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Study on time stability on reinforced soil slope by anchor under flood loading effect

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Abstract: In order to analyze the adverse effect of flood effect on slope stability, the analytical expressions of buoyancy force and capillary force, hydrodynamic pressure and impact force, and scour erosion were proposed based on the aging characteristics of soil shear strength and limit equilibrium theory. According to the load combination and flood action, shear failure occurs preferentially at the foot of slope. Then, the plastic zone continues to extend upward to produce traction landslide disaster mode. Furthermore, the power function relation between shear strength index and time was established. The nonlinear accelerated creep model was obtained. At the same time, the analytic formula of safety factor for flood loading effect slope aging stability, the time-varying characteristic value of anchor force and the compensation value of anchor force were also obtained. In addition, the numerical example shows that the slope safety factor decreases by more than 20% considering the effect of flood ascending scour and impact, and the compensation value of anchorage force increases obviously with time, and the change rate of compensation value of anchorage force increases nonlinearly with the increase of design safety factor.

Key words: anchored slope; flood response; loading condition; safety factor; anchorage force

1 Introduction

The disaster caused by flood causes great loss to personal safety and social production, which is one of the four major natural disasters, such as earthquake, flood, fire and plague. Flood disaster repair is characterized by the difficult, high cost, complex technology and so on. In particular, flood load has a serious impact on the geometrical form, strength, mechanical properties and structural stability of geotechnical materials. Disaster accidents caused by flood occur every year (Hankin et al., 2019; Jan and M, 2011; Prince et al., 2014). Therefore,
strengthening the forecast and early warning of the flood and strengthening the management of the affected structures have become an important topic in the disaster prevention and mitigation field.

The influence of flood on engineering structures is mainly reflected in load condition change, stress adjustment and weakening of material strength. However, the load condition change is the most important. Flood load mainly includes the loading effect of buoyancy force, capillary force, hydrodynamic pressure, drift impact force, wave force, erosion and biochemical force on structures (Guo et al., 2016), separately. At present, the load effects are considered instantaneous mechanical function. Research is focused on the dam body, the building structure of the flood damage evolution model and the impact of research for many. Considering the load classification and combination of the flood, the flood damage model is proposed (Cao et al., 2013). It is clear that a series of achievements is presented on the study of the theory of the structure damage and instability of human body made. Wu et al. (Wu et al., 2018) studied the time-history relationship between the impact force and displacement response of the flood on the bridge pier according to the control equation of fluid transient dynamics, established the impact effect coefficient, and revealed the instantaneous impact effect of the flood on the bridge pier. According to saint-Venant difference equation, Xiao (Xiao and Wang, 2010) carried out a flood impact load model with unsteady flow and summarized the change rules of impact parameters and occurrence environment of dam body. The above research results have certain positive effects on flood seepage characteristics, load boundary conditions and evaluation criteria of structural failure. Obviously, the instantaneous impact of flood has great influence on the bearing stability of engineering structures. However, the anchor structure of soil creep mechanics and anchoring force compensation research achievement are still rare, especially the flood load of soil slope failure mechanism, anchor aging stability evaluation of slope and anchorage parameters optimization design (Hobbs et al., 2011; Kurbanova et al., 2015). Many other problems have not yet completely solved. Project governance is still a large number of relying on experience for anchorage design parameters. For these reasons, this paper verified the flood load conditions of slope engineering and combination, the soil strength weakening, reinforcement landslide model and engineering to carry out theoretical research and practical application (Wu et al., 2011). Meanwhile, slope
stability limitation safety factor analytic form was conducted and the time-varying characteristics of the anchoring force and anchoring force compensation were founded in the condition of the given design safety coefficient values.

2 Flood effect slope load conditions

As known, flood effect changes the loading condition of slope mainly affected by water depth and flow rate. According to the structure and occurrence conditions of high and steep slope, flood basin is mainly distributed in the middle and lower part of the slope. In the process of water depth and velocity adjustment, flood infiltration can increase slope sliding force, weaken soil physical and mechanical parameters, and reduce the strength of the reinforced structure. Therefore, these factors can easily induce shear yield and increase of displacement and mutation of slope materials in flood area. In addition, the damage result caused by landslide disaster is disastrous (Wang et al., 2018). The load distribution of flood effect on slope is shown in Figure 1.

![Mechanical response on effected slope](image)

Fig.1 Mechanical response on effected slope: $v_z$ is the vertical rising speed of flood, $v_0$ is the horizontal speed of flood, $z_s$ is the scour depth, $h_0$ is the height of capillary water rising, $z$ is the flood depth, $n$ is the roughness of slope bottom and slope surface, $s$ is the distance flowing through slope bottom, $H$ is the calculated height of slope, $F_c$ is the capillary pressure, $G_d$ is hydrodynamic pressure, and $F_i$ is impact force.

In general, water level and flow velocity are constantly changing with time, which can lead to the adjustment of slope load distribution. Furthermore, the stress state and stability of slope potential sliding body is changed.
2.1 Buoyancy and capillarity

The water penetrates into the slope soil under the action of flood, and produces upward buoyancy and capillary force on the soil due to pore expansion and particle infiltration. According to the load distribution (see Fig.1), the buoyancy force and isotropic pore water pressure of slope soil in flood zone, in which the soil is between sliding surface and submerged surface, are expressed as:

$$F = e^{\frac{z}{v_c t - (x-s) \tan \alpha}} - 1 \quad (1)$$

$$\mu_w = \gamma_w [v_c t - (x - s) \tan \alpha] \quad (x \geq s) \quad (2)$$

Where \( t \) is the rising time of flood level, \( \alpha \) is the sliding angle of slope, and \( s \) is the distance of flood flowing at the bottom of slope.

In addition, the contact between the infiltrated flood and the soil particle surface will form a negative pore pressure along the water level in the slope. In order to facilitate the analysis of the distribution characteristics of capillary pressure in soil, the influence height of capillary water is obtained. It is assumed that the immersed surface of the slope is horizontal, so the height of capillary water rising in the soil pores under the action of capillary pressure can be depicted from the following equation:

$$h_b = 2 \theta \cos \psi / \rho_w g r_s \quad (3)$$

The capillary pressure can be calculated by the following Eq.(4):

$$\theta = \frac{h_b \rho_w g r_s}{2 \cos \alpha} \quad (4)$$

Where \( \theta \) is the capillary pressure, \( \rho_w \) is the flood density, \( \psi \) is the contact Angle, and \( r_s \) is the pore characteristic radius.

2.2 Hydrodynamic pressure and impact force (Xiao and Wang, 2010)

After flooding at the bottom of the slope, drag force is produced on the material of the submerged slope as the water level continues to rise. Considering that the flood depth at the bottom of the slope is generally shallow. It is obvious that the flood velocity is evenly distributed along the depth, and then the hydrodynamic pressure is derived from the following equation:
\[ G_d = 0.5 \rho_w C_d v_0 \]  \hfill (5)

Where \( C_d \) is the drag force coefficient, and \( v_0 \) is the flood velocity.

In the flow process of flood impinging on slope, a large number of facts show that when flood impinges on slope, its wave front decreases rapidly after impinging on slope at a certain speed and even flows in reverse. Moreover, this process takes a short time, and the effect is obvious. So the impact effect can not be ignored. According to energy conservation, the energy equation of the turbulence is calculated as follows:

\[
\frac{\partial \frac{\partial z}{\partial s}}{\partial t} ds + \frac{\partial z^2}{\partial s \partial t} ds dt + \frac{\partial}{\partial s} \left( \frac{v^2}{2g} \right) ds + \frac{1}{2} \frac{\partial^2}{\partial s \partial t} \left( \frac{v^2}{2g} \right) ds dt + \frac{v^2}{C^2 R} ds + \frac{1}{g} \frac{\partial v}{\partial t} ds = 0 \]  \hfill (6)

After the flood hits the slope, part of the kinetic energy is converted into impact force. Combined with the load distribution (see Fig.1), the head of flood impact force can be written as following:

\[
h = z_i + \frac{v_0^2}{2g} - z_H - \frac{1}{g} \left[ \int_i^H \frac{\partial v}{\partial t} ds - \int_i^H \frac{v}{C^2 R} ds \right] \]  \hfill (7)

Then, we can get the impact force is written as follows:

\[
P_h = \gamma_w \left[ z_i + \frac{v_0^2}{2g} - z_H - \frac{1}{g} \left[ \int_i^H \frac{\partial v}{\partial t} ds - \int_i^H \frac{v}{C^2 R} ds \right] \right] \]  \hfill (8)

Where section I-I is outside the range of slope toe, section II-II is the impact slope (see in Fig.1), \( h \) is the flood impact head at this depth, \( z_i \) and \( z_H \) are section I-I and II-II heads, respectively, \( v_0 \) is the flood horizontal velocity, \( \bar{v} \) is the average velocity of section, \( C \) is the coefficient related to flow, \( R \) is hydraulic radius and \( s \) is the distance flowing through the bottom of the slope.

On the other hand, water drift will also have impact on the slope when it flows. The impact force is related to the shape and stiffness of drift and the stiffness of slope structure. According to the impulse theorem, it is assumed that the drift is stationary after impacting the soil on the slope surface. Therefore, the impact time of the drift on the slope can be obtained as follows:

\[
t_D = \frac{\sqrt{(K_D + K_M) m_D}}{K_D K_M} \]  \hfill (9)
Furthermore, the impact force of drift on slope structure is obtained as follows:

\[
F_i = \frac{m_v v_d}{\sqrt{(K_D + K_M)m_D}}
\]

(10)

Where \( K_D \) is the stiffness of drift, \( K_M \) is the stiffness of slope structure, \( m_D \) is the mass of drift, \( v_D \) is the flow rate of drift, which is the same as the horizontal velocity of flood.

2.3 Wave forces and erosion

Wave load is mainly caused by wind load and storm surge, and wave pressure is high in flood flow. Considering the distribution characteristics of slope flood as shallow water, the influence of wave force on slope stability is not considered temporarily. The change of flood water level and flow velocity has a certain scour effect on the geometry and structure of slope soil, especially the influence of flood scour on loose soil or underconsolidated soil. At present, the depth of flood erosion soil slope is usually obtained by highway bridge and culvert standard or by experience, and the calculation result is not accurate. In order to obtain the scour depth of soil slope in flood area, according to flood runoff elements and Jiang Huanzhang's formula (Jiang, 2002), the scour depth of soil slope soil in flood is depicted as follows:

\[
h_e = \phi / C (z / \Delta)^{n_0} - 1 \]

(11)

Where \( z \) is the water depth, \( K_m \) is the upper and lower slope of slope support structure, \( \phi \) and \( C \) are the coefficient and are set to 2.4 and 1, respectively, \( n_0 \) is the vertical velocity distribution index, and \( \Delta \) is the height of the calculated position of sediment starting bottom velocity.

To sum up, the load combination of soil slope soaked by flood effect can be obtained as shown in Fig.2.
3 Flood action is influenced by the aging stability of anchor slope

3.1 Failure mode of flood induced slope

The flood disaster of soil slope usually occurs in the middle and lower part of the slope. As the flood water level continues to rise, the slope is subjected to increasing load conditions, which causes the stress release of the soil structure. Therefore, the deformation of the immersed soil becomes more significant. From the initial peristaltic deformation, it is intensified that sliding, even mutation, forming large displacement is obvious. In addition, under the action of flood, the destruction of soil slope is also the first compression shear yield at the foot of slope, and then the plastic zone extends, nucleates and connects to the top of slope, Finally, traction landslide can be formed.

3.2 Aging characteristics of soil shear strength

According to the inherent mechanical properties of soil creep and in combination with literature (Wang and Li, 2008), the relationship between the adhesive force and internal friction angle of shear strength index of soil under seepage condition with time is obtained as follows:
\[
c_{x}/c_{0} = 1/3 \sim 1/8 \quad (12)
\]

\[
\tan \varphi_{x} / \tan \varphi_{0} \approx 1 \quad (13)
\]

For the shear strength and aging characteristics of soil slope reinforced by bolt under seepage condition, the ratios of and \( c \) and \( \varphi \) are usually selected as follows:

\[
c_{x} / c_{0} = 1/5
\]

\[
\tan \varphi_{x} / \tan \varphi_{0} = 1
\]

Combined with the shear creep test results of soil, the aging relation of the bond force is in the form of the following power function.

\[
c_{i} / c_{0} = at^{m} + b
\]

Where \( c_{i} \) is the aging bonding force of soil, \( t \) is time, \( a \) and \( b \) are experimental constant, \( m \) is empirical constant, which is obtained by fitting creep experimental data.

According to the definite solution condition as follows:

1. \( t = 0, \quad c_{i} / c_{0} = 1 \):
2. \( t \rightarrow \infty, \quad c_{i} / c_{0} = 0.2 \).

Substituting into Eq.(14), the coefficients are as follows:

\[
a = 0.8, \quad b = 0.2
\]

Taking the logarithm of both sides of equation (14), the vary factors are written as follows:

\[
Y = \ln c_{i} / c_{0} - 0.2
\]

\[
X = \ln t
\]

The linear relation is obtained by combining Eqs. (14) - (16)

\[
Y = mX + \ln 0.8
\]

Finally, the least square method was used to obtain the value of the empirical constant, which was calculated. Moreover, the time-dependent relationship of the adhesive force under the seepage condition was obtained as follows:

\[
c_{i} = c_{0}(0.8t^{-1} + 0.2)
\]
3.3 Nonlinear creep model

Creep is one of the mechanical properties of anchorage structure materials. The creep deformation caused by external load is significant, which leads to unrecoverable plastic deformation. Under the action of flood, the strength of anchorage material is much stronger than that of soil. Under the action of flood load, especially shear force, the soil will produce large shear creep deformation and yield. When the shear stress is greater than the bond strength of the anchorage interface, the nonlinear accelerated creep occurs and the anchorage structure is easy to fail (Tamadu et al., 2010).

In soil creep analysis, element model is usually used to simulate creep deformation of soil. The creep stability of soil structure is further determined. The creep of soil is generally simulated by composite elements. It is clear that Kelvin body is usually used to simulate rod body. Creep analysis of earth anchor structure was simulated by parallel Kelvin body and elastic element. However, the element model does not reflect the accelerated failure characteristics of anchoring failure. Meanwhile, the soil anchorage structure is characterized by multi-phase and multi-interface structure. Under the action of flood, the creep deformation characteristics of such composite materials are very complicated. It is difficult to accurately judge the aging stability of soil-anchor structure with element model, especially the creep effect on prestress loss is more difficult to grasp. Therefore, in the process of anchoring failure, the soil is often the first to have a large deformation and yield failure. In addition, according to the displacement characteristics of each component of the soil-anchor structure, the author added M-C shear plastic element to simulate the accelerated creep characteristics of the soil, and reflected the three-stage creep characteristics of the soil-anchor structure. The creep element model adopted is shown in Fig.3.
In the creep analysis of multi-phase multi-interface composite structure anchored in soil, the following assumptions are made:

1) The soil is isotropic and homogeneous porous continuous material;

2) The creep load is the anchoring transfer load in the interface, without considering the prestress locking loss and stress relaxation, and without considering the dead weight of the soil.

According to nonlinear creep theory, creep equations of anchor segment, mortar anchor solid and soil in soil-anchor composite structure are obtained from Fig.3.

It can be observed that creep equation of anchorage section is depicted as follows:

$$\varepsilon_s(t) = \frac{E_{a1} + E_{a2}}{E_{a1}E_{a2}} \frac{1}{E_{a1}} e^{-E_{a1}t/\eta_s}$$ (19)

Solid creep equation of mortar anchor can be written as follows:

$$\varepsilon_g(t) = \begin{cases} \sigma_g \left( \frac{1}{E_g} + \frac{t}{\eta_g} \right) & (\tau < \tau_g) \\ (\sigma - \sigma_g) \left( \frac{1}{E_g} + \frac{t}{\eta_g} \right) & (\tau \geq \tau_g) \end{cases}$$ (20)

Creep equation of soil can be written as follows:

$$\varepsilon_s(t) = \begin{cases} \sigma_s \left[ \frac{t}{\eta_s} + \frac{1}{E_{s1}} + \frac{1}{E_{s2}}(1-e^{-E_{s2}t/\eta_s}) \right] & (\tau < \tau_s) \\ \sigma_s \left[ \frac{t}{\eta_s} + \frac{1}{E_{s1}} + \frac{1}{E_{s2}}(1-e^{-E_{s2}t/\eta_s}) \right] + \varepsilon_{MC} & (\tau \geq \tau_s) \end{cases}$$ (21)

Anchorage load of anchorage section can be written as follows:

$$\sigma_s = \int_0^{L_a} \tau(x) D dx$$ (22)
Where $E_{s1}, E_{s2}, \eta_{s1}, \eta_{s2}, \tau_s$ are the elastic modulus, viscoelastic modulus, viscoelastic coefficient, viscosity coefficient and shear yield strength of simulated soil creep, respectively, $\tau_g$ is the bond strength between bar and slurry, $E_j$ and $\sigma^\prime$ are to simulate the elastic modulus and creep stress of the free section of bolt, $E_{a1}, E_{a2}$ and $\eta_a$ are viscoelastic modulus, viscoelastic coefficient and viscosity coefficient of anchor bolt, respectively, $E_g, \eta_g, \tau_f$ and $\sigma^\prime - \sigma_g$ are the elastic modulus, viscoelastic modulus, shear yield strength and overstress of simulated mortar respectively, $\tau(x)$ are the shear stress distribution of soil-anchor interface, $d$ is the diameter of anchor solid, $\varepsilon_{MC}$ is the plastic strain reflecting accelerated creep and $L_a$ is the length of anchorage section.

In order to obtain the creep model parameters of the anchor system, displacement sensors are usually arranged on the mortar anchor solid at the top of the anchor and at the position close to the soil by bolt pull-out test. According to the displacement monitoring data, creep curves and displacement values under different tensile loads are obtained. Combined with the distribution characteristics of creep curve, viscoelastic correspondence theory and viscoplastic knowledge were used to identify and value model parameters using least square technology (Mu et al., 2020). Due to space limitation, the analysis process is summarized.

According to the Mohr-Coulomb yield criterion, the Mohr-Coulomb one-dimensional yield function is used in this paper as follows:

$$F = -\frac{1}{2}\sigma_x + \frac{1}{2}\sigma_s \sin \varphi + c \cos \varphi$$

(23)

Combined with reference (Mu et al., 2020), the viscoplastic strain rate of M-C in the nonlinear creep model is presented as follows:

$$\dot{\varepsilon}_{MC} = \eta_e \left[\frac{-\frac{1}{2}\sigma_x + \frac{1}{2}\sigma_s \sin \varphi + c \cos \varphi}{F_0}\right](-\frac{1}{2} + \frac{1}{2} \sin \varphi)$$

(24)

Where $c, \varphi$ are the adhesion force and internal friction angle of soil, $F_0$ is the initial reference value of soil yield strength, and the plastic strain can be obtained by differentiating equation (24).
3.4 Aging stability evaluation and anchorage force compensation

Bolt technology can provide sliding resistance of sliding soil, improve shear strength of soil and improve force conditions of slope. Anchoring technology plays an important role in enhancing the stability of slope (Sakai et al., 1998; Shi et al., 2020). In flood infiltration slope soil, prestressed anchor can resist flood load, increase anti-sliding force, reduce soil deformation, actively stabilize the soil in the lower part of the slope, control the further expansion of the plastic zone, strengthen the stability of the slope, and has been widely used in rock and soil reinforcement. Under the action of flood, the mechanical conditions of slope reinforcement with anchor are shown in Fig.4.

![Fig.4 Anchored slope under flood condition](image)

According to the principle of limit equilibrium method of soil slope stability, the safety factor of anchored soil slope is written as follows:

\[
K_S = \frac{F_R}{F_S} \tag{25}
\]

\[
F_R = T \cos(\alpha + \delta) + (G_d + F + \theta) \sin \alpha + (F_i + P_h) \cos \alpha + c_i l \tag{26}
\]

Down force is written as follows:

\[
F_S = (G_s + G_a) \sin \alpha \tag{27}
\]

By substituting Eqs.(26) and (27) into Eq.(25), the safety factor of anchoring slope under flood conditions can be obtained as follows:

\[
K_S = \frac{F_R}{F_S} = \frac{[T \cos(\alpha + \delta) + (G_d + F + \theta) \sin \alpha + (F_i + P_h) \cos \alpha] \tan \phi_i + c_i l}{(G_s + G_a) \sin \alpha} \tag{28}
\]

Where

\[
G_d = 0.5 \rho \gamma C_d v_0
\]
\[ F = \frac{z}{e^{z - (x-z) \tan \alpha} - 1} \]
\[ \theta = \frac{h_0 \rho_s g r_s}{2 \cos \alpha} \]
\[ F_i = \frac{m_0 v_D}{\sqrt{(K_B + K_M) m_D / K_D K_M}} \]
\[ P_h = \gamma_{w}[z_i + \frac{v_0^2}{2g} - z_{\mu} - \frac{1}{g} \left( \int \mu \sqrt{v} ds - \int \frac{\mu}{C^2} R ds \right)] \]

Where \( T \) is the anchoring force of bolt, \( \delta \) is the anchoring Angle of bolt, \( \psi \) and \( \phi \) are the effective shear strength index of soil in sliding zone, and \( l \) is the length of sliding surface.

As known, flood can change the structure and mechanical condition of slope soil. At the same time, accelerated deformation and large deformation of soil also have a serious impact on the prestress of anchor bolt. Once the anchoring force is not fully developed or insufficient, it will lead to the failure of anchoring load and the instability of slope. Therefore, the anchorage force should be constantly adjusted to enhance the stability of the anchorage slope under the action of flood.

According to Equation (22), the anchoring force of slope reinforced with anchor bolt can be obtained when the design safety factor is given as follows:

\[ T = \frac{K_s (G + G_u) \sin \alpha - c_{\mu}l}{(G + F + \theta) \sin \alpha + (F_i + P_h) \cos \alpha} \]  
\[ \tan \phi \cos (\alpha + \delta) \cos (\alpha + \delta) \]

Under the action of flood, it can be determined form Eq.(29) that the anchoring force and stability of anchor slope are mainly affected by flood load, sliding surface geometry, soil strength and anchor bolt arrangement. Especially, uncertain flood load has the most serious influence on anchorage force and safety factor. Therefore, it is necessary to improve the anchoring force to satisfy the stability of flood effect slope.

4 Numerical example

In order to verify the time stability on reinforced soil slope by anchor under flood...
loading effect, the high and steep homogeneous soil slope is taken as an example. The time characteristics of safety factor and anchorage force compensation value are studied. The following three conditions were analyzed: (1) the flood action at the bottom of slope was not considered; (2) consider the static water pressure at the bottom of the slope; (3) consider the impact of flood. The calculation parameters of soil slope, which slope sliding is plane sliding, are set as follows: slope height $H=12m$, slope angle $\beta=48^\circ$, sliding plane sliding angle $\alpha=34^\circ$, natural bulk density of soil $\gamma=18kN/m^3$, saturated bulk density $\gamma_{sat}=20kN/m^3$, $d_{so}=0.2mm$, effective cohesive force and internal friction angle $c_0=22kPa$, $\phi_0=15^\circ$, respectively, soil stiffness $K_M=2.2\times10^4kN/m$. In addition, the creep parameters are set as follows: viscoelastic modulus of 1.2 MPa, viscoelastic coefficient of 7.8MPa·d, soil viscosity coefficient of 20 MPa·d, bolt elastic modulus is 210GPa, the viscoelastic modulus of the anchoring section is 500 MPa, and the viscoelastic coefficient of the anchoring section is 30GPa. Meanwhile, the viscosity coefficient of the anchoring section is 480 MPa·d, the mortar elastic modulus is 140 MPa, the mortar viscoelastic modulus is 270 MPa·d, and the shear yield strength is 380kPa. Flood factors are set as follows: flow rate =6m/s, initial water depth=2m. In the present paper, water is considered as viscous incompressible fluid with dynamic viscosity $\mu=9\times10^{-4}Pa\cdot s$ and drift material is equivalent to crack-free trees, bulk density is 600 kN/m$^3$, compressive strength and stiffness along the grain are 50MPa, $K_D=1.8\times10^7kN/m$. The anchor rod is hot-rolled steel bar with $\varphi 32$ diameter crescent-rib, and the grouting material is 425# cement mortar.

According to the principle of limit equilibrium method, it is assumed that the sliding soil is rigid body and follows M-C criterion. The safety factors of all points on the sliding surface are the same and the flood action at the bottom of the slope is not considered, respectively. Considering hydrostatic pressure at the bottom of slope. Moreover, the time-history characteristic values of safety factor and anchor force compensation under three conditions such as hydrostatic pressure and flood impact are considered. The calculation results are shown in Figs.5 and 6.
It can be seen from Figs. 5 and 6 that flood has an important impact on the stability and anchoring force of the anchored slope:

1. Under natural conditions, the safety factor of the unreinforced slope is 1.21, indicating that the slope is in a stable state. At the beginning of the flood, the safety factor was 1.09, a 10 percent reduction. As the flood level continues to rise, under the impact force, the safety factor decreases rapidly to 1.03 after 6 hours, and to 0.94 after 10 hours, which is in a state of instability. (2) Under flood conditions, anchoring force continues to lose over time, especially the anchoring force loses faster after 6 hours. This is consistent with the time-varying characteristic value of the accelerated decline of safety factor. Therefore, it is necessary to compensate bolt anchoring force in time in flood area. When $K_s=1.30$, the anchorage force increases from 140kN to 195kN, an increase of 39.2%. When $K_s=1.15$, the anchorage force T increases from 112kN to 126kN, an increase of 12.5%. Therefore, in order to satisfy the stability of high and steep slopes under the action of flood, greater anchoring force must be used to compensate.

5 Conclusion

(1) Based on the static and dynamic action of flood, the analytic formula and load combination of buoyancy force and capillary force, hydrodynamic pressure and impact force and erosion erosion are obtained. The force system has an adverse effect on the structure, strength and deformation of soil. Meanwhile, the force system is the main controlling factor of landslide instability of soil slope under flood action, and it depends on time.

(2) According to the time and impact effect of flood, the disaster mode of traction landslide in water-damaged slope is studied. Furthermore, the nonlinear accelerated creep
model and the analytic formula of aging safety factor of anchoring reinforced slope are established. At the same time, the compensation values of anchoring force for different grade slopes with given design safety factor are obtained.

(3) The nonlinear variation trend of slope safety factor under flood action and its attenuation and increasing characteristics after 6 hours of flood seepage are obtained by numerical examples. Meanwhile, the time history curve of slope anchorage force is obtained. Especially after 6 hours, a larger compensation value of anchor force is needed to satisfy the given design safety factor to ensure the stability of the anchored soil slope.

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