EuroGeo4 Paper Number 262

INVESTIGATION ON DRAINAGE UNDER CANAL LININGS IN HIGH LEVEL GROUNDWATER CONDITION

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Abstract: Cracking of concrete lining will cause water loss and reduction in efficiency of operation. The main reason of the occurrence of such failures in areas with high ground water level is hydrostatic pressure, so called uplift, exerted to canal lining. Currently there are several methods such as weep holes and granular filters to control uplift pressure. Both methods have social and economical consequences. In the current research geosynthetics were used as drainage material to control uplift pressure and ground water level. The investigation was accompanied by computer modelling using Seep/w for simulation and physical modelling using various types of drainage materials. Results show that geosynthetic drains placed at the bottom lining of canal is more effective than one placed under side wall for neutralizing uplift pressure and lowering groundwater level. The computer model showed therefore that the drainage should only be provided at these locations.

Keywords: seepage, geocomposite, drainage, canal, physical modelling

INTRODUCTION

Cracking, rupturing and sometimes movements of concrete linings have been numerously reported in irrigation systems of Iran and other parts of the world in nearly all possible situations for example when the groundwater table is above the bottom of the canal, different canal construction stages and, diagnostic and continuous operation of the canal. Nevertheless, there are no provisions available today to avoid these difficulties. Two main causes that have been identified as culprits are the problems associated with the subsoil and the uplift pressure force. Studies have shown that one of the most useful ways to protect concrete linings is to place drains and filters in the vicinity of linings. The United States corps of engineers (1977), Christopher and Valero (1998) obviates the need for filters if subsoil consists of more than 30% clay. But a question that engineers are always concerned with is what kind of drains to use and how to arrange them so that their requirements are met?

Typically in regions where groundwater table is above the canal bottom, the most critical stability condition occurs when the canal is empty of water which results in maximum value of uplift pressure force and may end to severe damages to panels of linings. To eliminate the acting pressure force on the canal lining, it is necessary to provide its surrounding with feasibility of free drainage. Placing filters and drains in sidewalls and bottom of the canal develops a potential difference in the soil stratum so that the free drainage of the water will be possible and lowers the water table in Slope which besides eliminating the hydrostatic pressure, it will prevent cracking and rupturing of concrete lining in critical situations of operation.

The history of geotextiles dates back to the midst of 1960, when corps of engineers investigated the applicability of geotextiles as an alternative to filters and sandy drains to be used in erosion control systems and protection of side slopes (Mannsbart and Christopher 1996). In the late 1960s, Calhoun (1992) conducted some experiments on filter clothes. This project was aimed at developing some design criteria for plastic filter clothes with applications in filtration- drainage systems.

Recently, Mock et al. (2005) had a comparison between geotextile drainage systems and a general standard drainage system in basement walls. The first system was a strip geotextile drain while the second was a pipe drain that was covered with a layer of gravel and all these were enclosed by a cover of geotextile. Several different soil types were examined with theses drainage systems so that result could be extended to other regions with various soil textures. The results indicated that the first drainage system (geosynthetics) could be a reliable substitution for traditional drainage systems.

MATERIALS AND METHODS

In the present research, SEEP/W software that in addition of its user-friendliness, provides the feasibility of numerical simulation of the flow in both saturated and unsaturated porous media, was implemented. In order to establish a seepage condition in lab similar to that in the prototype, a physical model with appropriate dimensions must be designed so that the same conditions and problem scales as the prototype are represented in the lab. To accomplish this, seepage discharge for different geometrical dimensions was analyzed and ultimately appropriate dimensions for the physical model were determined. Figure 1 shows a typical output of the computer model that delineates the flownet and phreatic line directed towards canal walls.

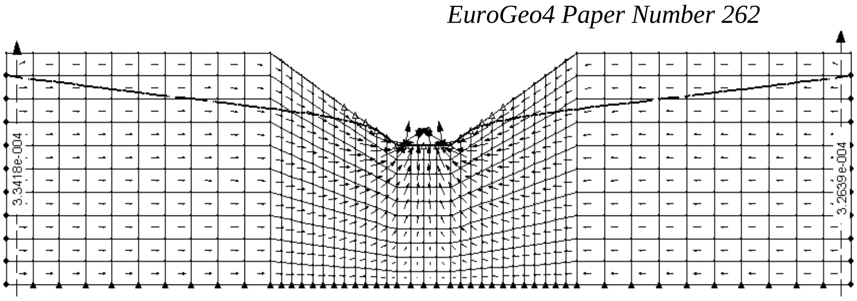

Figure 1. Groundwater table drop curve around the canal from computer simulations

The fundamental equation solved by SEEP/W is poisson equation in the form:

$$k_x \frac{\partial^2 h}{\partial x^2} + k_Y \frac{\partial^2 h}{\partial x^2} = q$$

Where k_x and k_Y are the coefficients of permeability in horizontal and vertical directions respectively, h is the potential head and q is the inflow (or outflow) discharge in the medium. The physical model was constructed in the central water research laboratory of the University of Tehran.

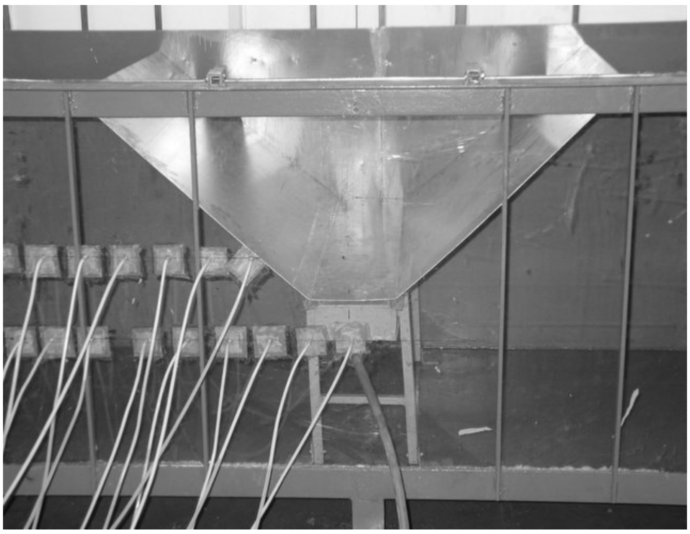

Figure 2. The physical model and piezometric pressure measuring appurtenances

To supply the necessary flow discharge, two tanks, each on one side and 2m away from the canal with dimensions of 0.2*1*1(m) were provided 40 piezometers arranged in three rows were constructed and placed at the side walls of the canal to measure piezometric pressure. The other end of the piezometers were connected to piezometric pipes which were installed vertically on a board so that the elevation of water surface in those pipes were indicative of the pressure at the certain location the pipe was linked to. As the water flows in the canal and saturates the soil medium and a steady state is reached, it is necessary to collect the outflow surplus water and exit from system. This was met using a collective tank at the end and just under the bench of the experimental canal.

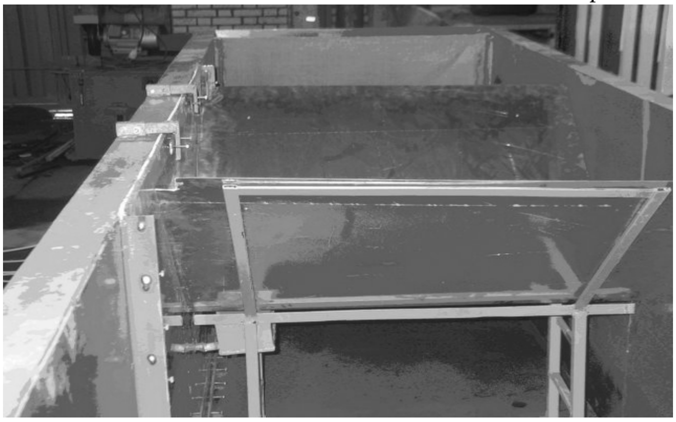

Figure 3. A side view of the canal and arrangement of drainage tank

Marine sand with median diameter (D50) of 0.28mm and permeability of 3(mm/s) was used as the experimental material forming the porous medium. The experiments were performed for three different hydraulic gradients. To establish these gradients water table in supply tanks on each side of the canal was regulated so that three water depths of 5, 15 and 25 centimeters were formed corresponding to each hydraulic gradients.

Aggregate drains with gradation properties of $D_{50} < 7mm$ and $0.3mm < D_{15} < 4.9mm$ where used. Here, D50 and D15 are respectively the diameters through which 50 and 15 percent of the total grain mass is passing. Also, geotextile drains (geocomposite) had a polyethylene core layered with a geotextile whose properties are indicated in table (1).

Table 1. Properties of the geotextile drain

Permittivity (s^{-1})	2.4
Flow discharge normal to filter surface ($l/m^2.s$)	115
Permeability(cm/s)	.35
Transmissivity (cm^2/s)	0.07
Resistance to puncture (N)	315
Apparent opening size (mm)	0.2
Weight (g/m^2)	200

RESULTS AND DISCUSSION

In order to determine the optimum location for the drains, experiments for various test cases i.e. for geotextile in canal side wall, geotextile in the bottom of the canal and aggregate drains in the bottom of the canal were conducted and water seepage lines around the canal were analyzed (Figures 4, 5 and 6).

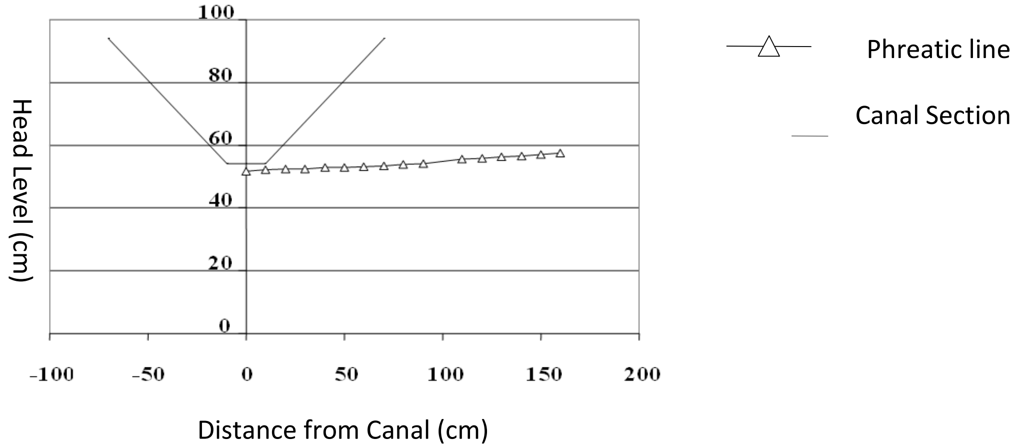

Figure 4. Drop in the seepage line as the geotextile is placed under the bottom of the canal and corresponding control of uplift pressure

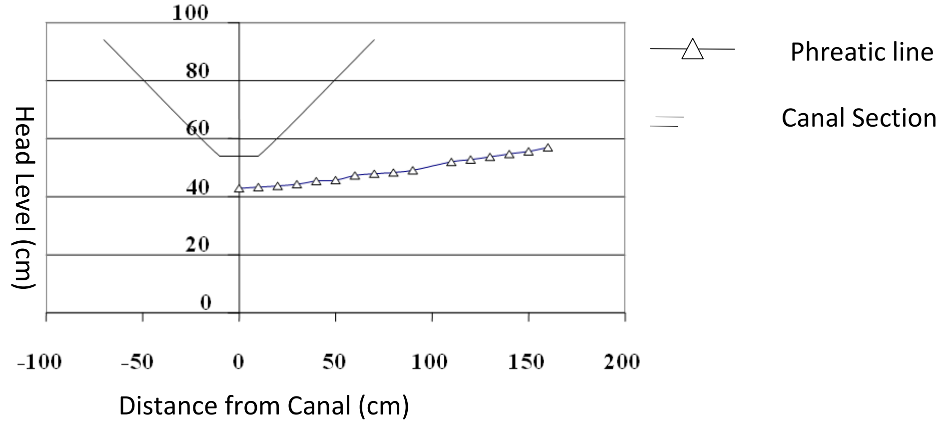

Figure 5. Drop in the seepage line as the aggregate drain is placed under the bottom of the canal and corresponding control of uplift pressure

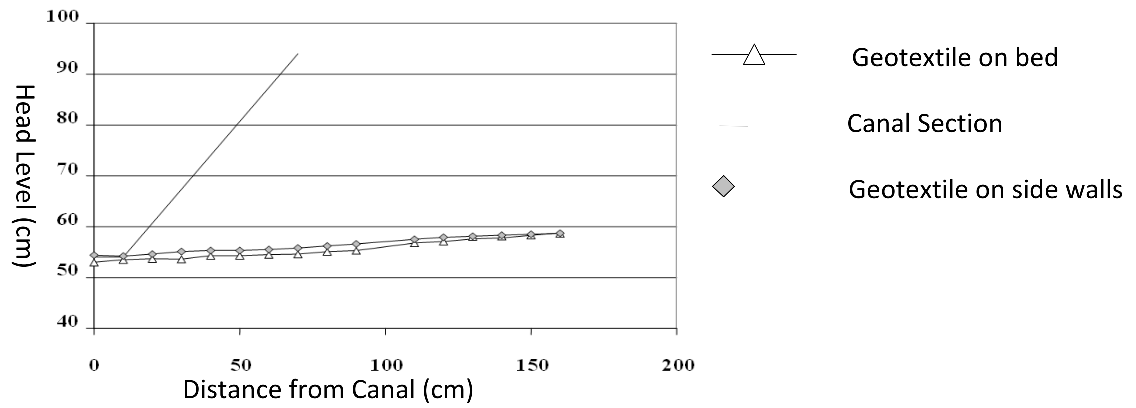

Figure 6. Comparison of seepage lines between two cases of geotextile in the sidewall and under the bottom of the canal

As Figures 4 and 5 show, placing the geotextile and aggregate drains under the bottom of the canal control the seepage zone thereby prevent the uplift pressure from acting on the canal. Also, since the aggregate drain controls the seepage area in lower elevations, referring to hydraulic parameters of the geotextiles in Table 1 indicates that geotextiles with transmissivity larger than 0.07 and permittivity larger than 2.4 must be selected for further lowering of seepage area. A comparison of seepage lines between two cases of placing the geotextile in the bottom and in sidewalls in Figure 6 shows that placing geotextiles in side walls doesn’t have an economic justification and can not control the uplift pressure. On the other hand, placing a layer of geotextile under the bottom of the canal not only reduces the cost of lowering the drainage area under the canal, but also controls the uplift pressure so effectively.

CONCLUSIONS

Experiments showed that both geotextile and aggregate drains could effectively control the uplift pressure. However, there are some advantages of using geotextile rather than aggregate drains. Geotextile reels are light and easy to carry and they are more resistant to chemicals and exposure than aggregate drains. On the other hand, aggregate drains are difficult to provide in some areas and the aggregate materials should be sieved in order to ensure they can fulfill their role as a drain. Therefore, paying attention to the high length of canal construction projects, it is very difficult to provide aggregate drains and to transport them to the site of the project. It is concluded that using geotextiles as a system of filter-drains under the lining of canals will be cost-effective. Therefore, it is a good field for researchers to conduct new research.

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