THE EFFECT OF CLIMATE CHANGE ON THE FLUCTUATION OF WATER TABLE AND SLOPE STABILITY

THESIS

INSAN KAMIL

0906580331

FACULTY OF ENGINEERING

MASTER DEGREE PROGRAM

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ON THE FLUCTUATION OF WATER TABLE AND SLOPE STABILITY

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Propose as one of the requirements for obtaining a Mater of Engineering

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This Thesis was the work of itself, and all sources whether quoted of referenced, I have stated correctly.

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ABSTRAC

Recently, one of the biggest challenges in this century is climate change and global warming. The climate change effect has changed that condition from the regular season to be unpredictable season on the word, where the more extreme conditions such as heavy rain falls and droughts. So To find out and well understanding the physical phases of value of cohesion of soil and slope stability due to water infiltration and rising water table we make the several models to fine FoS due to variation of cohesion and variation of inclination by using software Flac3d. And the result illustrated some of FoS in variation of total cohesion and variation of inclination angle for unsaturated condition.

Keyword : climate change, cohesion, slope stability, infiltration and rising water table, Flac3d

ABSTRAK

Isu terbesar di abad ini adalah tentang berubahan iklim dan pemanasan global. Efek dari perubahan iklim adalah perubahan dari musim yang biasanya menjadi tidak terprediksi dengan baik di dunia, diamana bias terjadi kondisi ekstrim seperti hujan yang sangat lebat maupun kekeringan yang panjang, kondisi ini sangat berpengaruh terhadap muka air tanah. Untuk mendapatkan dan mngetahui secara baik fase secara fisika dari nilai kohesi dari tanah dan kestabilan terhadap lereng akibat dari infiltrasi air dan naiknya muka air tanah maka dibuatlah model untuk mendapatkan nilai kemanan berdasarkan variasi nilai kohesi dan kemiringan menggunakan model numeric Flac 3D. Dan hasil digambarkan dalam fariasi angka keamaan berdasarkan total kohesi dan variasi kemiringan dalam kondisi tidak jenuh.

Kata kunci: perubahan iklim, kohesi, stsbilitas lereng, infiltrasi dan muka air tanah, flac3D

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NOMENCLATURE

θ	water content
ρ	density (kg/m3)
σ	stress / tension (Pa)
τ	shear stress (Pa)
ϕ	friction angle (rad)
ψ	suction head (m)
h_p	depth of ponded water
S	*Suction*
h_{wf}	*hydraulic gradient*
Z_f	Wetting front depth
c	cohesion
g	gravity (m/s2)
p	pore pressure (Pa)
n	porosity factor
K	hydraulic conductivity (m/s)

I. INTRODUCTION

1.1. Background

One of the biggest challenges in this century are climate change and global warming. In sub-tropical area, precipitation is likely to increase in winter but decrease in summer. Furthermore, spring warming will cause earlier snow melt and will change the soil moisture regime. Therefore, it is to be expected that ground water levels will be affected directly by the climatic changes with probably higher fluctuations in the future *(Reto Schnellmann a, Matthias Busslinger b, Hans R. Schneider c, Harianto Rahardjo, 2010)*. Climate history and model predictions for Central Europe show more extreme weather conditions such as heavy rainfall sand droughts are to be expected *(Christensen et al., 2007)*. And in tropical area, with the rainfall-intensity can reach until bigger than 120 mm/day. Climatic changes can cause are duction in matric suction near the ground surface due to rainfall infiltration. Such a reduction can be the triggering factor for shallow land slides, especially for fine-grained soils of low permeability. A significant triggering factor for coarse-grained soils of high permeability like sands is a rise of water table in combination with a decrease in matric suction due to rain fall infiltration. This condition can result in shallow landslides near the ground surface due to a reduction in matric suction or after sometime, it can result in deep landslides due to the rising of water table and increasing positive pore-water pressures at deeper depths.

In Indonesia (tropical area) more than 70 % land slide triggered by rainfall induced *(karnawati , 2006)* and most of the areas where the land slide happened in Indonesia are hilly and mountainous with a population livelihood is agriculture. And most types of crops grown are *Padi*, where *Padi* is a crop that requires a pond of water as a medium for cropping, the system is called *Terasering*. These conditions lead to a puddle on the acres planted to the position of the slope as showed on picture 1.1.

Figure 1. 1 Many of Padi's field lay on the top of slopes in Indonesia called *Terasering*

It will be full pond on the filed when rainy season and dry in summer. Unfortunately, the climate change effect has changed that condition from the regular season to be unpredictable season on the word, where the more extreme conditions such as heavy rain falls and droughts. Therefore, climate changes are expected to reduce increased variations in infiltration characteristics and of water table in slopes. Many slope failure have been observed to occur during times of water level fluctuation (*Raharjo, 2009)*.

1.2. Objective

This paper is submitted to accomplish the Master Degree, in objective:

To find out and well understanding the physical phases on differential value of cohesion of soil and slope stability due to water infiltration and rising water table by numerical analysis model using software Flac3d .

1.3. Planning

INTRODUCTION

This chapter discusses about the effect of climate change to slope stability, objective and the planning of this research

INFILTRATION ANALYSIS

This chapter discusses about influence of rainfall-induced and rising water table on bearing capacity and slope stability due to volumetric water content and suction

NUMERICAL ANALISYS

This chapter shows about the result about simple model stability analysis of slope with the finite element software FLAC3D

CONCLUSION

In this chapter summarizes entire chapter and suggest the topic for the next research

II. INFILTRATION ANALYSIS

The water infiltration in to soil during rainfall from the surface and then distributes in to unsaturated soil zone. The soil moisture condition, water pressure and permeability in unsaturated soil are the factors that influencing the water distribution process in to soil. The infiltration capacity (*i*), which is a measure of the maximum rate at which water can enter the soil, varies through out a rainfall event. It is controlled mainly by the permeability and water content of the soil and the topography of the slope .Generally in un saturated slopes the infiltration capacity is initially high as large suction pressures are present which compensate for the relatively low unsaturated permeability (K) of the soil. As infiltration continues the in situ suction and *i* reduce. The infiltration rate (I) is the rate of water supply to the slope, and generally speaking is equal to or less than the rain fall intensity *(Reto Schnellmann a, Matthias Busslinger b, Hans R. Schneider c, Harianto Rahardjo, 2010).*

2.1. The Safety Factor Of Slope

Shearing resistance in soil slopes is mainly governed by shear strength, which in turn is controlled by effective stress. Effective stress is defined as total stress minus pore-water pressure. Therefore, a rising water table increases pore water pressures in the slope, reduces the effective stress and consequently decreases stability of slope. Hence, pore-water pressures play a crucial role in the stability of earth structures. It is important to understand the response of pore-water pressures to changes in ground water levels in order to prevent damages like slope failures.

The stability evaluation could be performed by providing the soil parameters including shear strength properties and unit weight. The factor of safety at various slip plane depth were then calculated by using a modified infinite limit equilibrium method as follow *(Sung and Seung, 2002).*

$$FS = \frac{C + \sigma_n \tan \emptyset'}{\gamma h \cos\alpha \sin\alpha}$$

$FS = Factor\ of\ Saffety$

$C = Total\ cohesion$

$\sigma_n = Normal\ stress/tention$

$\gamma = Unit\ weight\ of\ soil$

$h = deph$

$\alpha = Agle\ of\ slope$

Saturated soil

$$\tau = c' + (\sigma_n - U_w) \tan \emptyset'$$

With,

$\tau = Shear\ streght$

$c' = Effective\ Cohesion$, *which is the shear strenght when the effective normal stress is equal to zero*

$\sigma_n = Normal\ stress/tention$

$U_w = Pore\ water\ pressure$

$\emptyset'$ = *Friction Angle*

Un-Saturated soil

The total cohesion (C) of unsaturated soil has been composed by two part, the first is effective cohesion (c') and the second represents contribution of suction to strength *(Kenneth Gavin and Jianfeng Xue, 2007).*

$$\tau = c' + (\sigma_n - U_a) \tan \emptyset' + (U_a - U_w) \tan \emptyset^b$$

$$C = c' + (\sigma_n - U_a) \tan \emptyset^b$$

The shear strength equation for unsaturated soil can also expressed in term of other combination of stress stat variable

$$\tau = c' + (\sigma_n - U_{wa}) \tan \emptyset' + (U_a - U_w) \tan \emptyset''$$

$$\tan \emptyset'' = \tan \emptyset^b - \tan \emptyset'$$

With,

$\tau = Shear\ streght$

$c' = Effective\ Cohesio$

$C = Total\ cohesion$

$\sigma_n = Normal\ stress/tention$

$U_w = Pore\ water\ pressure$

$U_a = Pore\ air\ pressure$

ϕ' = *Friction Angle*

ϕ^b = *Angle indicating the rate of increase in shear strength relative to the matric suction,* $(U_a - U_w)$

$\phi'' = Friction\ angle\ associated\ with\ the\ matric\ suction\ stress\ state\ variable$

2.2. Infiltration Mechanism

2.2.1. Green-Ampt Model

This model was derived to predict the infiltration of pond of water in to underlying soil. The basic assumption under pinning the model is that infiltration causes the development of well-defined wetting front. The soil above the wetting front is fully saturated, while below the wetting front it remains at the initial (pre-infiltration) water content. Gravity and matric suction effects control the movement of water in the saturated zone, and the hydraulic gradient (h_{wf}) at the wetting front is:

$$h_{wf} = \frac{h_p + Z_f + S}{Z_f}$$

Where ,

$h_{wf} = hydraulic\ gradient$

$h_p = depth\ of\ ponded\ water$

$Z_f = Wetting\ front\ depth$

$S = Suction$

And then by applying Darcy Law the infiltration capacity of the soil under non-pond conditions at *t* time can be calculated with ;

$$i = Ks(\frac{Z_f + S}{Z_f})$$

$i = Infltration\ Capacity$

$Ks = Permeabilty\ of\ saturated\ soil$

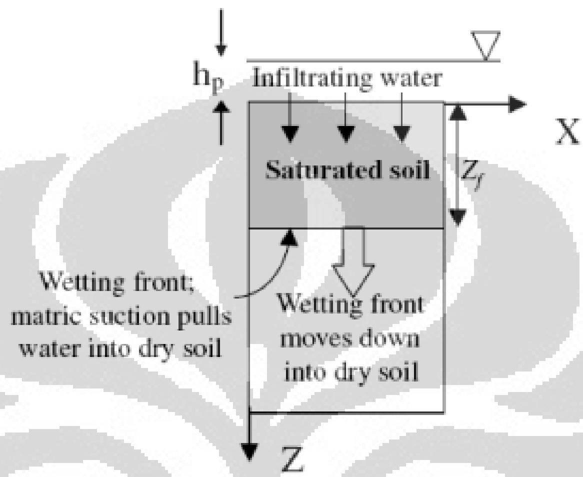


Figure 2. 1 Wetting front development in the Green-Ampt *(Kenneth Gavin, Jiangfeng Xue).*

The main assumptions in the Green–Ampt model is that the soil in the wetted zone is fully saturated. How-ever, field measurements and others show that failure occurs before the soil above the wetting front becomes fully saturated. If the soil is partially saturated, the water phase is not continuous, and the hydraulic head in this zone is controlled exclusively by matric suction. The hydraulic head Z is there fore not applicable to unsaturated soils under these conditions *(Kenneth Gavin 1, Jianfeng Xu)*.

2.2.2. The Model considering Suction Variation

The assumption for a slope which remains partly saturated at failure are *(Kenneth Gavin 1, Jianfeng Xu)*:

- The soil is continuously supplied with water but not fully saturated within the wetted zone. The assumption is generally restricted to the soils slopes, where the pond cannot occur and the supply of water to the soil is there for eliminated

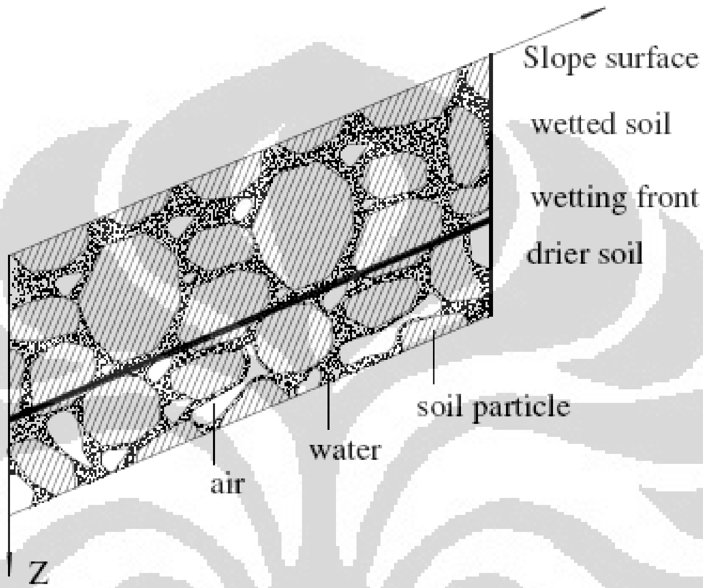


Figure 2. 2 Wetting front developed in unsaturated soil slope (Kenneth *Gavin, Jiangfeng Xue).*

- After rainfall the final suction profile in the wetted zone is linearly distributed within the wetting front. Although both the initial and final suction profiles are often non-linear as illustrated by *(Zhan and Ng)*,the analysis is greatly simplified by modeling complex nonlinear suction profiles with several discrete linier function.

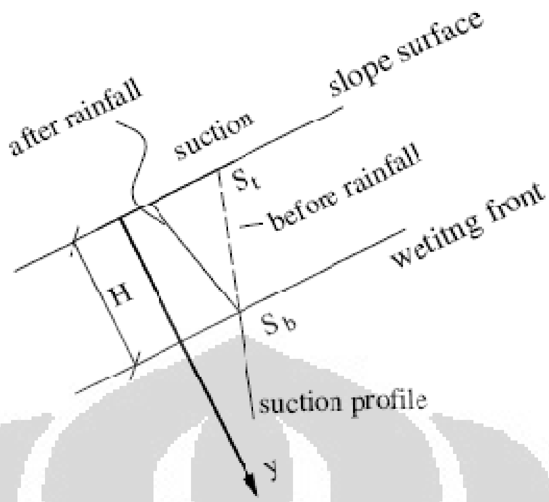


Figure 2. 3 Suction profile assumed in the new model *(Kenneth Gavin, Jiang feng Xue).*

- The permeability of the soil above the wetting front is uniform with depth and time. In the class of simple infiltration models considered, the soil permeability is often assigned a constant value (usually the saturated permeability because of the assumption that the soil becomes fully saturated during infiltration). If the soil is partially saturated the permeability depends on the negative pore water pressure (or the degree of saturation)

Due to the continuous supply of water at the ground surface (during rainfall), the matric suction at the ground surface is zero. Setting the ground surface as the reference elevation (where the total hydraulic head is zero) and given the suction value at a depth *y* is *Sy*, the hydraulic gradient *(hi)* between the surface and the depth of *y* is:

$$hi = (\frac{S_y - 0}{y})$$

and for infiltration capacity at the depth y can be expressed as:

$$i = K(\frac{S_y}{y})$$

Where;

$hi\ = Hydraulic\ gradient$

$i\ \ = infiltration\ capacity$

$S_y = Suction\ value\ at\ a\ depth$

$y\ = depth$

$K\ = Permeabilty\ of\ un - saturated\ soil$

The permeability of the soil and the hydraulic gradient due to matric suction is controlling the infiltration capacity. The infiltration capacity will be greater than the permeability of the soil when *Sy/y*>1. This situation occurs in dry soils with high initial matric suction. Under these conditions, an initially high hydraulic gradient can compensate for the low unsaturated soil permeability and result in a large infiltration capacity *(McDougall JR ,Pyrah IC)*. If the infiltration capacity is larger than or equal to the rainfall intensity *(i>Ir)*, all rainfall will infiltrate into the slope. Therefore, the infiltration rate is controlled by the rainfall intensity *Ir*. As the suction values in the wetted zone decrease and the wetting front depth increases, the hydraulic gradient and infiltration capacity decrease and runoff will start once the infiltration capacity is lower than the rainfall intensity *(Reto Schnellmann a, Matthias Busslinger b, Hans R. Schneider c, Harianto Rahardjo, 2010)*.

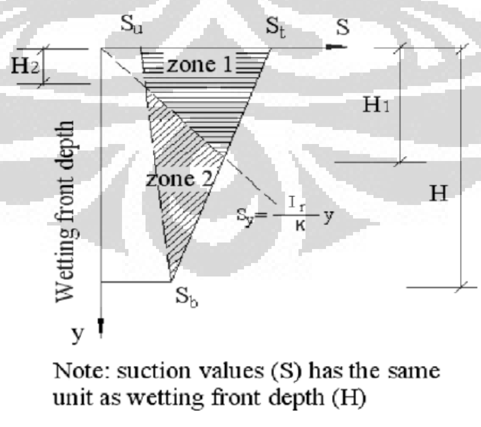


Figure 2. 4 Two zone in the suction profile within wetting front *(Kenneth Gavin 1, Jianfeng Xue)*

From the equation ;

$$Ir < K(\frac{S_y}{y})$$

We can rewriting,

$$S_y > y(\frac{I_r}{K})$$

This condition describe that the suction value is larger than $y(\frac{I_r}{K})$, indicate that the infiltration capacity is greater than the rainfall intensity.

In zone 1we have;

$$S_y > y(\frac{I_r}{K})$$

In this zone, the infiltration rate is controlled by the rainfall intensity Ir and all the water will infiltrate in to the soil.

And in zone 2 we have;

$$S_y < y(\frac{I_r}{K})$$

and

$$i = K\left(\frac{S_y}{y}\right) < Ir$$

In this zone the infiltration capacity is lower than the rain fall intensity

According to the law of mass conservation, in zone1, we have;

$$Ir\ dt = \Delta\theta\, dy$$

Rewriting the equation and integrating with depth *(y)*, we have the time required to form the wetting front to depth *H1* in zone 1

$$T1 = \frac{\Delta\theta\, H1}{Ir}$$

As infiltration continues, suction values in the soil decrease and eventually fall into zone 2. In this zone, the infiltration capacity is lower than the rainfall intensity and the actual infiltration rate *(I)* is given by:

$$I = i = K(\frac{S_y}{y})$$

Therefore;

$$K\left(\frac{S_y}{y}\right) dt == \Delta\,\theta_2 dy$$

By integration we get;

$$T2 = \frac{\Delta\,\theta_2(H^2\ - {H_2}^2\,)}{2KSb}$$

Where,

Sb = the suction value at wetting front

And then the total Time needed to form the wetting front is;

$$Ttotal = T1 + T2$$

$$Ttotal = \frac{\Delta\theta H1}{Ir} + \frac{\Delta\,\theta_2(H^2\ - {H_2}^2\,)}{2KSb}$$

2.3 Soil Water Characteristic Curve

The variation of permeability (or water content) with change in suction can be measured using a soil water characteristic curve (SWCC). Whilst the exact form of the SWCC will depend on the soil type and whether the soil is experiencing wetting or drying *(Zhan and Ng)* describe the general form of an SWCC shown in Fig.2.5, which shows the water content varying from the fully saturated condition at zero suction, to a residual water content at very high suction. It is clear that the SWCC relationship is highly nonlinear at suctions close to the saturated and residual values, whilst at intermediate suctions it is relatively linear (noting that suction is plotted on a log scale)

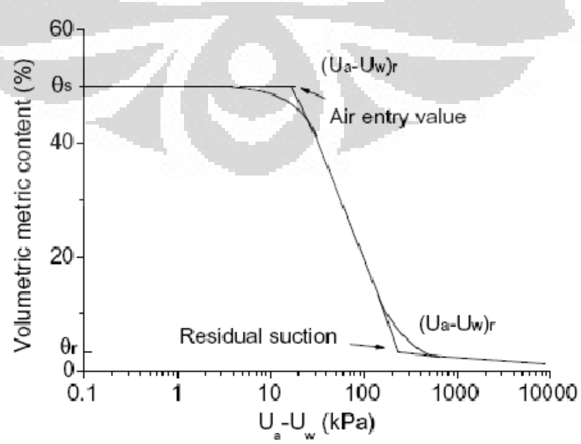


Figure 2. 5 Typical soil-water characteristic curve *(after Zhan and Ng)*

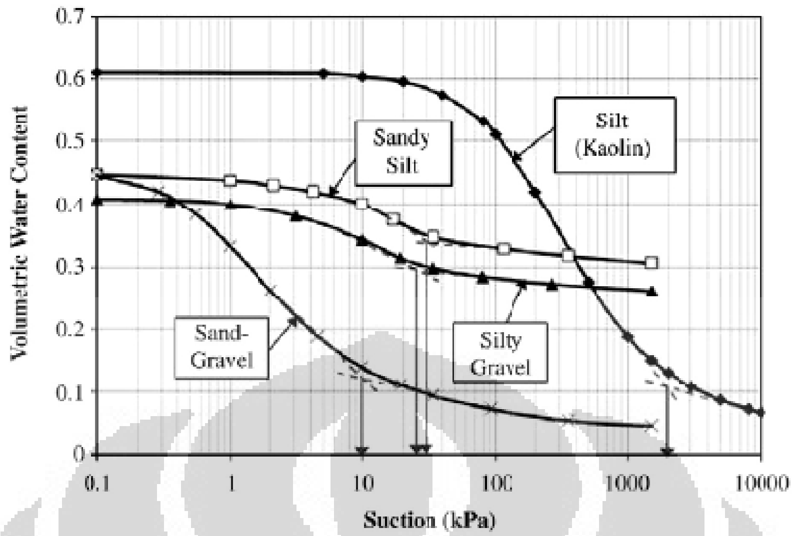


Figure 2. 6 Soil-water characteristic (SWCC) of soils *(Lee Min Lee, Nurly Gofar, Harianto Rahardjo)*

The soil-water characteristic curve (SWCC), determined from the laboratory pressure plate extractor tests, predicted from the method of *Van Genuchten (1980)*

III NUMERICAL ANALISYS

3.1. Definition Model

A simple models to examine the Safety Factor of slopes wit the 3 condition for 40^o inclination and in saturated condition in 3 inclination by using software Flac3d 2 dimension analysis, and the condition are:

1. For saturated condition, the simulation using 3 inclination models 35^o, 40^o and 45^o inclination:

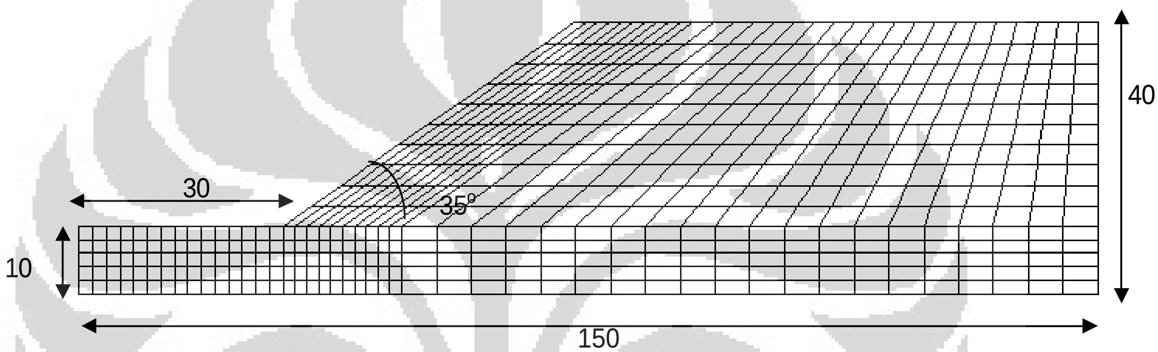


Figure3. 1 The geometry for 35^o inclination

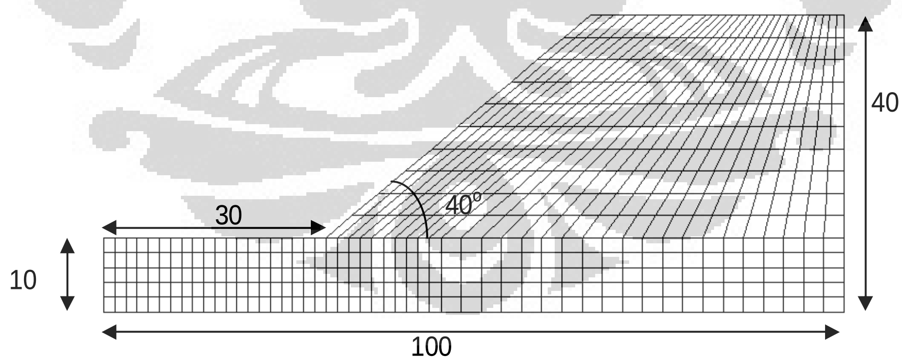


Figure3. 2 The geometry for 40^o inclination

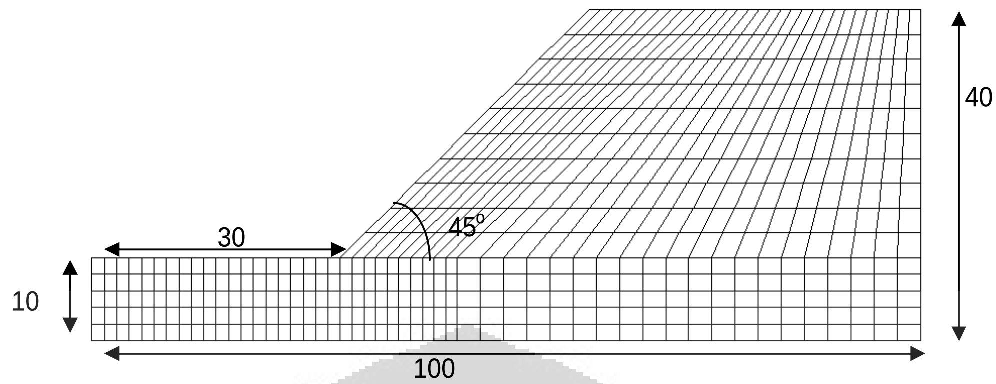


Figure3. 3 The geometry for 45° inclination

2. Normal condition (before rainfall) in 35° and 40° inclination,
   - First condition, when the water table in -10 m depth and the variation of suction linier to the top (zero on water table and increase until 500 kPa to the top linier)
   - Second condition, the simulation when rainfall induced when the suction 100 kPa until -2 m depth (wetting front)), 300 kPa in -2 m depth and 0 on water tabel, wetting front generally reach ± 2 m depth *(Kenneth Gavin 1, Jianfeng Xue, 2007).*
   - The third condition, when the suction value on the surface is zero and 100 kPa in -2 m depth.
   - And the fourth condition is saturated soil, where the model in fully saturated soil condition, when after rainfall induced and rising water table.

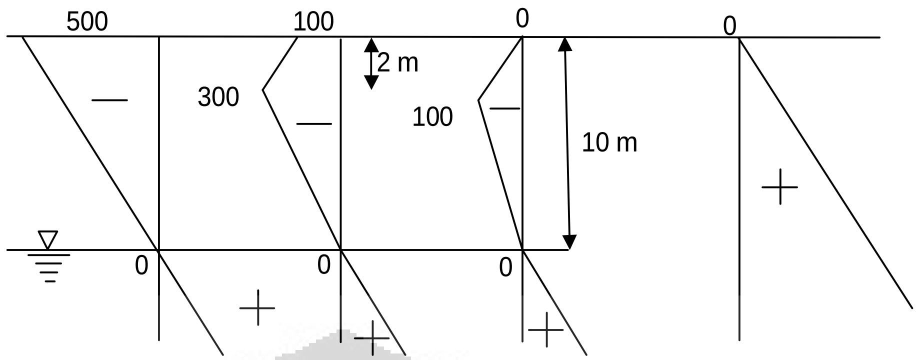


Figure3. 4. simulation condition for 40^o and 35^o inclination (a) water table -10 m (b) rainfall condition and (c) when the suction on the surface is 0 and (d) fully saturated

Table 1. Soil properties of model

Soil properties	Sandy clay
ρ_s (kN/m^3)	16,11
ρ_d (kN/m^3)	11,05
Gs	2,58
Void ratio	1,03
K (m/s)	1,57^{-7} – 6,31 x 10^{-5}
C' (kPa)	12,74
ϕ (^{o})	26,84
ϕ^b (^{o})	16,5

3.3. Boundary condition

- In unsaturated conditions, the simulation using 3 inclination models 35^o, 40^o and 45^o inclination, where three of models are in fully saturated soil condition where the cohesion is using c'= 12,74 kPa

- In Normal condition (before rainfall) in 35° and 40° inclination,
  - First condition, when the water table in -10 m depth and the variation of suction linier to the top (zero on water table and increase until 500 kPa to the top linier) , the variation on suction influence to deferential of total Cohesion by using the formula from *(Fredlund and Raharjo)).*

$C = c' + (\sigma_n - U_a) \tan \emptyset^b$

Or

$C = c' + (\sigma_n - U_a) \tan \emptyset^{"}$

And the result of the variation of total cohesion each layer are:

Table 2 Value variation of cohesion

Depth (m)	S (kPa)	$C = c' + (\sigma_n - U_a) \tan \emptyset^{"}$ (kPa)
0	500	141,79
-1	450	128,88
-2	400	115,98
-3	350	103,07
-4	300	90,17
-5	250	77,26
-6	200	64,36
-7	150	51,45
-8	100	38,55
-9	50	25,64
10	0	12,74

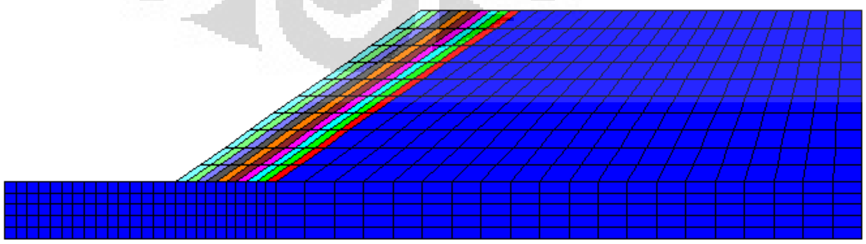


Figure3. 5 The variation of total cohesion in 30° inclination

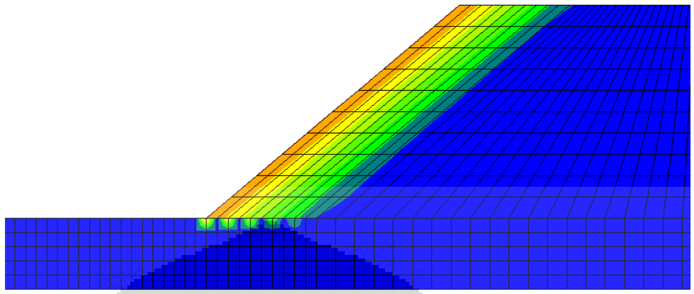


Figure3. 6 The variation of total cohesion in 40^{o} inclination

- Second condition, the simulation when rainfall induced when the suction 100 kPa until -2 m depth (wetting front)), 300 kPa in -2 m depth and 0 on water tabel, wetting front generally reach ± 2 m depth *(Kenneth Gavin 1, Jianfeng Xue, 2007).*

Table 3 the variation of cohesion value after rainfall

Depth (m)	S (kPa)	$C = c' + (\sigma_n - U_a) \tan \emptyset''$ (kPa)
0	100	38,55
-1	200	64,36
-2	300	90,17
-3	262,5	80,49
-4	225	70,81
-5	187,5	61,13
-6	150	51,45
-7	112,5	41,78
-8	75	32,10
-9	37,5	22,42
10	0	12,74

- The third condition, when the suction value on the surface is zero and 100 kPa in -2 m depth.

Table 4 the variation of cohesion value after rainfall

Depth (m)	S (kPa)	$C = c' + (\sigma_n - U_a)\tan\emptyset''$ (kPa)
0	0	12,74
-1	50	30,59
-2	100	48,43
-3	87,5	43,97
-4	75	39,51
-5	62,5	35,05
-6	50	30,59
-7	37,5	26,12
-8	25	21,66
-9	12,5	17,20
10	0	12,74

- And the fourth condition is saturated soil, where the model in fully saturated soil condition where the cohesion is using c'= 12,74 kPa.

3.4. Stability analysis of slopes

For saturated condition, the simulation using 3 inclination models 35^o, 40^o and 45^o inclination and the result are:

Table 5 The FoS in Saturated condition

Slope Inclination	FoS	deviation
35^o	1,19	
		0,14
40^o	1,05	
		0,11
45^o	0,94	

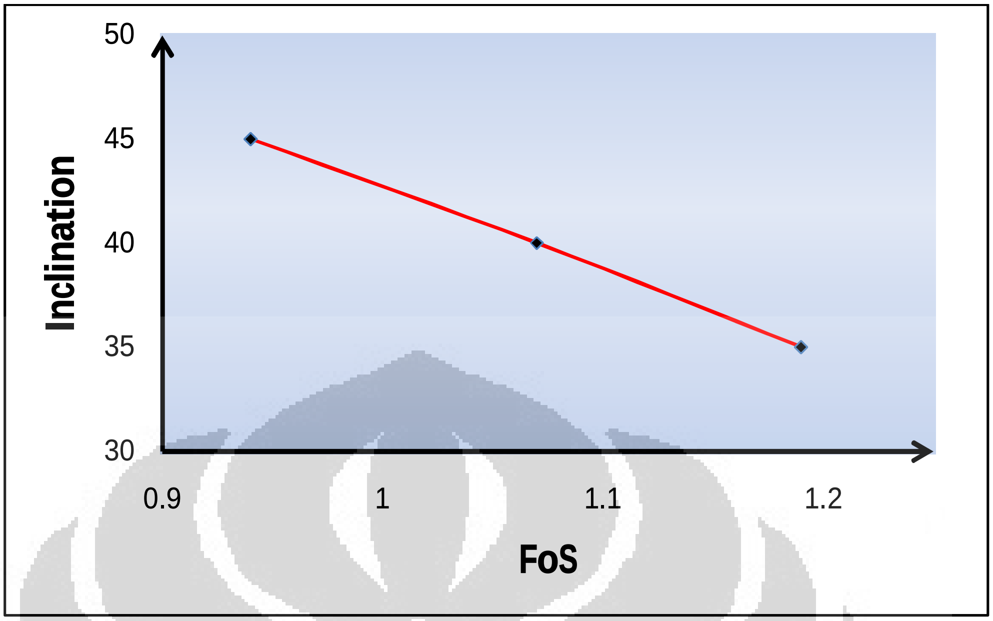


Figure3. 7   FoS vs Inclination in saturated soil

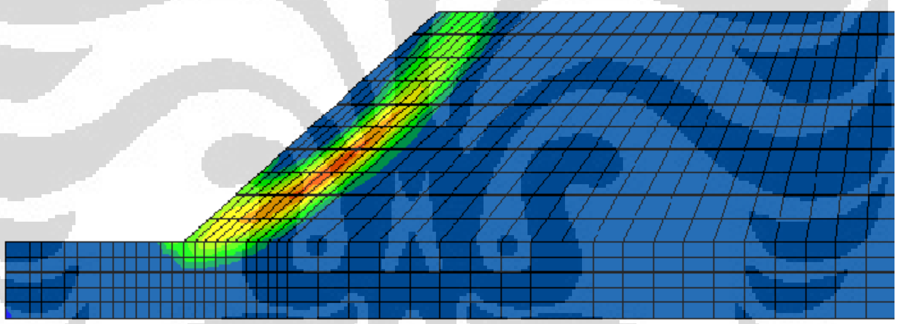


Figure3. 8 The Shear strain rate in saturated condition in 35^{o} inclination and FoS is 1,19

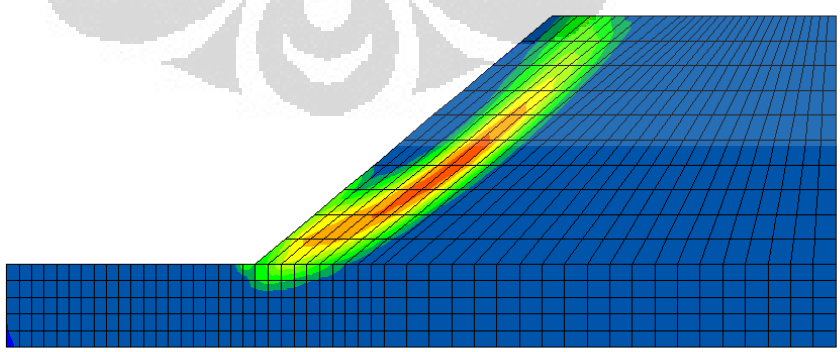


Figure3. 9   The Shear strain rate in saturated condition in 40^{o} inclination and FoS is 1,05

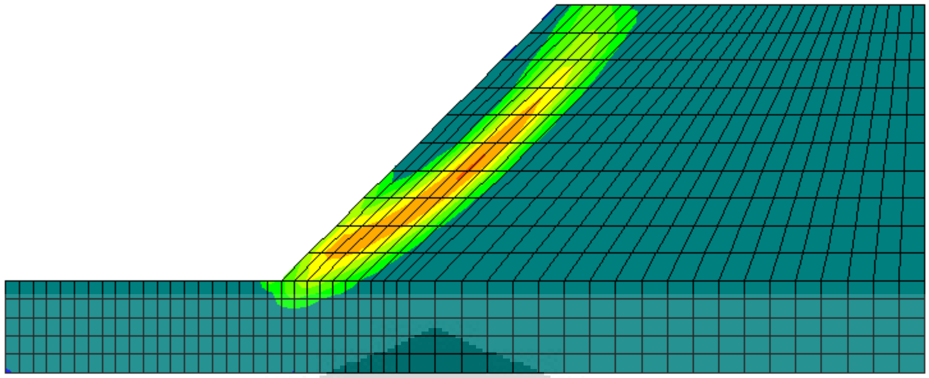


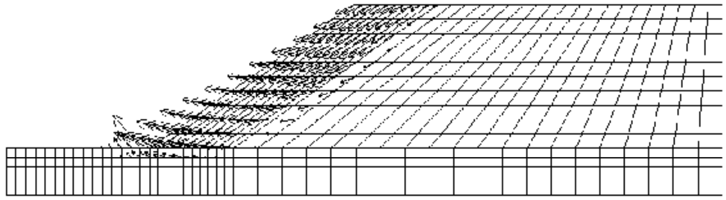
Figure3. 10 The Shear strain rate in saturated condition in 45^o inclination and FoS is 0,94

From the graphic 3.1 we can see that the changes of safety factor in saturated condition almost linier between safety factors against inclination of slope, where the deviation between slope 35o and 40o is 0,14 and the deviation between slope 40^o and 45^o is 0,11. So that, the decreased in safety factor due to increasing of inclination in the same condition and soil properties is in range 0,11-0,14.

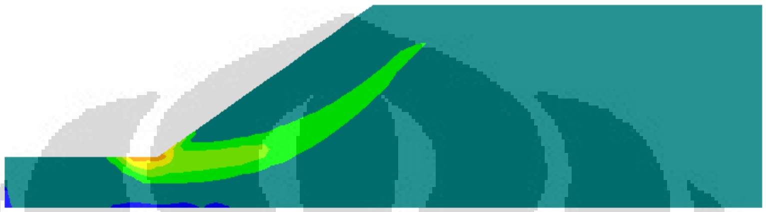
And then, from stable slopes with SoF more than 1 are 40^o and 35^o will be calculated SoF on the 4 condition and will be seen the behavior of FoS due to inclination and variation of cohesion.

Normal condition (before rainfall) in 35^o and 40^o inclination,

- First condition, when the water table in -10 m depth and the variation of suction linier to the top (zero on water table and increase until 500 kPa to the top linier)

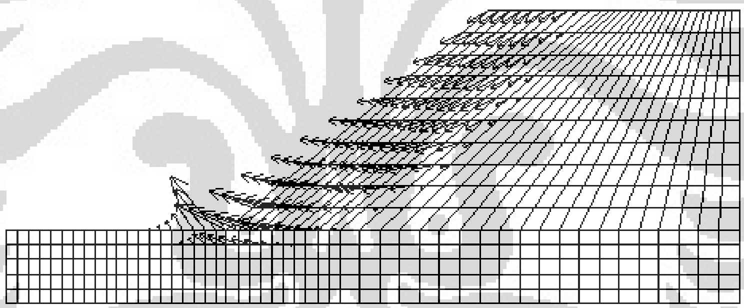


(a)

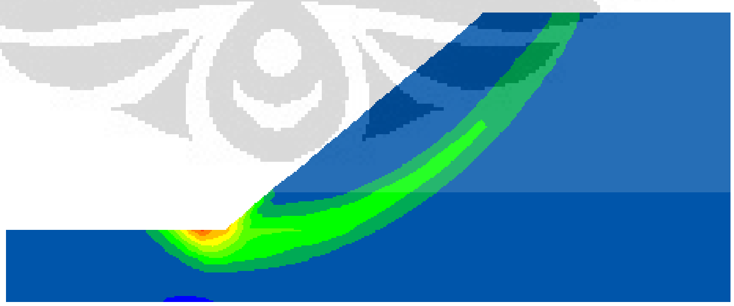


(b)

Figure3. 11 The Shear strain rate in unsaturated condition in 35° inclination and the FoS is 1,38 (a) Displacement vector (b) Shear Strain rate



(a)

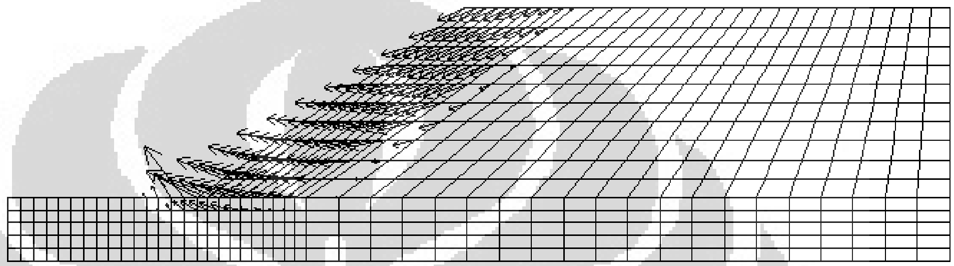


(b)

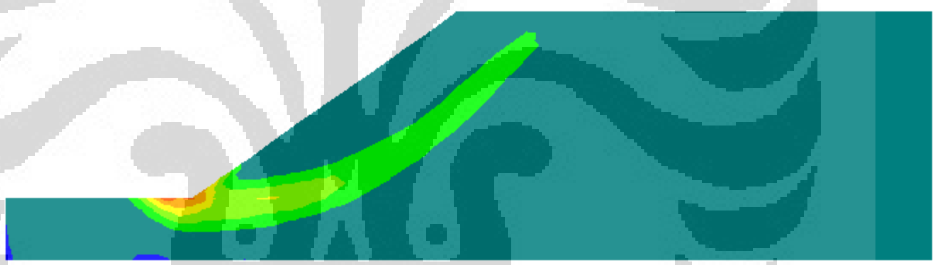
Figure3. 12 The Shear strain rate in unsaturated condition in 35° inclination and the FoS is 1,26 (a) Displacement vector (b) Shear Strain rate

The result indicated that the critical value happen on the water table slip with factor of safety 1,38 for 35^{o} and 1,26 for 40^{o}.

- Second condition, the simulation when rainfall induced when the suction 100 kPa until -2 m depth (wetting front), 300 kPa in -2 m depth and 0 on water tabel, wetting front generally reach ± 2 m depth *(Kenneth Gavin 1, Jianfeng Xue, 2007)* water tabel, depth.

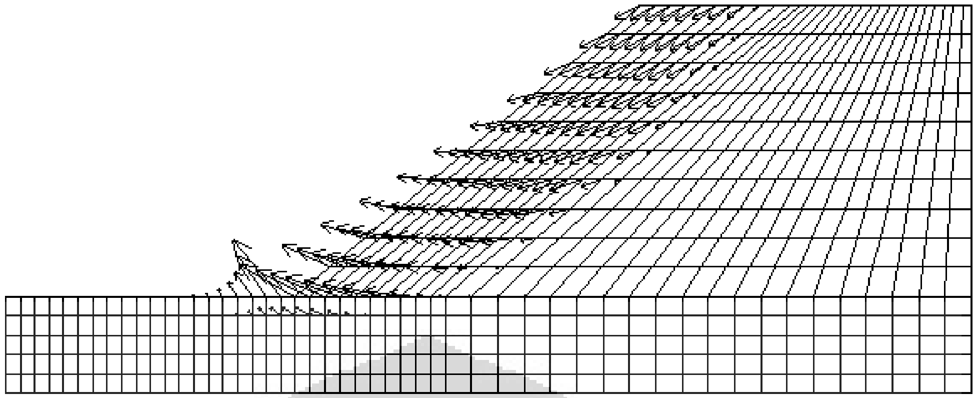


(a)

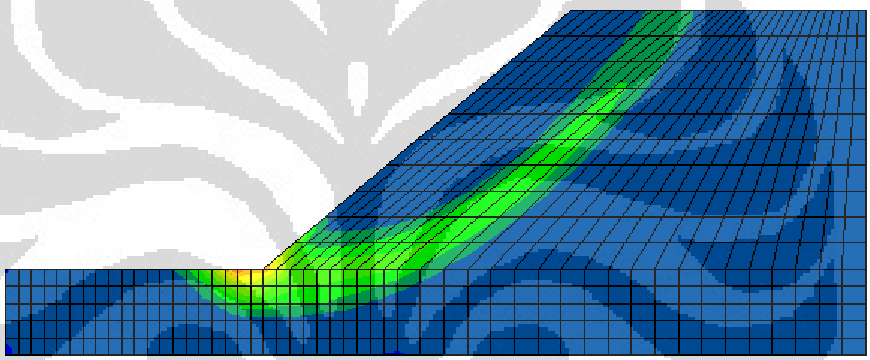


(b)

Figure3. 13 The Shear strain rate in unsaturated condition in 35^{o} inclination and the FoS is 1,37 (a) Displacement vector (b) Shear Strain rate



(a)

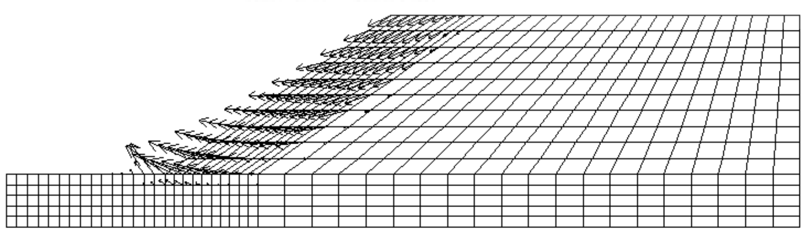


(b)

Figure3. 14 The Shear strain rate in unsaturated condition in 40° inclination and the FoS is 1,22 (a) Displacement vector (b) Shear Strain rate

The result indicated that the critical value still happen on the water table.

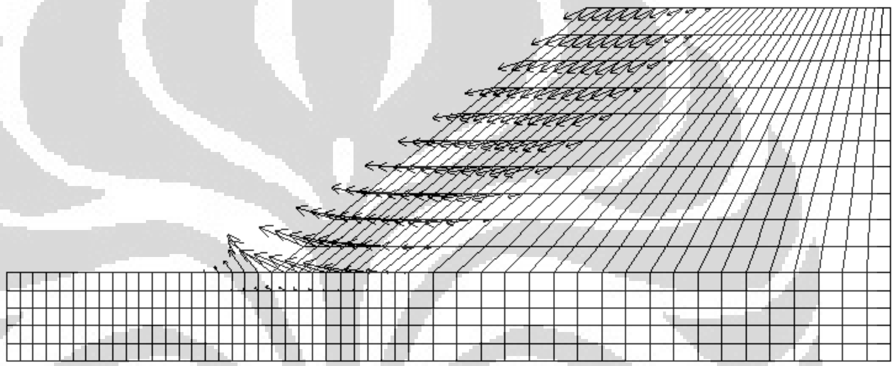
- The third condition, when the suction value on the surface is zero and 100 kPa in -2 m depth.



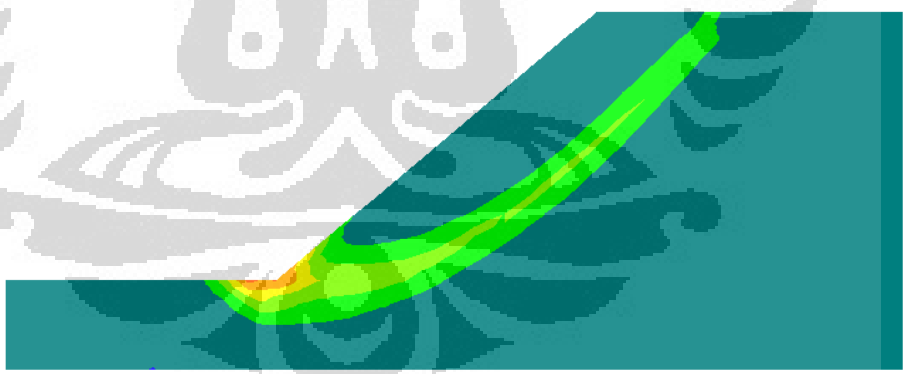
(a)

(b)

Figure3. 15 The Shear strain rate in unsaturated condition in 35^o inclination and the FoS is 1,33 (a) Displacement vector (b) Shear Strain rate



(a)



(a)

Figure3. 16 The Shear strain rate in unsaturated condition in 40^o inclination and the FoS is 1,20 (a) Displacement vector (b) Shear Strain rate

- And the fourth condition is saturated soil, where the model in fully saturated soil condition, when after rainfall induced and rising water table. The results are SoF 1,19 for slope 40o and SoF 1,05 for 35o slope

And the result of FoS calculation can see in table 4.

Table 6 FoS and Condition of soil in 40^o inclination

Condition of soil	FoS 35^o	FoS 40^o	deviation
1. Unsaturated	1,38	1,26	8,6 %
2. Rainfall	1,37	1,22	10,9 %
3. After rainfall induced	1,33	1,20	9,8%
4. saturated	1,19	1,05	11,7%

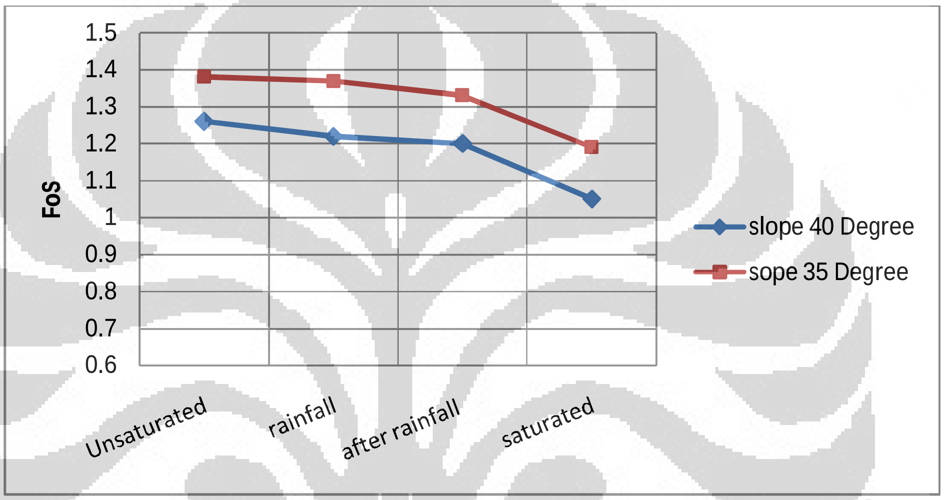


Figure3. 17 FoS vs condition of Total Cohesion

On the slope 35^o, changing FoS of the condition 1to 2 is 0.1, from condition 2 to 3 is 0.4 and the condition 3 to 4 is 0.14, while from condition 1 to 4 the deviation is 0.19

On the slope 40^o, changing FoS of the condition 1to 2 is 0.4, from condition 2 to 3 is 0.02 and the condition 3 to 4 is 0.15, while from condition 1 to 4 the deviation is 0.21.

From the analysis result, indicated that rainfall induced and rising water table is really give big influence to the slope stability in sandy clay. Where, in the same soil properties and equal treatment with 5^o deference the the biggest change of FoS occur from condition 3 to 4. And from condition 1 when the suction occur to saturated condition when the suction I zero, the Fos decrease about 0.19-0.21 on slope 35^o-40^o, this behavior indicate that suction is really give big influence to the slope stability.

4.5. Evaluation

Those three analyses are just a result of simplified model and general models from the field condition. So the result needs to be evaluated due to field mass movement occasion.

IV CONCLUSION

Numerical result of the slope stability analysis (FoS) shows that the soil mass movement for slope is influenced by rainfall induced. From three models in the angle of inclination 40^o and 35^o, it is proved that the value of safety factor for the first model did not change significantly. And, from condition 1 when the suction occur to saturated condition when the suction I zero, the Fos decrease about 0.19-0.21 on slope 35^o-40^o, this behavior indicate that suction is really give big influence to the slope stability.

Due to field condition where the pond condition is happen on the top of sloop (because of *Padi's* field laying on it), so the saturated condition is occur on the slope. This condition will give a big difference on the variation of angle of inclination (in saturated condition). It also gives big influence for slope stability where the value of FoS are 1.19 for 35^o, 1.05 for 40^o and 0.94 for 45^o inclination.

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