Research of Slope Disaster Chain-Stage and Evolvement Rules

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Abstract. The slope disaster chain-stage characteristics are intuitive, visual and vivid, and it is the key of understanding the chain evolvement rules. This paper summary of the slope disasters chain-styled characteristic, and divide the chain-styled developmental stages. The principle and evaluative law of slope disasters are expressed by chain-styled relation, so that chain-cutting disaster reduction can be pertinently controlled based on adequately grasp of the characteristic of each chain-styled stage. When the slope disasters are in the weak environment, we carry out chain-cutting disaster mitigation, which will be able to resist the disaster evil to threaten the human, and have possibility and great significance of disaster prevention.

1. Introduction
Slope, especially the high-speed slope, sometimes severe and occurs rapidly and is catastrophic destruction of the geological environment or engineering geological environment of a major geological disaster. It is fast and impulse large. Some high-speed slide a huge amount of sideslip, sliding away from very far. slope often destroy projects, ruin houses, interrupt transportations, damage farmlands, block rivers, wash out bridges and culverts; sometimes it can make the devastating disaster, and personnel casualties, economic, and engineering activities to bring serious harm or threat.

In this paper, it studies on the evolution to explain the development of landslide mechanism according the angle of the disaster chain-stage characteristic, in essence, to grasp the evolution of the regularity of landslide disaster. The development of landslide mechanism is a process of long-term accumulation. As well as the inevitability from the quantitative to qualitative changes. When the energy gathered to a right time, the slope will be disruptive, leading to the occurrence of slope hazards. Meanwhile, the landslide disaster of the “nurturing - latent – induced”, in the three periods are interrelated. The former for the latter provided the material and energy, and the development of conditions for the later stage; this also formed the stage of the Inter-chain development regular. As early as mid-term is equivalent to a quantitative change process, the later stage is a qualitative change process.

2. Slope Time Evolvement Rules and Chain-Stage

2.1. Research of Slope Time Evolvement Rules
Slope early-warning forecasting research has been a subject of domestic and foreign scholars are concerned about topics at the forefront [1,2], Through the majority of scholars to the hard explore.

From the 20th century, 60 years M. Saito [3] the experience of forecasting formula for the beginning, has experienced the phenomenon of the experience equation prediction and forecasting, statistical analysis and prediction, nonlinear prediction, and comprehensive forecasting, real-time
tracking dynamic prediction in several stages [4, 5]. According to incomplete statistics, at present domestic and foreign scholars have put forward not less than 40 species of landslide prediction model, a series of prediction methods and criteria [6,7]. However, a large number of slope warning prediction Practice shows that the slope prediction based on existing models and criteria, and cannot make a real accurate forecasts when the slope will occur to the deformation behaviour and evolution. The reason was mainly due to the slope has a strong personality, the deformation evolution of behaviour related to their environmental conditions in which the geological structure and the slope is closely combined. Moreover the existing forecast models can not consider Personality characteristic of these slope, the main rely on mathematical deduction to get the forecasting model, its appropriateness and the accuracy of forecasting is self-evident [8].

From the needs of slope prediction, in theory, the development of slope can be divided into multiple stages, and according to different stages to come up with prediction methods. Thus, an accurate understanding of slope development stages, it is important to make targeted observing according to different developmental stages of the slope. According to the monitoring data show that: In the gravity,

2.2. Analyse the Slope Disaster Chain-Stage Mechanism

The slope disaster chain-stage mechanism analysis namely Studies have certain constitutive characteristics of the slopes or slope, located in its particular environment (stress field or system of forces), the various factors coupled with each other, and Organic links and mutual restraint to occurrence the development of the law .slopes dynamic according to their slip rate and essence, and the sliding camp factor action and change, it can be divided into three phases. It contains an early embryonic stage (pre-slip instability in the accumulation phase), the medium-term latent phase (creep stage) and late-induced phase (sliding phase).

(1) The first phase the early embryonic section:

Natural slope stability factor (K), due to the different camps of landslide material and energy input power factor, the impact of constant changes in the ups and downs .However, the general trend is a gradual lower. The early stage of the disaster of the "nurturing" phase, at this time it has formed a very weak or destructive Energy is also in the initial stage of assembly or coupling, for such a long process of disaster it’s most effective to carry out chain-breaking to reduce disaster. It don’t require a great investment, you can receive significant results. This is the basic idea of “carry out chain-breaking to reduce disaster”.

(2)The second phase the medium-term latent section:

Slope deformation in a weak place and developing slowly; when approach to sliding stage, it is a steep rising. it’s main to a deep-seated creep dominated for the deformation and displacement before slipping. When the body of all local shear slope surface (surface creep) link up, and it also link up with the top of the hill with pull cracks .when it happen to the slightest disturb by external factors that evolve into landslide. Late phase of the medium-term duration bears on the slope of the stress concentration and fractionation of the speed and the intensity of external force, it is generally to keep a longer duration. in the early the chain-breaking unsuccessful, when in the medium term remedial measures should be taken to strengthen the inspection and control creep, so that the direction of evolution not to slide.

(3)The third phase the late-induced phase section:

Sliding surface linking, cutting edge appears exports; landslide occurs on both sides to the different mechanisms of fracture and has partial collapse. Landslide displacement rate is increasing, and the back edge of the rapid crack is opened and disturbed .Posterior wall continuously collapsed; the leading edge of the table and on both sides of the Ministry collapsed. It’s on the further to destruct the Sliding surface (belt)of rock and soil structure, moisture content increased, sometimes it can outflow of a large number of mud and water with the smooth tongue out .while Landslide at a high speed to forward slip ,it can reach ten meters per second, a longer sliding distance. If the sliding speed is very high, it can produce air waves. Late-stage last relative short duration in general. Landslide slip
through the long-distance, the centre of gravity lower kinetic energy generated when sliding gradually consumed in overcoming the resistance to slipping and sliding body deformation. Late stage of landslide stability factor is gradually increasing. Only the new factors of instability accumulate to a certain extent, the stability factor makes in turn reduce, they enter another landslide process. Landslide dynamics in three stages is a significant difference (table 1)

| Table 1. Landslides stages and characteristics of the dynamic chain. |
|---------------------------------------------------------------|
| **The main aspects of Landslide dynamics diversity** | **Landslide dynamic basic characteristic of different stages** | **Late-induced phase** |
| Phase of early embryonic ——pre-slip stage | Phase of medium-term latent ——Creep stage | When the material, energy accumulated to a certain extent, and inner stress of landslides reached a critical value, the external incentives to outbreak |
| Most of the business edge of landslide areas to slope stability factors are reduced, but some of the main, the environment constantly give material, energy input | Material, energy began to accumulate further | A significant and rapidly growing fast, but then re-by slow, mainly shear change |
| Deformation displacement Deformation does not occur | Small, slow, but in recent sliding phase, the rate of deformation displacement increased, mainly of the slow changes in the deep | |
| Landslide battalion strength factors and energy accumulation | Landslide has not yet formed | Landslide come into being, and then destroyed in the process of sliding into a landslide, with all the cracks |
| Formation and landslides landslide dynamics | Slopes arc cracks appear, and gradually form the embryonic form of Sliding Bed | Stability factor is less than 1 |
| Landslide Stability Activities of time | Tends to a temporary stable state a longer duration under normal circumstances | Short-term or transient, low-speed, landslides exception |
| In the state of stress | Part of the accumulation of cell stress exceeds its maximum load stress | Further accumulation of stress, when the reached a critical value and the mutation took place under the action of the external fluctuation |
| Stress distribution Disorder | Disorder | Orderliness |
The three-stage evolution of slope deformation law is the slope of rock and soil deformation under the action of gravity to follow the evolution of a universal law. Landslide early warning in the forecast should firmly grasp the evolution of this time, based on monitoring curve accurately determine the slope in which the deformation stage, and accordingly take appropriate coping strategies and measures.

3. Nonlinear Dynamic Analyse Chain-Stage Process of the Slope
Many pregnant state variables are required to correctly describe the Landslide slip during pregnancy, studies have shown that [9], for most landslide systems, its general there are three state variables can be adequately described. Set X, Y, and Z for three different prediction error, because its sequences, dimension and magnitude are different, the first standardized, and then base on the physical properties of the system take the \( i \) set to some non-linear function. For the non-linear slide systems, \( i \) is hard to write the specific form, but according to Qin Si-qing et al [10-11], combined with characteristic features of the process chain, it can be set to the following general form:

\[
\begin{align*}
\frac{dX}{dt} &= a_1 X + a_2 Y + a_3 Z + a_4 X^2 + a_5 Y^2 + a_6 Z^2 + a_7 XY + a_8 XZ + a_9 YZ \\
\frac{dY}{dt} &= b_1 X + b_2 Y + b_3 Z + b_4 X^2 + b_5 Y^2 + b_6 Z^2 + b_7 XY + b_8 XZ + b_9 YZ \\
\frac{dZ}{dt} &= c_1 X + c_2 Y + c_3 Z + c_4 X^2 + c_5 Y^2 + c_6 Z^2 + c_7 XY + c_8 XZ + c_9 YZ
\end{align*}
\]

Here, \( a_1, a_2, ..., a_9, b_1, b_2, ..., b_9, \) and \( c_1, c_2, ..., c_9 \) is an invert determined constant. For equation (1), (2) and (3) , with the Runge-Kutta numerical integration method for predictive value. It’s precision to compare with observed values and predicted values.

By equation (1), (2) and (3) consisting of Jacobi matrix J as follows:

\[
J = \begin{bmatrix}
\frac{\partial X'}{\partial X} & \frac{\partial X'}{\partial Y} & \frac{\partial X'}{\partial Z} \\
\frac{\partial Y'}{\partial X} & \frac{\partial Y'}{\partial Y} & \frac{\partial Y'}{\partial Z} \\
\frac{\partial Z'}{\partial X} & \frac{\partial Z'}{\partial Y} & \frac{\partial Z'}{\partial Z}
\end{bmatrix}
\]

Here, \( X' = \frac{dX}{dt}, Y' = \frac{dY}{dt}, Z' = \frac{dZ}{dt} \).

The characteristic polynomial for the matrix J

\[
\lambda^3 + A\lambda^2 + B\lambda + C = 0
\]

Where \( \lambda \) is the eigenvalues of Jacobi matrix; A, B and C are as follows:

\[
A = -\left( \frac{\partial X'}{\partial X} + \frac{\partial Y'}{\partial Y} + \frac{\partial Z'}{\partial Z} \right)
\]

\[
B = \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} + \frac{\partial X'}{\partial X} \frac{\partial Z'}{\partial Z} + \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} - \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} - \frac{\partial X'}{\partial X} \frac{\partial Z'}{\partial Z} - \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z}
\]

\[
C = \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} + \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} + \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} - \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} - \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z} - \frac{\partial X'}{\partial X} \frac{\partial Y'}{\partial Y} \frac{\partial Z'}{\partial Z}
\]
Dynamic stability analysis by the theory [12] we can see, the system stability, necessary and sufficient conditions are:

\[ A > 0, \quad AB > C, \quad C > 0 \]  

(9)

If the type conditions are met, pregnant landslide slip system power evolution behavior expressed as steady-state; the other hand, was Instability. it’s possible to turn up the dissipative structures only after The system in the unstable state. We can start as a landslide criterion, namely, Landslide-induced late phase of the entry criteria.

If use the observation data, it can be More accurately inversion the non-linear dynamic model. It This non-linear dynamics study provides a new way, in particular, it is not exactly know the dynamic model of the practical problems, in this way modeling is very effective. However, in Specific application, it also encountered some practical difficulties, in particular, should be noted that:

(a) Data filtering. As the actual observed data contain the combined effect of many factors, in order to highlight the main features of the system, making inversion of the original data prior to filtering, as much as possible to eliminate the noise impact. (b) Inversion accuracy. The longer the inversion accuracy of the information sequence of the higher, but information on many specific issues rather short sequences, in order to ensure the accuracy of its inversion iterative inversion method can be used as follows:

\[ D - GP_n = G\Delta P_n \]  

(10)

Which \( \tilde{P}_n \) in the previous inversion parameter values, \( \tilde{P}_n = \tilde{P}_{n-1} + \Delta P_{n-1} \), using (10) repeated iterations until \( \Delta P \rightarrow 0 \). It reaches the required accuracy. This relatively when short sequence in the data processing situations, it also can obtain more results that are satisfactory.

(c) Of this method requires that \( q_i \) is an autonomous system.

(d) Observational data must be standardized (ie, dimensionless), and to select the appropriate characteristic time, so that the observed time interval and the difference of the time step in line. If the observation time interval is too long, as a rough approximation, the two observations can be interpolated.

(e) For the practical problems, first need a certain degree of diagnostic analysis to determine which variable is selected as the \( q_i \).

This approach is still in the exploratory stage, there are many issues remained to be further studied. However, we believe that further improvement and refinement, this approach has broad application prospects.

4. Conclusion

This paper represent slope disaster theory and slope disaster change rules with chain relations could control the corresponding step of slope chain breaking and disaster mitigation on the base of well mastering all kinds of chain phase specifications, and could greatly improve the effect of slope disaster control and expansions.

The chain cutting from pregnant source is an effective method to slope disaster mitigation in the early long pregnant phases of disasters when the destruction forces are weak or even inexistent and the energy and information is still in gradual accumulation or coupling status, the action of chain-cutting disaster mitigation would be low-cost but very effective. To minimize the losses, it is proposed that the disaster pre-alarm function be traced and extended back to the disaster pregnant phases, so the initial disaster mutation characteristics and representation morphologies should be monitored, to pioneer the disaster mitigation from the pregnant sources and achieve the best effects from the chain-cutting practices.
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