Applied Mechanics and Materials *Online: 2012-05-14*
ISSN: 1662-7482, Vols. 170-173, pp 1174-1178
doi:10.4028/www.scientific.net/AMM.170-173.1174

Stability Analysis of High Filling Slope Affected by Precipitation Intensity

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Keywords：precipitation intensity, stability of high filling slope, transient saturated-unsaturated seepage

Abstract：Aiming at researching on stability of slope affected by precipitation intensity, transient saturated-unsaturated seepage finite element method and slope stability finite element method are combined in this paper. Vadose field of slope is simulated in different precipitation intensity. Based on vadose field, the writers analyzed the stability of slope affected by precipitation intensity. The research results indicate that water is brought together in the interface first. Then the water level moves toward up and down respectively from the both sides of the interface. On the basis of saturated-unsaturated seepage theory, precipitation intensity has little effect on the slope stability in the first 6 hours after precipitation. After that, slope safety coefficient is relatively high when precipitation intensity is smaller, and vice versa.

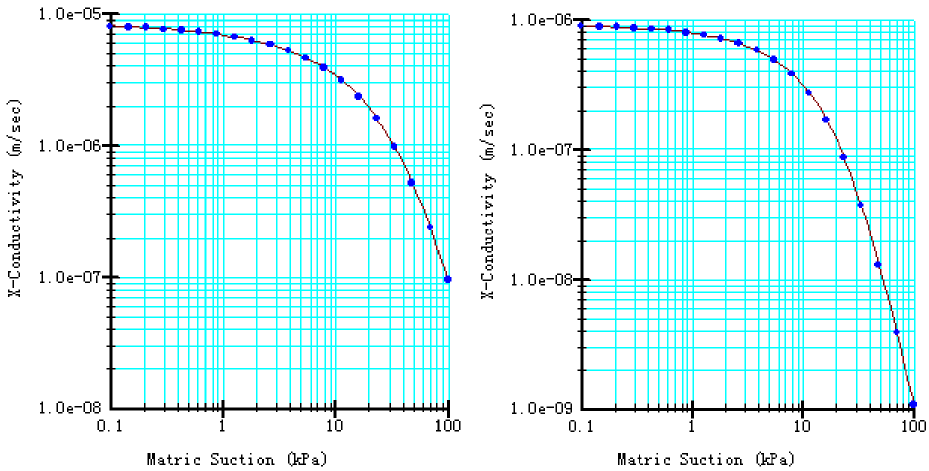
Introduction

The stability of slope affected by precipitation has been researched for many years. So far, researching on the stability of slope effected by precipitation focuses on two aspects. One is principle study based on statistical analysis of the mathematical relationship between landslide and precipitation. The other is researching on the mechanism of landslide induced by precipitation. In this paper, the stability of slope affected by precipitation intensity is researched through studying on water distribution of the slope in the process of precipitation.

Finite Element Model of high filling slope

Project Overview. A double-level retaining wall was built in Panzhihua steel plant. The higher retaining wall is anchored plate retaining wall which is 39.5m in length and 9m in height. The lower retaining wall is balance weight retaining wall, which is 12m in height. Plain fill is backfill in the area between retaining wall and slope surface. After the heavy rain, creep deformation occurs; the sliding surface is located at the contact surface between plain fill and silty clay with gravel. Creep deformation area is semicircle, 36.3m in length, 55.2m in width in the plane. The creep deformation volume is about 10800m^3. The main sliding direction is 90^0. This project is used to research the stability of high filling slope affected by precipitation in this paper.

Permeability coefficient. Permeability coefficient is an important parameter for studying water distribution of the slope in the process of precipitation. It is constant for saturated soil, but for unsaturated soil it is a function of matric suction. It is complex to obtain the relation curve between permeability coefficient and matric suction through the experiments, so many methods were proposed to predict the curve. Van Genuchten function which was proposed by Van Genuchten in 1980 is used to define the permeability coefficient in this paper. Permeability coefficient defined by Van Genuchten function is shown in Fig.1.



(a) plain fill (b) silty clay with gravel

Fig.1 Relation curve between permeability coefficient and matric suction

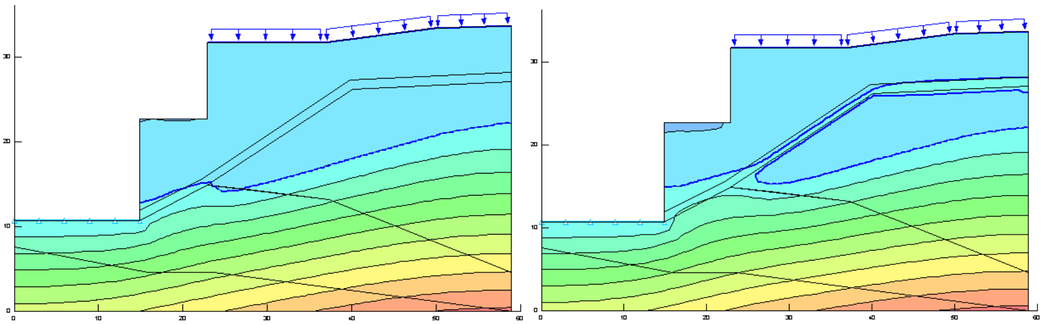
Other physical and mechanical parameters. Other physical and mechanical parameters used in the computational model are listed in Table 1.

Table.1 Physical and mechanical parameters

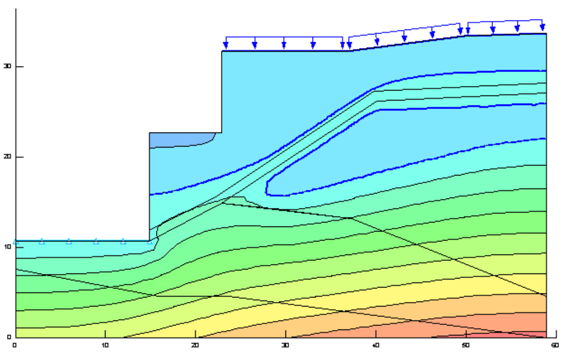
Soil layer	Unit weight (kN/ m^3)	Elastic modulus (MPa)	Poisson ratio	Cohesion (kPa)	Angle of internal friction (degree)	Saturated permeability coefficient (m/ s)	Constitutive model	Strength theory
Plain fill	18.5	14	0.45	20	15	$8.12x10^{-6}$	Ideal elastoplastic model with Mohr-Coulomb yield criterion	Mohr-Coulomb theory
Silty clay	19.5	32	0.38	20	15	$8.96x10^{-7}$		
pebble	22	100	0.27	15	35	$1.0x10^{-5}$		

Stability analysis of High Filling Slope

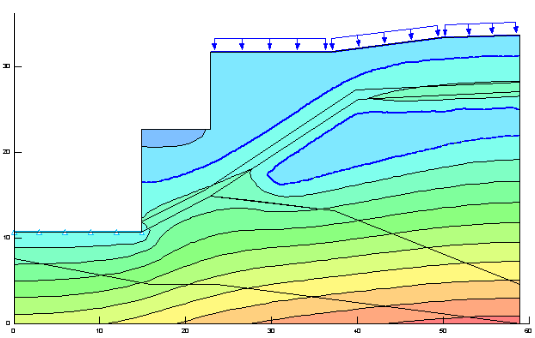
Water distribution of the slope in the process of precipitation. Seep/w software is used to simulated water distribution of high filling slope in the process of precipitation for 12 hours.After transient flow analysis, underground water level is recorded once every two hours. Different precipitation intensity simulated by setting unit flow boundary of the top model boundary are $1.0x10^{-6}$m/s, $3.0x10^{-6}$m/s, $4.0x10^{-6}$m/s separately.Fig.1 show the underground water of precipitation for 2hours, 4hours, 6hours, 8hours, 10hours, 12hours, when the precipitation intensity is $4.0x10^{-6}$m/s.



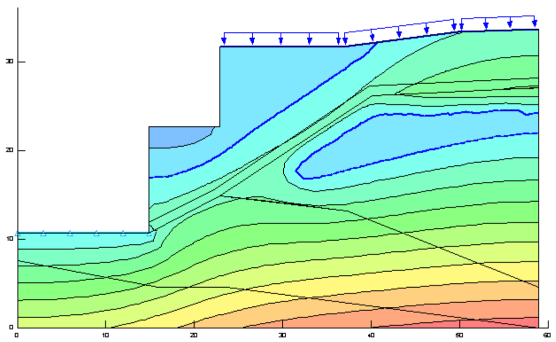
(a)Underground water level after precipitation 2hours (b)Underground water level after precipitation 4hours



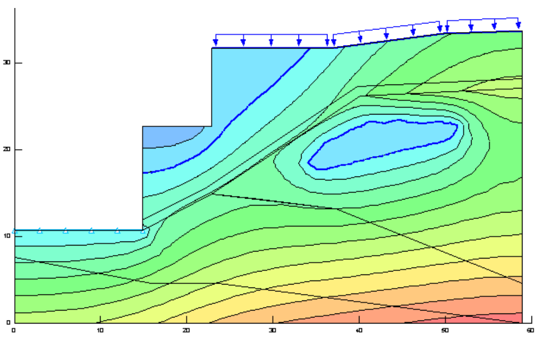
(c)Underground water level after precipitation 6hours



(d)Underground water level after precipitation 8hours



(e)Underground water level after precipitation 10hours



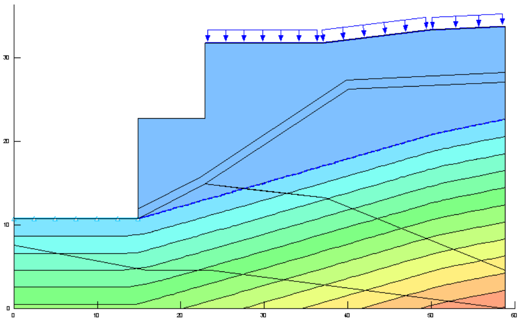
(f)Underground water level after precipitation 12hours

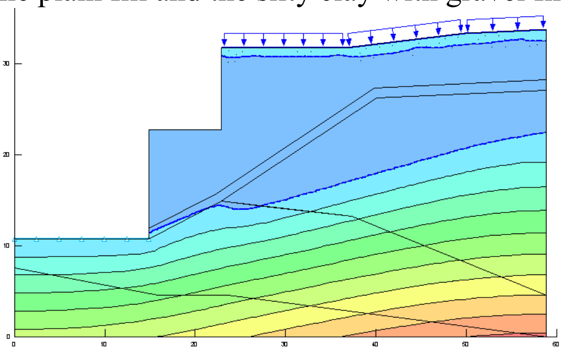
Fig.2 Changes of underground water when the precipitation intensity is 4.0×10^{-6}m/s

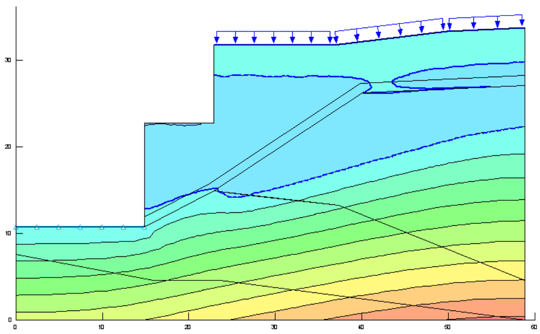
Changes of underground water when the precipitation intensity is 4.0×10^{-6}m/s are shown from Fig.2(a) to Fig.2(f). 2 hours after the beginning of precipitation, water is brought together in the slope toe, and then gradually fills in the interface between the plain fill (saturated hydraulic conductivity is 8.12×10^{-6} m/s) and the silty clay with gravel (saturated hydraulic conductivity is 8.96×10^{-7} m/s).After 6 hours, the soil in the interface position is saturated, with the passage of time, the water level moves towards up and down respectively from the both sides of the interface. The saturated range expands gradually. 10 hours after the beginning of precipitation, part of the surface soil is saturated. After 12 hours, most of the soil is saturated except a small residual closed unsaturated zone.

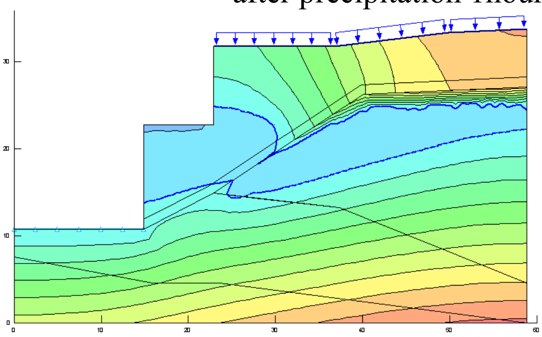
Observe Fig.2 carefully, we will find that the underground water distribution is consistent basically at the same time for three kinds of precipitation intensity within 6 hours after the beginning of precipitation, after that differences begin to emerge gradually. This phenomenon seems unreasonable, but it can be explained through the relationship between permeability coefficient and saturation. The permeability coefficient is affected by void ratio for saturated soil, but for unsaturated soil it is affected by both void ratio and saturation (or moisture).Water only moves through the pores filled by water. Part of pores are filled with air for unsaturated soil. Not only water movement channels are occupied, but also increasing the flow of water movement. So the permeability coefficient of unsaturated soil relative to the saturated soil permeably coefficient is much smaller. Within 6 hours after the beginning of precipitation, saturation zone wasn't large enough to form a seepage channel. At this time the soil permeability coefficient depended on the unsaturated permeability coefficient, which is smaller than precipitation intensity. Precipitation intensity didn't impact on the underground water distribution obviously. 6 hours after the beginning of precipitation, saturation zone was large enough to form seepage channels. At this time the soil permeability coefficient depends on the saturated permeability coefficient, which is greater than precipitation intensity. Precipitation intensity impacts on the underground water distribution gradually.

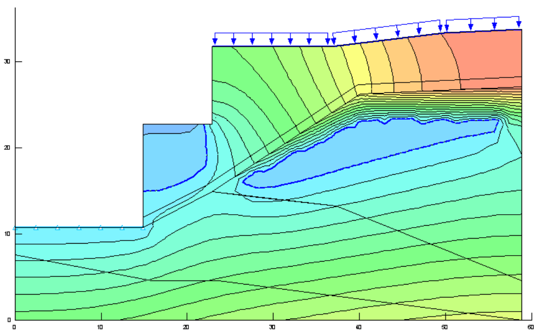
When the precipitation intensity is greater than the saturated permeability coefficient, underground water distribution is another state, as shown in Fig.3. Fig.3 shows the Changes of underground water when the precipitation intensity is $1.0x10^{-5}$m/s which is greater than the saturated permeability coefficient ($8.12x10^{-6}$ m/s).Part of the precipitation infiltrates into the soil, the residual drain away from surface. Water that infiltrated into the soil make the surface soil saturated, and part of it is brought together in the slope toe at the same time. Two water levels appear in the soil, the range between the two water levels is unsaturated zone. With the passage of time, the precipitation infiltrate continuously, the scope of unsaturated soil reduced gradually. In the process water still fills in the interface between the plain fill and the silty clay with gravel first.


(a)The initial water level


(b)Underground water level after precipitation 1hours


(c)Underground water level after precipitation 2hours


(d)Underground water level after precipitation 3hours


(e)Underground water level after precipitation 4hours

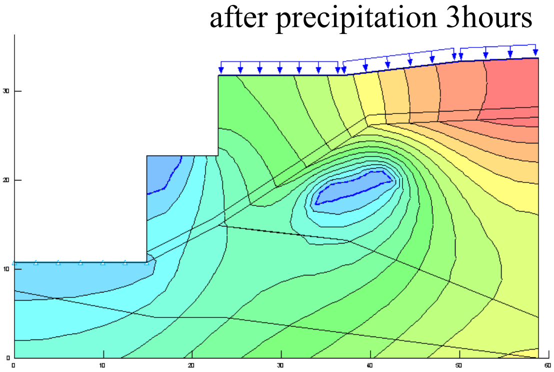

(f)Underground water level after precipitation 5hours

Fig.3 Changes of underground water when the precipitation intensity is $1.0x10^{-5}$m/s

Precipitation intensity impact on the stability of the high filling slope. How did precipitation intensity impact on the stability of the high filling slope is further analyzed in this section on the basis of the last section. SIGMA/W software is used to couple stress and pore water pressure which has been calculated in the last section in order to calculate the effective stress. Finally the effective stress is used in the slope software to study the slope stability.

Relation curves between precipitation intensity and slope safety coefficient is shown in Fig.4.Changes of the slope safety coefficient are shown within 12 hours after the beginning of the precipitation when the precipitation intensity is $1.0x10^{-6}$m/s, $3.0x10^{-6}$m/s, $4.0x10^{-6}$m/s separately.

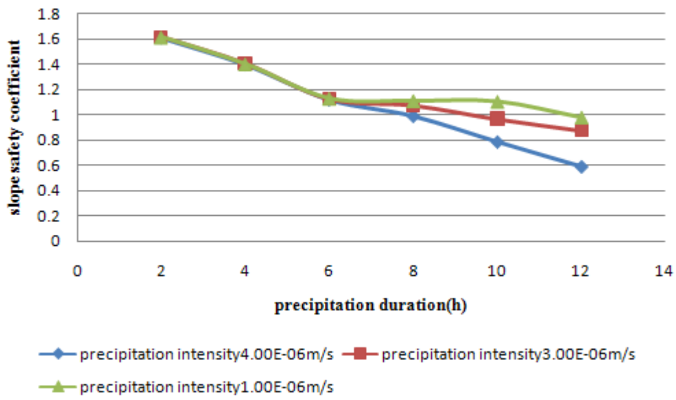


Fig.4 Relation curves between precipitation intensity and slope safety coefficient

Within 6 hours after the beginning of the precipitation the slope safety coefficient is basically the same corresponding to the same time of three kinds of the precipitation intensity.In the first 6 hours after precipitation the slope safety coefficient shows different for different precipitation intensity gradually,slope safety coefficient is relatively high when precipitation intensity is smaller, and vice versa.This phenomenon is consistent with the underground water distribution rule in the last section. This rule applies to the premise that precipitation intensity is less than the saturated permeability coefficient of the soil.

Conclusion

Based on the transient saturated-unsaturated seepage analysis and slope stability finite element method, the study is conducted on stability analysis of high filling slope affected by precipitation intensity, thus making the following conclusions.

Water is brought together in the interface first. Then the water level move toward up and down respectively from the both sides of the interface. Through saturated-unsaturated seepage theory, precipitation intensity has little effect on the slope stability in the first 6 hours after precipitation. After that, slope safety coefficient is relatively high when precipitation intensity is smaller, and vice versa.

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