Preliminary Study of One Dimensional Infiltration of Water into Manado Soil with Hydrus Software 2D/3D

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ABSTRACT: Preliminary study of one dimensional infiltration of water into Manado soil, sand bentonite soil and Manado Soil and compare with sand bentonite(5%) soil was analyzed with Hydrus Software 2D/3D. The Manado soil was classified with USDA soil standart which is loamy sand. Sand Bentonite (5%) was used Soil Water Characteristic Curve (SWCC) and by using Van Genuchten formula to provide the properties of soil such as residual water content(θr), saturated water content(θs), fitting parameter n,l and α. Hydrus software 2D/3D was used to compute the one dimensional infiltration of water into 1cm x 100cm vertical column for Manado soil or loamy sand and sand- bentonite(5%) soil. Ponded infiltration is initiated with a zero pressure head at the soil surface, while free drainage is used at the bottom of soil profile. The infiltration of water into the soil was measured for five days. The change of water content (θ), pressure head (h) and hydraulic conductivity (K) along the five days (time) were measured for each of soil at observation depth N-50cm of vertical column. The result was shown that sand bentonite better compare than Manado soil to resist water.

Keywords: hydraulic conductivity; infiltrations; manado soil; pressure head; sand bentonite soil; water content;

1 INTRODUCTION

Infiltration has long been a focus of geotechnical problem such as slope stability, erosion and also in agriculture and water research because of its fundamental role in land-surface and subsurface hydrology. A large number of mathematical models have been developed to evaluate the computation of infiltration. The Richards equation was derived using the mass conservation law and Darcy's law (Lei et al., 1988). As a physically based numerical model, the Richards equation has been extended into many complex conditions ([Brunone et al., 2003], [Pachepsky et al., 2003], [Barontini et al., 2007] and [Elmaloglou and Diamantopoulos, 2008]). However, the Richards equation is strongly non-linear and cannot be solved analytically, especially under complex initial and boundary conditions. Consequently, numerical methods such as finite difference and finite element methods have been used to solve Richards equation (Arampatzis et al., 2001). The numerical solution of Richards equation requires an iterative implicit technique with fine discretization in space, which results in tedious solving process (Damodhara Rao et al., 2006). Based on finite element method, the HYDRUS-1D and 2D/3D code was developed to solve the Richards equation and was widely used to simulate one-dimensional and two-three dimensional water movement in variably saturated media (Šimůnek et al., 2005).The literature of unsaturated soils in terms of hydraulic conductivity, water content and pressure head is reviewed. The behavior of unsaturated soil was studied using numerical simulation of 1D modeling in HYDRUS software 2D/3D. Manado soil and sand-bentonite mixed soil (5%) specimens were investigated.

2 MODEL TEST

Two type of soil were used in this analysis. Manado soil was taken from Manado city in Indonesia. Some test such as sieve size analysis,specific gravity, density, direct shear test and water content were done in the laboratory to provide the physical and mechanical properties of Manado Soil . By using the physical and mechanical properties of Manado soil than classified with USDA soil standard Manado soil was loamy sand. The sand bentonite mix soil properties tests were conducted by Dev Raj Pokhrel, 2009. Bentonites are special type of clay which falls on the category of monmorrilonite. Bentonite deposit has two forms, Na-monmorrilonite or Ca-monmorrilonite or both. They have cat-ion exchange capacity; the swelling behavior due to adsorption of water molecules at interlayer cations and at mineral surface. Sodium bentonite is referred to as swelling clay (Koch. D., 2002), which has single water layer particles containing Na+ as the exchangeable ion. Bentonite has excellent water absorption capacity, which is much higher than ordinary clays. When the sodium bentonite gets saturated, its volume increases approximately 14 times greater than that of its original volume. The sodium bentonite is commercially available in the market in the name of "Natural Gel". Sample is prepared by taking a sand- Bentonite mixed soil (5% Bentonite, with initial volumetric water content 0.49) in a consolidation steel ring which is then directly placed in a SWCC device for the test. No special method of sample preparation is done for sand bentonite soil. The data obtained from laboratory tests were given as input in HYDRUS software. The laboratory test data were percentage of sand, percentage of silt, volumetric water content at 33 kPa, and volumetric water content at 1500 kPa. The physical and mechanical properties of Manado soil and sand bentonite mix soil were shown in Table 1 and Table 2.

Table 1. Physical & mechanical properties of soil.

Name of Soil	Sieve Size Analysis			Direct Shear Test	
	% Sand	% Silt	% Clay	C (kN/m2)	φ (o)
Manado Soil	85.3	13	1.7	1.06	32.0
Sand-Bento-nite(5%)	92	5	3	0.03	40

Table 2. Physical & mechanical properties of soil.

Specific Gravity	Bulk Density	Permiabilty Coef.	Initial Water Content
	kg/cm3	m/sec	θ (%)
2.34	1.1	-	1.85
2.65	1.3	2.06E-10	49

3 MODELLING IN HIDRUS-2D/3D

Bentonite soil is not included in the Hydrus 2D/3D soil hydraulic parameter so indirect method was used to provide the initial water content θ_r, saturated water content θ_s, α, m and n (empirical parameters). The soil water retention curves were measured with pressure-plate method. The measured results were fitted to the retention curve equations proposed by van Genuchten (1980) and Brooks and Corey (1964) with the RETC code developed by van Genuchten et al. (1991). The equation of van Genuchten model is described as (van Genuchten, 1980) :

$$\frac{\theta-\theta_r}{\theta_s-\theta_r}=(1+|\alpha h|^n)^{-m} \qquad h>0 \tag{1}$$

$$\theta=\theta_s \qquad h\le 0 \tag{2}$$

where h is the soil water pressure head (cm), θ is the water content (cm^3/cm^3), θ_r and θ_s are the residual and saturated water contents (cm^3/cm^3), respectively, α, m and n are empirical parameters and $m=1-1/n$.

The equation of Brooks–Corey model is (Brooks and Corey, 1964) :

$$\frac{\theta-\theta_r}{\theta_s-\theta_r}=\left(\frac{h_a}{h}\right)^{\lambda}=\left(\frac{1}{\alpha' h}\right)^{\lambda} \qquad \alpha' h>1 \tag{3}$$

$$\theta=\theta_s \qquad \alpha' h\le 1 \tag{4}$$

where α' is an empirical parameter (1/cm) and it is the reciprocal of h_a, h_a is often referred to as the air entry value (cm), and λ is the pore-size distribution parameter affecting the slope of the retention function. The fitting results indicated that the measured soil water retention curves were well described by the van Genuchten model. In this case, the unsaturated hydraulic conductivity of each soil layer can be expressed as (vanGenuchten et al., 1991) :

$$K(h) = \frac{K_s\left\{1-(\alpha h)^{mn}\left[1+(\alpha h)^n\right]^{-m}\right\}^2}{\left[1+(\alpha h)^n\right]^{ml}} \quad (5)$$

where K_s is the saturated hydraulic conductivity and l is an empirical parameter found to be equal to 0.5 for most soils. The corresponding soil hydraulic parameters of each soil are shown in Table 3. The air entry value h_a was obtained from Brooks–Corey model (Table 3).

Table 3. Soil hydraulic parameters of each soil

Name of Soil	Residual Water Content	Saturated Water Content	Saturated Conductivity
	-	-	cm/day
Manado Soil	0.057	0.410	350.2
Sand Bento-nite(5%)	0.01	0.485	0.006205

Table 4. Soil hydraulic parameters of each soil.

Name of Soil	n	l	α
	-	-	-
Manado Soil	2.28	0.5	0.124
Sand Bento-nite(5%)	2.725	0.5	0.0045

The HYDRUS-2D /3D code was based on the one-dimensional Richards equation to simulate water movement in variably saturated media, and the equation was solved by numerical method (Šimůnek et al., 2005). The basic water movement equation was described as :

$$\frac{\partial\theta(h,t)}{\partial t} = \frac{\partial}{\partial z}\left[K(h)\left(\frac{\partial h}{\partial z}+1\right)\right] \quad (6)$$

where h is the soil water pressure head, θ is the volumetric water content, t is time, z is the vertical coordinate with the origin at the soil surface (positive upward), and $K(h)$ is the unsaturated hydraulic conductivity determined by Eq. (5).

For the initial condition and upper boundary condition were:

$$h(z,0) = h_i(z) \quad (7)$$

$$h(0,t) = h_0 \quad (8)$$

where $h_i(z)$ is the initial soil water pressure head through the soil column, and h_0 is the soil water potential at soil surface

The free drainage was to be considered as lower boundary condition :

$$\frac{\partial h}{\partial z} = 0 \quad (9)$$

Hydrus software 2D/3D was used to compute the one dimensional infiltration of water into 1 cm x 100cm vertical column for Manado soil or loamy sand and sand- bentonite (5%) soil and ponded infiltration is initiated with a zero pressure head at the soil surface.

4 RESULT AND ANALYSIS

The Hydrus 2D/3D program was run and the result was given as follow ;

Figure 1 shows that the pressure head of Manado soil was decreased rapidly before one day and constant on the other hand for sand-bentonite (5%) was decreased slowly until 5 days.

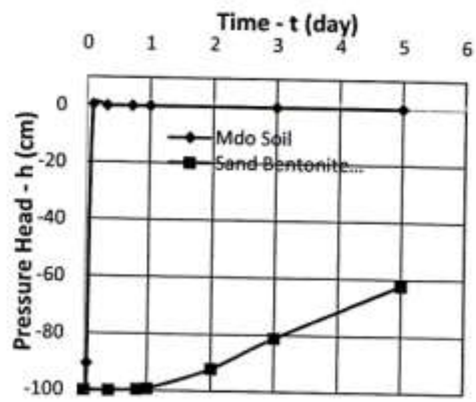

Figure 1. Relationship between Pressure Head – h and Time – t.

Figure 2. shows that the water content – θ of Manado soil was increased and became fully saturated before one day while sand-bentonite (5%) was rapidly fully saturated and slowly increased until 5 days.

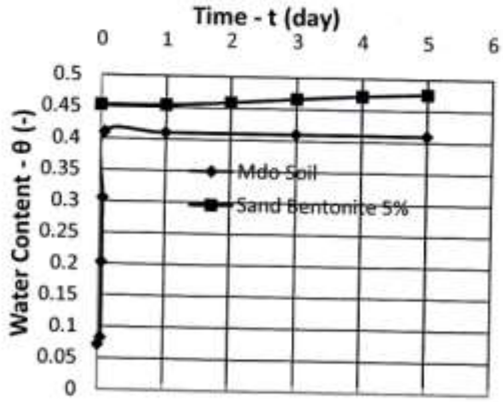

Figure 2. Relationship between Water Content –θ and Time – t.

Figure 3. shows that the hydraulic conductivity significantly larger for Manado soil than for sand-bentonite (5%) soil and decreased when the soil becomes unsaturated. The hydraulic conductivity of sand-bentonite (5%) soil was not changed even the water content increased. When expressed as a function of the pressure head as shown in Figure 4. The hydraulic conductivity was decreased for Manado soil on the other hand for sand-bentonite (5%) the results was not changed.

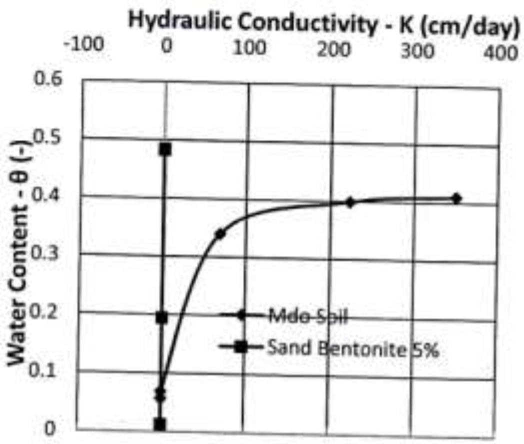

Figure 3. Relationship between Water Content – θ and Hydraulic Conductivity – K run for 5 days.

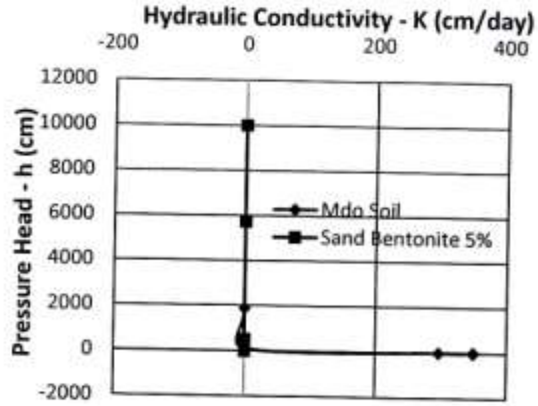

Figure 4. Relationship between Pressure Head – h and Hydraulic Conductivity – K run for 5 days.

5 CONCLUSIONS

One dimension analysis of water infiltration into Manado soil and sand bentonite soil was analysed with Hydrus 2D/3D software.

The water content, hydraulic conductivity and pressure head was analyzed for each soil.The results was shown that sand-bentonite (5%) given a good absorption of water compare than Manado soil.

Sand-bentonite was better to used for protection the water infiltration of cut off – wall, soil water contamination, erosion and slope stability cause of cheap.

For further research various sand-bentonite mix soil and experient in the laboratorium are needed.

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