Particle Flow Code Method-Based Process Analysis for Loess Landslide

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Abstract: In the movement process, loess landslides often form a unique internal structure. Through the numerical model test, a similar model is established and analysed under different conditions to get the information of deformation and failure processes. Through the above analysis, this research draw the loess landslide movement process and analysis the impact of the main factors which influence the process.

1. Introduction
The loess landslide is a typical geological disaster in the loess area of China, which restricts the development of the regional economy for its high frequency and damage[1][2]. In the research of loess landslide process, many works pay attention to the mechanism of landslide, like its formation mechanism, triggering factors and forecasting, few researches pay attention to the deformation and failure within the loess landslide. It is helpful to get more information on the deformation and damage of loess landslides, and it have a strong guiding significance on predicting the form and scope of damage[3]. Due to the fact that the discrete element numerical method is capable of computing the deformation of large-scale rock masses, more and more applications are being made to the simulation of landslide sliding[4][5][6]. Taking the landslide on the south of Jing river as the study area, this paper summarizes the development characteristics of loess landslides in the study area through the field investigation and indoor data, and the geological model is established. Particle flow numerical model test method is used to investigate the deformation and failure process of terrace stratum and the movement characteristics.

2. analysis of internal structure of loess landslide
The study area located in the Weihe basin, which produce strong modern tectonic activities. It is a Cenozoic complex graben fault block depression, controlled by the two major faults. From top to bottom, the plateau on the south of the river contains loess layer from Q₃, Q₂ to Q₁. On the spot investigation, it was found that layer below the water line is saturated. The periphery is alluvium, springs exposed at the edge of the plateau. In the mountainous area, the mountain area has been rising slowly for many years, rising by about 1.2mm/y, provides favorable conditions for the birth of landslides [7].

During the continuous lateral erosion under the action of the river, loess landslides on the edge of plateau are well developed, which are the major factors influence the irrigation of loess landslides. The previous analysis show that the movement process contain the external integral movement and the internal partial rupture.

Figure 1 is the section of landslide named Zhaitou. The length of the sliding mass is about 200m, the
material of the terrace widely exposed out. As the landslide occurred long time ago, the sliding body has been paved and planted with fruit trees. The detailed landslide section and terrace section are shown in Figure 2. We can see that the terrace is uplifted under the pushing force of loess landslide, and the red part is the internal shear plane.

![Figure 1: Section of the Zhaitou landslide](image1)

![Figure 2: Sketch Map of Trench](image2)

It can be concluded that the loess landslide in the study area is a movement which contain shear fracture but maintain a certain structure. In this process, landslides have a greater scope of damage, and there is a false impression that the sliding distance is far away. In fact, this is the result of the rupture of the terrace material. After the terrace material bursts, there will be parallel shearing and rupturing planes in the interior, similar to thrusting and nappe structures, and the former horizontal terrains have the opposite tendency to the direction of landslide movement.

According to the field geological survey, the sliding surface morphology before landslide start up is summarized. The uppermost section is almost upright. The slope of the middle section ranges from 45° to 70°; the last segment is arc-shaped, extending down to the terraces inside. In general, the posterior wall of the loess landslide on the south bank of the river is steep and presents a segmented characteristic. A marker layer is provided to illustrate the internal deformation during the landslide movement. The action of landslide movement is divided into three stages:

- **The first stage** is shown in Figure 3.a. At this time, the landslide is in a state of peristalsis. Under the long-term comprehensive influence of various factors such as irrigation and weakening of the long-term strength, the slope is in danger. Any accidental factors that cause the sliding force to be greater than the sliding resistance, such as earthquakes and heavy rains, will cause the slope to lose its stability and cause deformation and damage.

- **The second stage**, shown in Figure 3.b, is an accelerated process of the loess body. After the slope starts to slide down, the strength of the sliding zone soil weakens to the residual strength. Under the action of the gravitational potential energy being transformed into kinetic energy, the moving speed of the slope body increases continuously. At the same time, the sliding surface extends to the interior of the terraces, and the process of partial rupture and sliding surface development inside the terraces is squeezed. Local shear occurs within the terraces and develops continuously, forming a complete sliding
bed. The leading edge of the landslide is squeezed, show a wavy landscape;

![Pattern map of landslide movement](image)

**Figure. 3. Pattern map of landslide movement**

The third stage is shown in Figure 3.c. At this time, due to the inertia, the loess slide continues its forward movement. This stage belongs to the deceleration stage of the slide body. The terrains under extrusion are distorted and deformed. The plots are squeezed and show a shingled shape. This is the three stages of the push mode of loess landslide proposed in this paper.

### 3. the numerical analysis of loess landslide

Particle flow software was used to establish a large-scale loess plateau model and to calibrate the parameters of the grain size, so that the model have the same deformation characteristics as the study area. By setting the model parameters, the effect of liquefaction on the degeneration and destruction of terrains was studied.

According to the field survey, a two-dimensional numerical model of particle flow was generalized. The model was designed as Figure 4. The left side of the model was loess, which is 42 m height. The back wall was divided into three sections, the first section is 10 m long. The second section is 33m long, the slope(α) is 60°, the third section is an arc section, extending to 9.8m below the terraces of terrace. The dark part on the right is terrace stratum with a length of 100 m. A control experiment was set up to reduce the strength of the particles at the bottom of the terrace model to simulate the liquefaction. Under rapid shear and undrained conditions, water pressure increases, and the experiment is divided into two groups.

![Sketch map of numerical model](image)

**Figure.4. Sketch map of numerical model**

#### 3.1. Calibration of Microscopic parameters

Numerical biaxial experiments were carried out by the generational numerical servo, and the microscopic parameters of loess and sand were obtained by repeatedly correcting the microscopic parameters. The triaxial curves of typical soils are similar to the numerical triaxial curves, and this parameter is used as the microscopic parameter of the numerical model particles.

#### 3.2. Crack Propagation Numerical Model Test

In the initial stage of landslide movement, the shear plane at the bottom of the model can be seen from Fig. 5.a. It shows that when the loess slope moves to push the terrace, the sliding surface extend further into the terrace. There are several shear planes near the stratum profile in the model, and the upper surface of the model will form a wavy pattern. It can be explained that the wavy micromorphology is
formed by the shear surface near the surface when the partial landslide movement distance is little.

As the model moves further, the terraces uplift, wavy micromorphology disappear (Fig. 5.b). At the bottom of the model, the rupture surface develops further, and some of the near-surface rupture surface preferentially develops and extends to the interior of the slope body, forming a continuous shear band.

![Figure 5. Crack development chart of particle flow model](image)

When the model moves further the shear zone has been formed to form a pseudo-thrust nappe structure and push the terrace to form a new through shear plane (Fig. 5.c), which further increases the damage range of the landslide. If the movement of the wall is promoted, the model will be further uplifted along the penetrating shear plane and the soil within the scope of the model will be further squashed and distorted. At the same time, it is also found that the model has become the shear plane inclined in the same direction as the landslide. Once again, the large-scale numerical model test proves the pushing mode during the loess landslide discussed before.

Groundwater in the south bank of the river is shallow and the sand layer is mostly saturated. The loess on the south of Weihe basin contain the phenomenon of double-layer liquefaction, that is, the sliding surface and the slide bed will liquefy during the movement. Field exploration trench also found that soil prone to liquefy, so the friction coefficient of the soil close to the sliding surface of the numerical model is set to 0.1, that simulated pore water pressure increasing during the movement. The weakened part of the soil mass is the 2m thick and 35m long at the bottom of the model.

![Figure 6. Pattern of model fracture development after pore water pressure increase](image)

The strength of the local map at the bottom of the terrace model is weakened, and the pore water pressure is simulated to increase. The crack growth process of the model is shown in Figure 6. In the initial stage, as shown in Fig. 6.a, dense shear cracks appear on the upper surface of the model. The same surface will form a wavy shape. That is the appearance of the shear fracture and the shear at the bottom crack. When the landslide is moving for a period of time, as shown in Figure 6.b, the cracks in the ground surface and the cracks in the bottom are further developed. The model is uplifted, and the internal cracks appear to have the same tendency as the landslide movement. Finally, as shown in Fig. 6.c, the shear band formed through the model is formed, and the soil within the scope of the model destruction is further crushed and distorted.

By comparing the two sets of tests, we can see that the soil strength of the first model is normal and the maximum damage range of the model is 34m. In the second experiment, the friction coefficient of the fine particle parameters in the local range of the sliding surface is 0.1. The maximum damage range of the model is 39m. It shows that the liquefaction of the sliding soil will obviously increase the damage range of the model. The movement makes the destroyed soil further crushed and distorted, which can explain the complicated superimposed section of the south bank of the river.

4.Conclusions and Outlook

According to the deformation process of terrace, the movement process of landslides can be divided into three stages: the temporary slip stage, the accelerated slip stage and the deceleration slip stage.

Affected by the influence of the landslide deformation, as the water pressure increase, the range of soil damage increase, and it is easier to form a tile-like micro-topographical features.

Through the analysis and calculation of the movement characteristics of loess landslides on the south bank of the river, the prediction of damage scope and destruction may be made in the future.
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