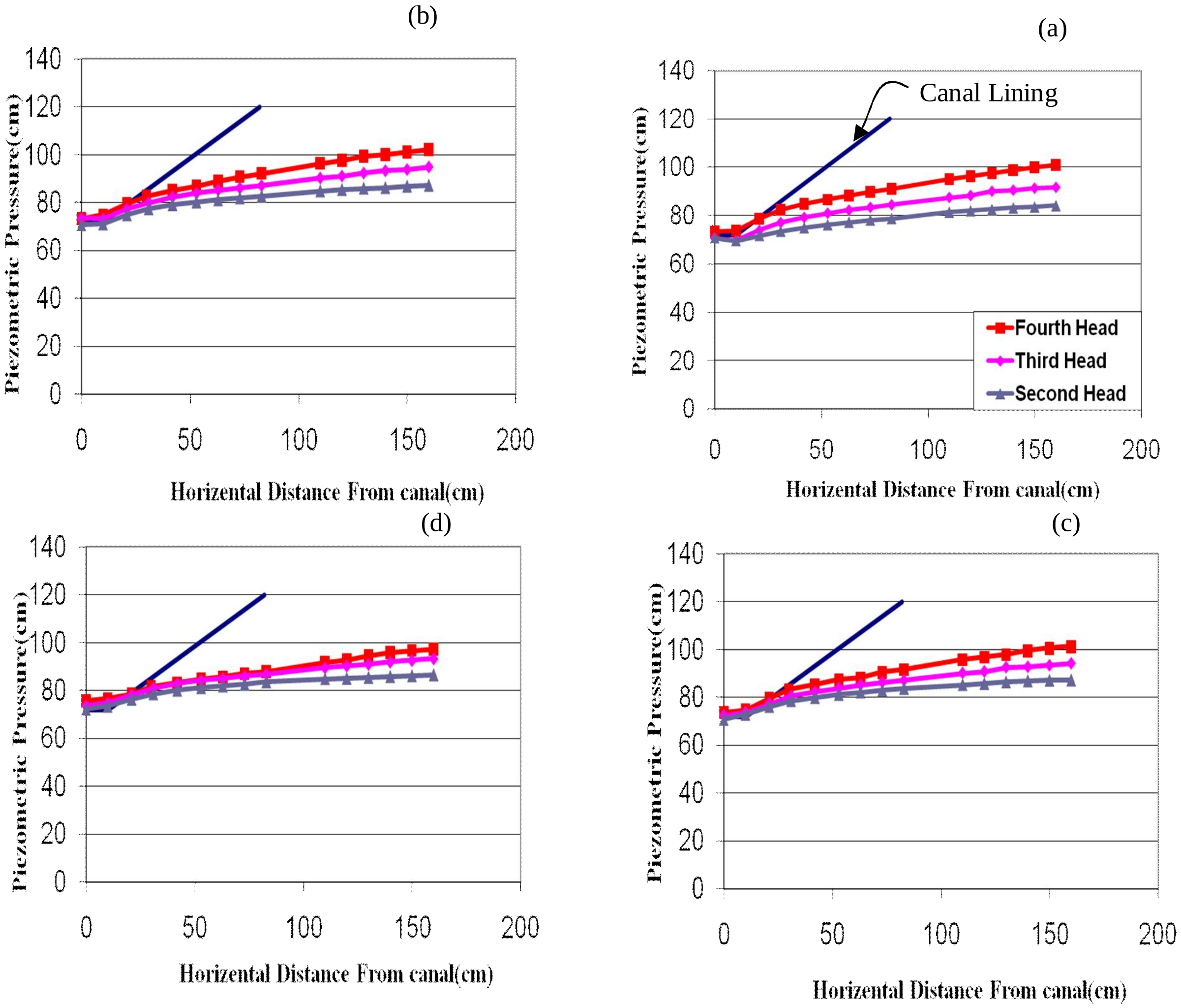

Figure 7: Seepage lines for 12 mm thick geonets placed under both bottom and sides of the canal
a) G.T300, b) GT250 , c) Needle-punched GT , d) Thermal GT.

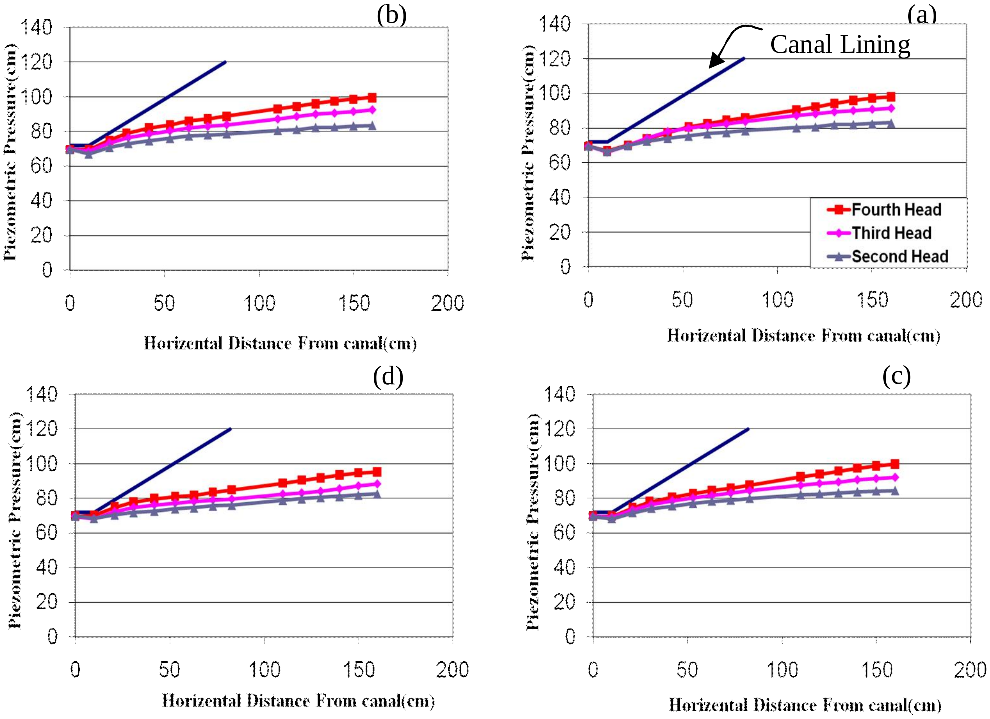

Figure 8: Seepage lines for 24 mm thick geonets placed under both bottom and sides of the canal
a) GT300, b) GT250 , c) Needle-punched GT , d) Thermal GT

3.3 COMPARISON OF GRANULAR AND GEOCOMPOSITE FILTER-DRAINS

One of the objectives of this study was an assessment of the performance of geocomposite filter-drains in comparison with the common granular filters. For this purpose a graded granular filter was prepared in accordance with the specifications discussed in Section 2.4 and placed under the canal and tested as before. Figure 9 shows the results of experiments carried out on the granular filters. At all water levels the seepage lines are under the canal bottom, i.e., the 150 mm thick granular filter has been able to relieve all excess pore pressure and safely discharge the seepage water around the canal. In this case the discharge of outflow was also higher in comparison with the geocomposite filter-drain. The percent increase in discharge capacity is given in Table 4. Comparison of Figures 9 and 6 reveals that seepage lines will experience more drawdown when the granular filter is used.

The results of the experiments show that in general the granular filter is more capable than geocomposite filter-drains of relieving the excess hydrostatic pressure and of discharging seeped water under canal lining. This is mainly due to the much higher thickness of the granular filter. If designed and implemented properly geocomposite filter-drains are also able to act as a safe drainage system. The final decision should be made based on economy, availability of the material, environmental considerations and ease of implementation.

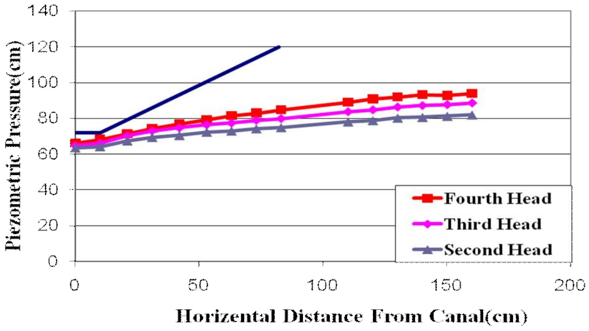

Figure 9: Seepage lines for granular filter.

Table 4: Percent increase in drainage capacity of granular filter in comparison with geocomposite filter-drains.

Second Head (%)	**Third Head** (%)	**Fourth Head** (%)	**Geotextile Type**
12	12	6	**GT300**
22	23	13	**GT250**
25	24	20	**Needle-Punched**
29	26	27	**Thermal GT**

4 CONCLUSIONS

Based on the overall results of the conducted experiments, the following conclusions can be made:

- In general the geocomposite filter-drains, if they are designed with adequate thickness and other required physical properties (such as transmissivity and opening size), are capable of discharging seepage water under the canal lining and controlling the uplift pressure.
- The provision of filter-drains under side walls of the canal does not have a considerable effect on the drainage capacity of the system. This agrees with the theoretical studies.
- The drainage capacity of the geocomposite filter-drain, due to its flexibility, is reduced by the weight of concrete lining which also increases the excess hydrostatic pressure. This is an important issue in design and implementation of geocomposite filter-drains. To reduce this effect, a less flexible material should be employed.
- The performance of granular filter-drains of common thicknesses (at least 150 mm) is better than geocomposite filter-drains. However, the final decision with regard to selection of the most appropriate drainage system should be made based on the cost, ease of usage, durability, availability and environmental issues.
- Generally speaking, artificial filter-drains are acceptable alternatives to granular filters as a drainage system under canal linings if they are designed to meet the required technical specifications.

5 ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the vice presidents for research affairs of University College of Agriculture & Natural Resources and Tehran University for their full support of the present research.

6 REFERENCES

Chang, D., Wu, J., Nieh, Y.C, (1996), Use of Geosynthetics in the Uplift Pressure Relief System for a Raft Foundation, Recent Developments in Geotextile Filters and Prefabricated Drainage Geocomposites, ASTM, Special Technical Publication 1281: 196-221.

Hwu, B. L., Koerner, R.M., And Sprague, C.J., (1990), Geotextile Intrusion into Geonets, Proceedings of 4th Intl. Conf. on Geotextiles, Geomembranes and Related Products, The Hague, 351-356.

Koerner, R.M et al., (1993), Long Term Performance of Geosynthetics in Drainage Applications, Transportation Research Board, Final Report, NCHRP Project, pp 15-13.

Koerner, G.Ret al, (1996), Field Performance of Geotextile Highway Drainage Systems, Recent Developments in Geotextile Filters and Prefabricated Drainage Geocomposites, ASTM, Special Technical Publication 1281, 165-181.

McKean. J., Inouye K., (2001), Field Evaluation of the Long-Term Performance of Geocomposite Sheet Drains, Journal of Geotextiles and Geomembranes, Elsevier, Vol.19, pp. 213-234

Rahimi, H., Gobadi.N, M., And Ahmadi, H., (2003), Application of Geosynthetics Material as Drainage Layer under Canal Lining, Proceedings of Workshop on Drainage System under Canal Lining, Iranian National Committee on Irrigation and Drainage, Report No.93, PP. 113-134

Shukla, Jian Hua, (2006), Fundamentals of Geosynthetics Engineering, Taylor & Francis e-Library

Siahi, M.K., Baghbanzade, B., (2003), Drainage System Under Concrete Canal Lining in Rice Field of Sefidrood, Proceedings of Workshop on Drainage System under Canal Lining, Iranian National Committee on Irrigation and Drainage, Report No.93, PP. 151-164.