The Study on Erosion Mechanism of Loess Slope under Rainfall Condition based on Seep Model

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Abstract. In this paper, simulated rainfall infiltration phenomenon on the loess slope under rainfall condition based on seep/w model and studied the mechanism of rainfall on loess slope erosion from microscopic perspective by analyzing the distribution of pore water pressure in different monitoring locations at different times during rainfall. The results showed that under the condition of rainfall, the slope shoulder that is nearest to the slope top is always in high water pressure and is the first place where runoff erosion begins; and with the increase of the slope gradient, water pressure of each monitoring site gradually increased and the degree of erosion of slope surface erosion is more serious.

1. Introduction
Soil erosion is one of the main reason of soil erosion and land resource degradation, in which rainfall erosion is an important part of soil erosion. The rainfall erosion of the loess slope mainly includes the splash of rainfall on the slope and the erosion of the runoff Scouring on the slope. When raindrops fall from high altitude at the beginning of rainfall, great potential energy is transformed into kinetic energy, which directly impacts the bare surface. The loose soil particles are displaced on the slope surface under great impact force, and then the original surface structure on the slope is destroyed. when the rainfall is greater than the soil infiltration rate, the runoff is formed gradually on the slope surface, and the downward flow along the lowland of the slope, leads to the rill erosion on the slope.

According to statistics, the distribution of loess in China is very wide with an area of about 6.4×105km²[1]. The terrain in the loess area is dilapidated and the water and soil loss is quite serious. The total area of soil and water loss is about 4.3 × 10⁹km²[2]. Over the years, the study of slope erosion has never ceased. Li Peng and Wang Xian et al, studied the mechanism of erosion and erosion on the loess slopes exposed to heavy rainfall by analyse the law of rainfall runoff and sediment loss in loess slopes with different slope ratios through rainfall experiments [3,4]. Some scholars also studied soil erosion kinetics Study soil erosion mechanism [5].

2. Study on the erosion mechanism
Seep/w is a finite element software for the analysis of groundwater seepage and excess pore water pressure dissipation in porous materials such as soils and geotechnics. this software can be used to analysis of time-dependent saturated and unsaturated seepage problems. In this paper, we use the seep/w module in Geo-Slope software to simulate rainwater infiltration on loess slopes under rainfall
conditions, studied erosion mechanism of loess slope by analyzing the distribution of pore water pressure at different times during rainfall and different test sites.

2.1. Physical parameters of the slope
The slope height of the simulated loess slope model is set to 15m; the model slope is set to 25°, 45° and 65° respectively; the model set 4 monitoring points where at a distance of 1m from the slope surface and the vertical distances from the slope to the monitoring point are respectively 1m, 5m, 10m and 15m, Monitoring point settings shown in Figure 1.

Figure 1. Monitoring set point diagram

The loess is collapsible, which is a special property of loess. Loess has a homogeneous soil texture, loose structure and pore development. Under dead weight or external load, the structure rapidly destroys the sudden sinking property under the influence of water. the loess is generally higher strength and less compressibility not wet. Refer the date of loess slope, the physical parameters this of loess slope simulation in paper set as follows.

| Severe (kN/m^3) | Deformation modulus (MPa) | Poisson's ratio | Cohesion (MPa) | Internal friction angle (°) | Cohesion | Permeability coefficient (m/s) | Porosity |
|-----------------|---------------------------|-----------------|-----------------|----------------------------|-----------|-------------------------------|----------|
| 20              | 2                         | 0.38            | 1.85            | 25                         | 35        | 2×10^-5                       | 0.52     |

Simulate the slope seepage law under rainfall conditions by Seep/w software. Rainfall is used as a boundary condition, that is, when the rainfall is less than the saturated permeability coefficient of the soil, the rainfall is all seeped, and the boundary condition is the flow rate Boundary, and the size of the flow is equal the amount of rainfall. When the rainfall is greater than the saturated permeability coefficient of the soil, only part of the rainfall infiltrates and the rest flows by the surface runoff. At this time, the boundary condition is the fixed head boundary. It should be noted that this model does not consider the effect of groundwater on rainfall infiltration law, taking the slope top and slope as the rainfall infiltration boundary during rainfall. In order to ensure that rainfall erosion and erosion phenomenon are obvious, the rainfall intensity was set as 3.24×10^-4 m/s in this simulation; The duration of rainfall scour and computing time were all 60min, and the bottom of the model was free boundary.
2.2. Results Analysis

**Figure 2.** Rainfall Infiltration Head Pressure at 65°Slope at 60min

From the cloud point detection and monitoring data can be seen, the top of the slope is always in the high head pressure during the scouring process, followed by the slope foot, and the head pressure in the middle of the slope is the smallest. Under continuous rainfall, the slope top and slope soil quickly reach saturation. At this moment, part of the rainfall is transformed into loss of surface runoff while the other part of rainfall continues to infiltrate. The seepage field inside the slope body is constantly changing.

**Figure 3.** Head pressure at different slope monitoring points changes with time

In figure 3, it is clear that the head pressure at monitoring point A is always slightly higher than the head pressure at point C, and the head pressure at point C is also slightly higher than the head pressure at point B. This proves the fact that the lower part of the slope soil In addition to accept the vertical infiltration of rainwater directly, it will also accept the upper diarrhea further infiltrates.

It can also be found the head pressure and its increasing trend are greater than other monitoring points of point D at any moment during the rainfall erosion process, which well explains that the slope started to erode from the top of the slope during rainfall erosion. It agrees well with the experimental results of previous scholars.
According to the change of head pressure at the same monitoring point with different slope over time, the head pressure at each monitoring point of 65° slope is greater than 45° slope and greater than 25° slope, and the head pressure of each monitoring point showed an increasing trend with the increase of rainfall time under different slope.

2.3. Theoretical analysis
In the process of rainfall, when rainfall intensity is greater than soil infiltration rate, the part that exceeds the infiltration rate will converge on the slope to form surface runoff velocity. Because the ground runoff depth due to rainfall is small, usually only 0.01~0.05 m. The flow width is far greater than the depth ground runoff, so in theoretical calculation runoff radius is numerically equal to runoff depth.

The ground flow rate of the unit width on any section is $q$:

$$ q = v h_i B / B = v h_i $$  \hspace{1cm} (1)

By hydrology, calculated directly by rainfall unit width runoff $q$:

$$ q = \phi I x B / B = \phi I $$  \hspace{1cm} (2)

Since surface runoff is produced by rainfall, the two single-width flows should be equal. So the expression of water depth $h_1$ of slope runoff is derived:

$$ h_1 = \sqrt{\frac{\phi I x}{C}} $$  \hspace{1cm} (3)

Through theoretical analysis to draw slope water flow expression formula:
According to Eq. (4), when the rainfall intensity and the length of the streamline are constant, the runoff velocity and the scouring force of the flow generated by the slope will increase with the increase of the slope; on the contrary, the slope can be effectively reduced ground runoff and soil erosion force, which same with the simulation law exactly that rainfall erosion also aggravates with the increase of slope gradient under same rainfall intensity conditions.

3. Conclusion
This article draws the following conclusion by seep/w software through analysis the pore water pressure distribution law on the slope of loess slopes under different rainfall conditions. First, the earliest slope erosion on loess slope is the slope shoulder position of slope under the condition of rainfall followed is the position of slope foot and slope. Second, the head pressure at each monitoring site also increases as the slope gradient increases, and the erosion of slope slopes also aggravate.

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