The slope stability analysis in geotechnical engineering biology essay

The slope stability analysis in geotechnical engineering is complicated its mechanism and the geological history of the slope. The classical way to analysis the slope stability is accessed using two methods; the basic continuum mechanics or the limit equilibrium approach. There are some post-mortem analyses of landslides in the past; it was found the cause the slope failure due to tension cracks. The rainfall infiltration and seepage through tension cracks in soil slope is widely recognized (Fan Ping et al., 2005) and (Chowdhury & Zhang, 1991).

There are several factors involved in rainfall induced slope failure. Mainly in this chapter, there are only two factors influence in soil slope failure will be discussed. Numerical analysis of the rainfall infiltration through fracture and how it changes the seepage patterns and slope failure into soil slopes and influence of vegetation cover in slope stability analysis calculations. The rainwater infiltrate through soil fracture into deeper layers and changes the seepage patterns and pore water pressure conditions of soil.

Forty years before researchers incorporating the vegetation effects in slope stability analysis but the vegetation effects usually ignored in conventional methods of slope stability analysis. The vegetation impact on slope stability calculation, in this research only applied the root reinforcement effects in slope stability calculations.

The root reinforcement adds as the apparent cohesion into the Mohr-Coulomb model. The back-analysis of some slope failures indicates the operational effective strength of roots in slopes. The pioneer studies show the significant influence in soil slopes analysis.

2. 2 Slope with a fracture

Findings from previous researchers are examined in an attempt to present a general background to the effects of rainfall infiltration in the slope with fracture, how its affect the general slope mechanism. The rainfall infiltration through slope fractures is one of the most probable factors in slope stability analysis. The researchers carried out several methods and try to simulate the rainfall infiltration through soil slopes with laboratory experiments and theoretical calculations.

Some tension cracks are often found at the upper edge of natural cut soil slopes. The tensile region developed in upper part of the slope, the cracks appear in tension zone. The array of micro cracks are oriented in such way (Cai et al., 2005), the micro cracks will form the distinct cracks at the upper edge of the soil slopes during dry period after prolonged wet and dry cycle (Nurly Gofar et al., 2006).

The rainwater flow through the cracks and change the seepage pattern in deeper layers, the water head in the crack changes the usual seepage pattern and water table in soil slope. If the crack propagates up to ground water table, it is possible to foam the saturated soil column from the surface layer. The smaller depth cracks also foam the saturated soil column around the crack area at rainy season. The rain water infiltration through cracks, the water head help to increase the infiltration ratio in a soil slope at wet season, the moisture content above the soil's phreatic surface and around tension crack area clearly increases and reduces the soil's matric suction in a soil slope (Azman et al., 2008).

Fan Ping et al (2005) studied the behaviour of the fracture in a soil slope with different type of fracture properties. The study has been conducted to analysis in different ways. The rainfall infiltration through fractures with different fracture depth, different fracture width, influence of crack locations along the slope face and different surface conditions.

The effects of tension cracks in soil slope stability, now it has been widely recognized. The recent researchers try to study some new methods to determine the location of the tension crack and its appropriate depth. The previous approach for calculating the tension cracks in soil slope based on Rankine's earth pressure theory using Taylor's equation (Chowdhury & Zhang, 1991). When the earth pressure undergoes to negative of earth pressure in a cohesive soil medium, it's free to yield (move) laterally.

; Dt = Zc (2. 1)

In which and are the effective shear strength parameters, angle of internal friction and cohesion respectively and is the unit weight and Zc maximum depth of tension crack, it is depend on the slope geometry. It's based on assumption active Rankine state only applicable to homogeneous soil and it's not consider to geometry of the slope and factor of safety.

Stephen et al (1994) used new approach for direct prediction of the tension cracks on riverbank. The tension cracks mainly form by two groups of forces. The forces generated by shrinkage on soil and it caused by desiccation and the second forces associated with gravitational force, the weight of the soil block mass detaches by a tension crack. The tension cracks are formed at the point of the failure surface when the tensile stress (³s€© exceeds the tensile strength (³ ´€©.

 ³ ´€ € €½€ € ³s (2. 2)

Where € ³s = tensile strength of the soil (kPa) and ³ ´€ = tensile stress at the ground surface

If the tensile strength of the soil slope is not zero the predicted value for tension depth is less than the predicted value.

(Chowdhury & Zhang (1991) also studied the classical way of approach Equation 2. 1 For that equation, for calculating factor of safety used mobilized shear strength parameters are

and (2. 3)

The pore water pressure depth at Z below the upper slope boundary is represented by

(2. 4)

Spencer modified the classical equation for particular depth for tension crack to the limit equilibrium slope stability analysis.

(2. 5)

Chowdhury & Zhang (1991) studied to calculate the depth of tension crack with new approach. He used inter slice force in any limit equilibrium method of slice, for that approach used modified the generalized Janbu procedure of slice and he combined with optimization approach involving the Simplex Reflection method.

More importantly, as not by (Hung Runqiu & Wu Lizhou, 2007) and many subsequent authors (e. g Fan Ping et al., 2005) studied the influence in tension cracks of unsaturated soil slopes with different depths. They studied the tension crack influence with factor of safety with different parameters. (Hung Runqiu & Wu Lizhou, 2007) studied the expansive soil slopes, the crack depth is influenced with slope ratio. The steeper slope cause longer depth tension cracks. Normally tension crack are formed in soil slopes during dry period after prolonged wet and dry cycle (Nurly Gofar et al., 2006). Their slope stability analysis the factor of safety is 37% bigger than the cracked slope factor of safety.

There is an interesting landslide case study, have studied by (Nurly Gofar et al., 2006); the rainfall induced open coal mine dump failure landslide occurred in 2002 December at Air Laya Indonesia. The dump slope surface is about 5(1V: 15. 5 H). This case study analysis shows the main reason for failure is the reduction of shear strength, the increment in soil moisture content cause for the reduction of shear strength. The formation of cracks in soil increases the soil moisture content. In other words, the rainwater infiltration through cracks increase pore water pressure and it consequently decrease in shear strength of soil slopes (Azman et al., 2008). The main reason for this failure is formation of tension cracks on slope surface. Some desiccation cracks possible to extent at dry periods by presence of certain vegetation (Greenwood et al., 2004).

The classical way of slope analysis, the slope failure is assessed by two different ways they are continuum mechanics or limit equilibrium approach. The researcher (Cai et al., 2005) studied the vertical cut slope stability using certain number of soil parameters, crack geometry at upper slope surface, a series of curves relating parameter S(strain energy density factor) and the non dimensional variable from slope geometry N (H/C-slope height vs crack distance from edge ratio) at vertical cut slopes, the curves which can be constructed through numerous parametric studies. From this research the researcher observed the failure path is not in circular on a simple straight line, however failure surfaces are well agreement with the classical slope stability analysis

The desiccant cracks may possible to develop during the dry period after prolong wet and dry period, (Nurly Gofar et al., 2006) studied the case study of rainfall induced landslide, dumping coal mining site in Air Laya Indonesia. The landslide happened 27 November 2002. Tension crack observed in mid October 2002 at the slope crest, tension crack were 5 to 10 cm width and believed 4 m deep. Water infiltrate through crack in deeper layer and increasing moisture content. This infiltration leads to propagate the tension crack as deep as 40 m prior to landslide occurrence.

This parametric study requires some parameters for analysis, these parameters have chosen prior to the literature study. The initial crack depth, maximum depth and width has chosen according to the Indonesia case study and other literature study, they are initial crack depth is 10 m and its increment by 10 m up to 40 m depth, crack width is 5 cm and crack location is in the slope upper surface 5m interval from slope crest up to 40 m distance.

2. 2 Impact on vegetation cover

The vegetation effect is well recognized in slope stability. The vegetation plays in civil and geotechnical engineering in two ways, known as hydrological effects and mechanical effects (root reinforcement). The hydrological effects remove the water content from soil by evapo-transpiration through vegetation (Greenwood et al., 2004), which action increase the soil suction (negative pore water pressure) hence, increases the soil shear strength. The vegetation cover is sustainable approach to using in slope stabilization reinforcement works to decrease the probability of slope failure (Joanne & John Greenwood, 2006). The main part involved in slope stabilization is root system and its root mechanical properties. There are lots of remedial techniques used in geotechnical slope stabilization works; like soil nails, reinforcement piles and concrete are common experience in geotechnical engineering.

The past researchers have suggested that the vegetation's root reinforcement effect can be considered in conventional slope stability design by adding the term root cohesion (). More importantly, as not by (Chok et al., 2004) and many subsequent authors (e. g Joanne & John Greenwood, 2006) studied the root cohesion. Incorporating with the vegetation effect in the Mohr-Coulomb envelope for soil

(2. 6)

Some researchers also measured the wind loading for general slope stability; the wind force involved much smaller proportion force for potential disturbance force in slope stability (Greenwood et al., 2004) and (Joanne & John Greenwood, 2006).

The researchers (Chok et al., 2004) have studied the mechanical properties, the root reinforcement effect on soil slope stability finite element calculations. The researcher analyzed the two vegetation independent parameters for his finite element mesh, they were apparent root cohesion () and depth of the root zone (). He incorporated these parameters in his finite element method for slope stability factor of safety (FOS) analysis.

In this study he used the apparent cohesion () was varied in a range

0 â‰¤ â‰¤ 20 kPa

The root depth zones values in his finite element calculations

HR âˆˆ { 1m, 2m, 3m }

This researcher has studied two different scenarios (1) the vegetation cover applied to the slope only (2) applied the vegetation cover entire slope surface.

The recent researcher (Preti & Giadrossich, 2009) have studied recently for Spanish Brooms specie’s root bio-mechanical aspects and root reinforcement and field rooting ability how it enhance the slope stability and bio-mechanical applications at Mediterranean areas. The single root element was tested for the tensile test in order to analysis the root density. The direct and indirect measurements were helped to analysis the Root Area Ratio (RAR)

The formula we used to estimate RAR was the following

RAR (z) = (2. 7)

Where:

Ar(z)i= area of the i-th root

As(z) = rooted-soil area

Z = depth

D(z)i = diameter of the i-th root

Ds = measured largest soil diameter explored by the root system (cylindrical rooted volume is assumed)

m = number of roots at z depth

From his experiment he used to calculate the additional root cohesion (Cv) from the following formula, according to the previous researchers formula.

Cv (z) = K (2. 8)

Trj= Tensile strength of the j-th diameter class

n = number of diameter classes at z depth

By putting K= 1. 2 as standard, root cohesion value could be consider maximum value.

Greenwood et al (2004) has studied the different ways of contribution of vegetation in slope stability. The mass of vegetation have a major influence on slope stability calculations, its applicable only larger trees (dbh of > 0. 3m, dbh- standard measurement of trunk diameter taken at breast height 1. 3 m on slopes, dbh is measured from the upslope side of the tree.) the well-stocked forests have the tree height of 30-50m contribute the loading 0. 5-2 kN/m2 and a 30m height of tree having the average dbh approximately 0. 8m and its weight of 100-150kN (Joanne & John Greenwood, (2006) & Greenwood et al., (2004)) . If such trees located at the toe of potential slip surface, they contribute 10% of factor of safety eventually if located at toe could be reduction of 10% factor of safety.

(Gao & Pan, 2008) have studied the landslide occurring during or after a rainfall, also studied the slope pore water changes during and after the rainfall and generate the initial slope pore water pressure conditions to slope/w tool using 5 orders of magnitude less than the simulated rainfall intensity. In this research they selected both rainfall conditions; the rainfall intensity is less than and higher than the saturated hydraulic conductivity of the soil.

This parametric study requires some parameters for analysis, these parameters have chosen prior to the literature study. The soil slope simulated two kind of rainfall intensities (1×10-05 m/s and 1×10-07 m/s), they are higher and lower than the soil saturated hydraulic conductivity (ksat

= 2. 66×10-06 m/s). The initial pore water pressure simulated with 5 orders of magnitude less than the rainfall intensity. The intensity of initial rainfall is assumed to be 1×10-10 m/s. The soil parameters have chosen from SEEP/W manual, hydraulic conductivity and volumetric water content functions.

The previous researchers considered the apparent root cohesion 1 kPa to 20 kPa. The larger trees give higher root cohesion, in order to penetrate larger root depths. If we consider the larger trees need to consider the weight of the trees effects on soil slopes. So this parametric study neglects the weight effect of the trees and chosen the smaller root cohesion up to 5kPa. This value may take from the smaller trees and bushes.

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