Performance of Non-Woven Geotextile againts Water Infiltration by Numerical Simulation

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1 Introduction

In environmental engineering point of view, evaluate infiltration process is quite important for protection of soil againts water erosion. While water infiltration can affect at soil stability, surface runoff have strong correlation to soil erosion. One of the erosion countermeasures is using geotextile, performance of geotextile to control soil erosion are depend on their inherent properties[4]. In this paper concerns performance of geotextile againts water infiltration.

2 Governing Equation

Nowdays, governing equation of saturated water flow is widely used to calculate ground water flow. its pressure based equation is described as:

$$S_s \frac{\theta}{\eta} \frac{\partial \Psi}{\partial t} + \frac{\partial \theta}{\partial \Psi} \frac{\partial \Psi}{\partial t} = \nabla . K(\Psi) \left\{ \nabla \Psi + \hat{k} \right\} \qquad (1)$$

where S_s is specific storage of the soil mass $\left(L^{-1}\right)$, θ is the water content, η is the porosity, Ψ is the pressure head (L), $t$is the time of infiltration (T), $K(\Psi)$ is the hydraulic conductivity $\left(LT^{-1}\right)$, and $\hat{k}$ is the unit vector. If change of volume mass is neglected, the Eq.(1) becomes Richard's equation:

$$\frac{\partial \theta}{\partial \Psi} \frac{\partial \Psi}{\partial t} = \frac{\partial}{\partial z} \left(K(\Psi) \left(\frac{\partial \Psi}{\partial z} + 1 \right) \right) \qquad (2)$$

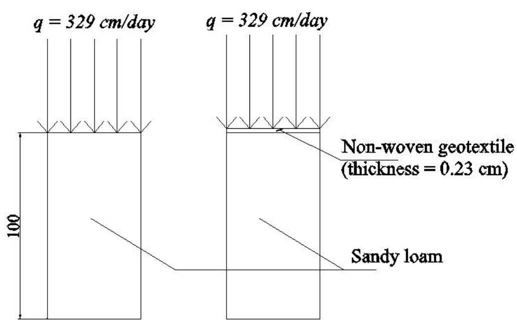

Figure 1: Soil speciment for numerical simulation

Above equation can be solved using numerical methods, i.e. finite difference method, finite element method, etc., and then to satisfy the conservation mass law, the solution have to be eavaluated using mass ballance error[2]. Furthermore the soil water characteristic curve can be solved using Van Genuchten-Mualem equation (1980)[5]:

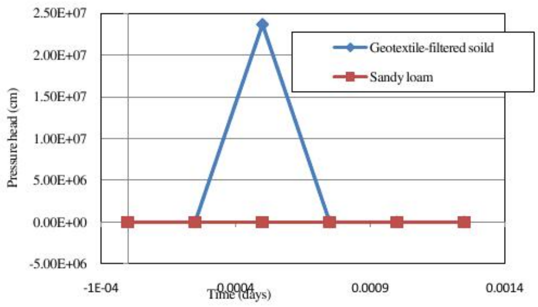

Figure 2: Pressure head vs times

$$\theta = \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha|\Psi|)^n\right]^{1-\frac{1}{n}}} \qquad (3)$$

where θ is related to inverse the air-entry suction $\left(cm^{-1}\right)$ and n is related to pore-size distribution

3 Numerical Modelling

In this numerical model, 1D implicit finite difference method was used to solve Richard's equation which leads to tridiagonal matrix problem, in this case, Thomas algorithm was used to solve it. Originally, Due to hydraulic conductivity varies with respect to pressure head, it make the equation is not linear. So that, Picard iteration needed to silve non linear algebraic equation problem[1]. For numerical modeling, Neumann boundary condition with a constant flux (q) of 329 $^{\mathrm{cm}}/_{\mathrm{days}}$ employed for 1.8 minutes. Soil elements size (Δz) are 0.01 cm, with length of speciment model is 10 cm. The soil column is described in Figure1. Times stepping for this numerical model ranging from 3.6 to 10.8 s. Initial pressure (Ψ) of -500 cm is employed throughtout the soil column, therefore initial water content can be evaluated using Eq. (3)

The numerical simulation is performed on two soil conditions, i.e. sandy loam and non-woven needle-punched polyester geotextile-layered sandy loam. The soil and geotextile materials used in this analysis are based on Vogel et al.[6], Nahlawi et al.[3] researches. Referencing Vogel (2000)[6], saturated soil water content (θ_s), residual water content (θ_r), saturated hydraulic conductivity (K_s),α, and n respectively are 0.410, 0.065, 106.1 $^{\mathrm{cm}}/_{\mathrm{day}}$, 0.0750 cm^{-1}, and 1.89. The filter layer, a non-woven needle-punched polyester geotextile [3] with the Van Genuchten parameters described in Table 1 is utilized.

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Table 1: Soil materials and Van Genuchten properties

No	Materials	θ_s	θ_r	K_s $\mathrm{cm}/\mathrm{days}$	α cm^{-1}	n
1	Sandy loam	0.410	0.065	106.1	0.075	1.89
2	A non-woven needle-punched polyester geotextile	0.875	0.117	34560	0.063	6.363

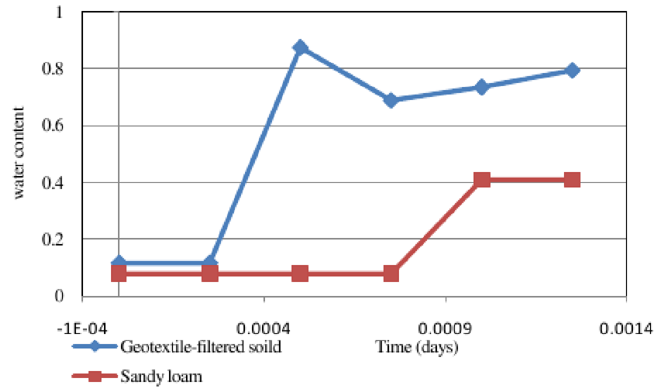

Figure 3: Pressure head vs times

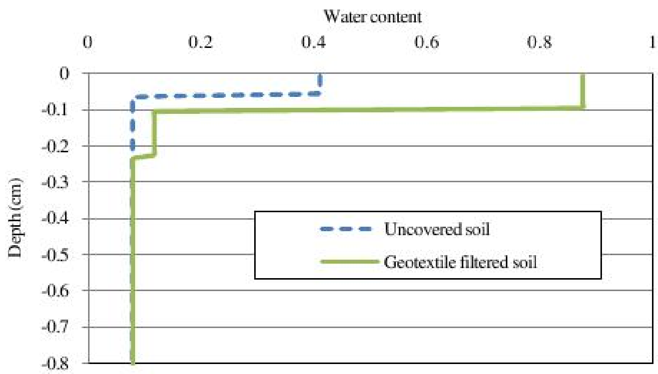

Figure 4: Water content-soil depth curves at 21.6 seconds

4 Results and Discussions

Results of numerical simulation presented here are relation of pressure head and water content against time and filter types effects in 1D water infiltration against pressure head shown in Figure 2, 3 and 5 respectively. The node of -1.85 cm is selected to represent the water content and pressure head behaviour. Based on Figure 2 and 3, the trend of water content and pressure head is increased along the time, but in certain time, it's decreased. This behaviour is influenced by wetting front reachs to sandy loam layer. In Figure 5, it's shown that in the same discharge rate, non-woven geotextile-layered soil requires highest energy compared with anothers, it means if we set up the boundary condition as Dirichlet boundary type, in the same pressure head, water flux throughtout non-woven geotextile has lowest rate, it describes that non-woven geotextile-layered soil has highest energy loss. Again, it relations are related to α and n, so we can consider that air entry-suction and pore-size distribution have strong relation to energy loss.

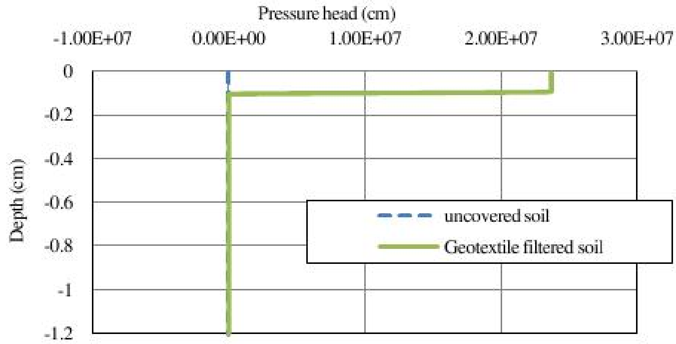

Figure 5: Pressure head-soil depth curves at 21.6 seconds

5 Conclusions

Based on the results of numerical simulation, it's shown that energy needed to discharge the water of non-woven geotextile-layered soil is highest,this situation is influenced by saturated hydraulic conductivity, range of residual water content to saturated water content, etc. Moreover, in certain time, the pressure head is decreased after wetting front reachs the sandy loam layer.

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