International Core Journal of Engineering Volume 7 Issue 9, 2021
ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0015

Study on Deformation Characteristics and Water Content Response of Typical Soil Landslides in Sanmenxia Open-pit Mining Area, Western Henan

Zudong Hu[1,a], Zhengjiang Liu, Na Li

[1]Institute of Resource and Environment, Henan Polytechnic University, Jiaozuo 454000, China.

[a]2030906217@qq.com

Abstract

In the process of open-pit mining, the special type of soil landslide is formed by the accumulation of peeling soil and the disturbance of mining pit slope. There is a great difference between the geotechnical properties of the landslide and the soil landslide cultivated by the original soil, and the stability is poor, which seriously threatens the life safety of mine workers. Based on field investigation and physical model experiment, the deformation characteristics and moisture content variation characteristics of soil landslide induced by typical open-pit mining in Sanmenxia area, western Henan province were systematically studied. By analyzing and summarizing the breeding conditions and evolution characteristics of typical soil landslide in Sanmenxia area, western Henan province, the breeding process of soil landslide can be divided into three stages: embryo stage, development stage and maturity stage. Through indoor physical model experiment, the process of landslide instability under natural state and rainfall condition was simulated, and the variation characteristics of soil moisture content were observed synchronously throughout the whole process. The results show that the slope stability in natural state is mainly affected by the slope, and the breeding of soil landslide is mainly controlled by the slope and water content under the rainfall condition. The water content in the embryonic stage range from 12.5% to 21.8%. Affected by the collapseability of the soil itself, fine cracks first develop in one place. In the development stage, the water content range from 21.9% to 40.3%. The surface slope was eroded and cracks developed. The erosion degree increased step by step from the top to the toe of the slope. In the mature stage, the water content is in the range from 40.4% to 46.9%, the internal and external cracks are fully developed, the tensile crack surface is formed, and the regional small collapse causes the soil in front of the slope foot to be empty. Under the same conditions, the greater the slope, the more likely the instability is.

Keywords

Soil Landslide; Deformation Characteristics; Moisture Content; Physical Model.

1. Introduction

China suffers from frequent geological disasters every year. From 2010 to 2019, 121,048 geological disasters occurred across the country, with an average annual casualty of 825 people and an average annual direct economic loss of 4.48 billion yuan, which threaten the safety of the people and restrict the economic development of various regions. Landslide disaster is the type of geological disaster with the highest proportion and the greatest harm among all kinds of disasters [1].

Sanmenxia in western Henan province is a resource-based city. The reserves of bauxite in this area account for about 23% of the national reserves, which plays an important role in the economic

ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0015

development of Henan Province [2]. The buried depth of bauxite is relatively shallow due to the influence of metallogenic environment and tectonic movement, restricted by mining technology and other conditions, it is mostly open-pit mining, and in the process of mining, the stability of surface slope rock and soil mass is disturbed and damaged greatly, and the distribution of quaternary strata in the area is extensive, low intensity, to a certain extent determines the Sanmenxia City open pit mining area universality and particularity of soil landslides and similar areas. The extensive development of soil landslides in the area not only threatens the safety of people's life and property and the surrounding geological environment increasingly, but also causes a certain degree of negative impact on the image of Sanmenxia tourism city [3]. At the same time, mining is a dynamic process, which does not have the feasibility of comprehensive geological disaster exploration. Therefore, the effective investigation, real-time monitoring, effective prediction and evaluation, and timely warning of soil landslides in the open-pit mining area of Sanmenxia Bauxite mine, so as to reduce losses as much as possible, are the urgent needs of areas potentially threatened by landslide disasters [4].

Landslide can be divided into soil landslides and rock landslides according to their material composition. Among all kinds of landslides that have occurred, soil landslides account for more than 60%. The identification and monitoring of soil landslide breeding process is the basis of various research, and it is also the key to early identification, early warning and emergency treatment of soil landslide, which helps to deepen the earthiness landslides inoculation phase of the study on the dynamic change of mechanism and process, as the research area, It provides reliable water content threshold for soil landslide prevention and early warning in the study area, promote the development of the whole process of the dynamic monitoring system for disasters. At the same time, it has important practical guiding significance for sanmenxia bauxite open-pit mining area to carry out geological environment restoration, green mine construction and ecological restoration of mountain, water, forest, farmland, lake and grass.

2. Overview of the study area

Sanmenxia city is located in the west of Henan Province, at the junction of The three provinces of Henan, Shanxi and Shaanxi. It is a new industrial city on the bank of the Yellow River. Geographic coordinates are 110°21 '42 "-112 °01' 24" E, 33°31 '24 "-35 °05' 48" N. Sanmenxia city is located in the eastern extension of the Qinling Mountains, with an average altitude of 300m-1500m, and a length of 153km from east to west and a width of 132km from south to north.

Sanmenxia is a semi-arid inland climate of warm temperate monsoon type, which is controlled alternately by subtropical high and westerly circulation. With four distinct seasons, the annual average temperature is 14.2℃, the annual rainfall is generally between 400mm and 700mm, and the rainy season is concentrated from July to September. The average annual evaporation is 1,951mm, and the annual sunshine time is about 2,051.6 h.

The strata in the study area are North China type strata with relatively complete development and mainly exposed archean, Proterozoic, Neogene and Quaternary strata. The carboniferous, Jurassic, Cretaceous and Paleogene strata are scattered in the area, and a large number of silurian, Devonian and lower Carboniferous strata are missing [5].

On the whole, the tectonic line direction in this region is NORTHwest-trending and nearly east-west trending, with strong structural deformation, relatively developed fold and fault structures, and a fan-shaped horst arch fault with "one vault, three folds and three faults" interlocking [6]. The three folds include Daimeichai anticline, Mianchi syncline and Xin 'an syncline. The three folds were formed in Yanshanian period. The three faults were formed in order of east-west high Angle normal fault, North-East high Angle strike slip normal fault and north-west strike slip normal fault. The three groups of faults developed in a triangular crisscrosis and separated the vault and syncline, forming a three-great horst type fan-shaped fault block and faulted basin bounded by The Kemenshan fault and the Longtangou fault [5][7].

Volume 7 Issue 9, 2021
DOI: 10.6919/ICJE.202109_7(9).0015

3. Development characteristics of soil landslides in the study area

3.1 Analysis of the formation and gestation conditions of soil landslides

The structures of soil landslides in the study area mainly include landslides within soil layer, soil-basement contact surface landslides and soil-bedrock landslides [8].

The background investigation and disaster model evaluation of soil landslide geological hazards play an important role in the correct understanding and prevention of soil landslide. The formation and breeding background control the engineering characteristics of soil and the disaster mode of landslide in the region. The formation and breeding of soil landslide need to meet four conditions:

3.1.1 Formation of effective face

The study area is a hilly landform, and the slope of the platform area is mostly about 30°, while the slope is more than 45° after open-pit mining. The internal friction Angle of quaternary soil and its soil is 19°-30 °. When the gradient of slope is close to or greater than the internal friction angle of soil, the slope stability is poor, which is the dominant area for the development of the free face of soil landslide. The activity intensity of the studied block is moderate, and the neotectonic movement leads to the different ups and downs among different blocks and tectonic units, which can form effective free face. This area is rich in mineral resources, and the stress distribution on the steep slope will change during the process of human mining the mineral resources. Under the action of rock unloading, weathering and other factors, the effective free face can be formed.

3.1.2 Characteristics of slippery rock and soil mass

The original soil in the study area is porous, contains a lot of calcareous concretions, and has strong water sensitivity, that is, its volume expands rapidly under immersion and saturation, and even mud turns into fluid-plastic body. It’s deformation strength increases, while the shear strength and stability decrease.

3.1.3 Formation of weak tectonic surface

The strata in the study area are mainly quaternary loess deposits. The physical and chemical properties of the quaternary strata were affected by the climatic alternation of the quaternary glacial and interglacial periods, and the loess and paleosol were deposited in the form of alternating stratification. Influenced by the sedimentary environment, the overlying bedrock is mostly sandy clay, sandstone and conglomerate, resulting in poor permeability and weak corrosion resistance of the bedrock. Affected by groundwater infiltration [9], it is easy to undergo gravity erosion and form large-scale soft structural surface with the bedrock.

3.1.4 External inducing conditions

The study area is located in the Fen-Wei Tensile fault seismic zone in the southeast source of Tai-ao in Ordos. The historical seismic activity intensity and frequency are high, and the vibration will accelerate the fragmentation of rock mass, promote the fissure to develop in depth, which leads to the occurrence of landslides. The rainy season rainfall is concentrated in the study area, which accounts for 52.44% of the annual average rainfall. Short duration rainstorm and rainfall accumulation are the most important inducing factors of soil landslide in the study area.

3.2 Evolutionary Stages of Soil Landslides

Landslides have strong personality characteristics, and their evolution behaviors vary greatly due to their different environmental conditions. By summarizing a large number of landslide monitoring data, Xu Qiang et al believe that the deformation of slope rock and soil mass can be divided into three deformation evolution stages,initial, constant and accelerated, according to the deformation velocity [10].

According to the development characteristics of soil landslide in the study area, the deformation of soil landslide can be divided into incubation stage and accelerated deformation stage. The incubation stage (AD section) can be further divided into three stages: embryo stage (AB section), development stage (BC section) and maturity stage (CD section). The accelerated deformation stage (DF section)

ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0015

can be subdivided into middle acceleration stage (DE section) and high acceleration stage (EF section).

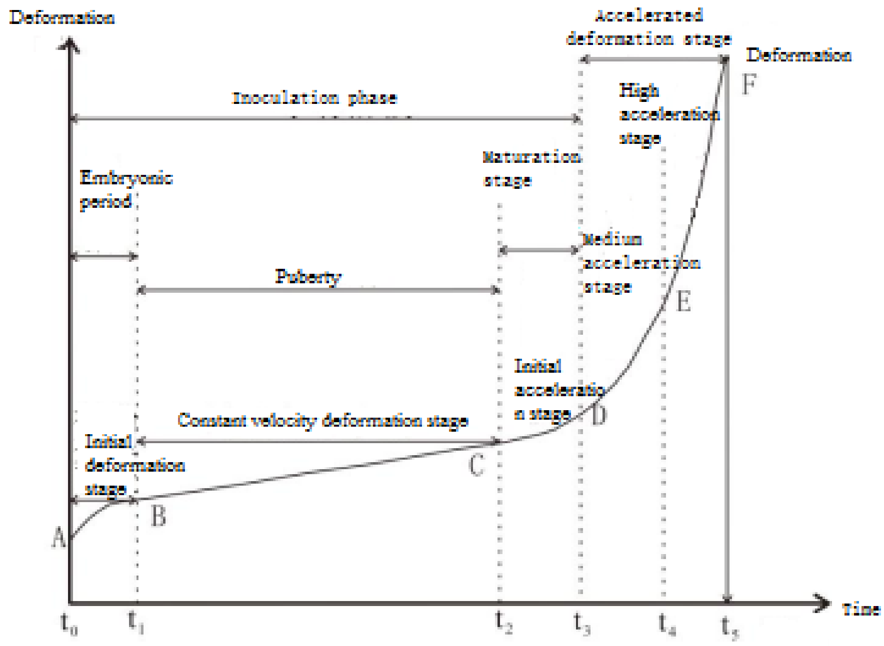


Figure 1. Stages of slope deformation evolution [10]

4. Experimental study on the developmental characteristics of soil-based landslides

For the study of the failure mechanism of conventional soil slope, the existing research means mainly include numerical simulation, field instrument measurement and physical model test. The physical model test has a good visual, operability, and the advantages of flexibility, it can restore and simulate various lithology, boundary conditions, rainfall and other complex factors to the maximum extent under the condition of basically satisfying the similarity principle, scientifically reflects the internal various soil slope rock mass mechanics parameters, interaction, etc.

4.1 Experimental Design

Firstly, the relationship between different thicknesses of disturbed piled soil and the critical slope of instability under natural state was simulated by grouping experiments, and the critical slope value of instability of different thickness accumulation in natural state is obtained. In the range of relatively stable slope, select suitable slope for group test, simulate the whole process of soil landslide from breeding to development and then to occurrence under the condition of rainfall. The relationship between water content and displacement and the stability of this kind of landslide in the inoculation process of different slope and different slope shape are analyzed, which lays a theoretical foundation for the spectral response characteristics and dynamic monitoring system of soil landslide inoculation process.

4.1.1 Basic parameters of soil sample

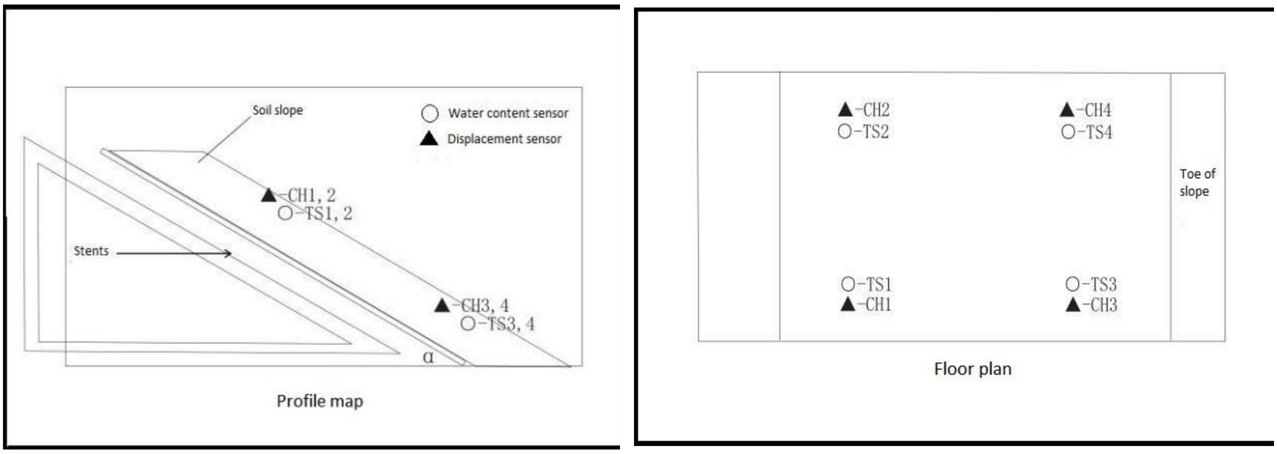
The soil material used in the research institute of physical model test of disturbed soil accumulation landslide was mining disturbed soil, and the soil was taken from an open-pit bauxite mine dump in Mianchi County, Sanmenxia city, with coordinates of N34°47 '23 "and E111°33' 49". Table 1 shows the physical and mechanical indexes of the remolded soil samples collected from the measured soil test after sampling. Soil sample and laboratory test were carried out in accordance with the provisions of "Standard for Geotechnical Test Methods" (GB/T 50123-2019), and physical parameters of soil samples were obtained through experiments.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0015

Table 4-1. Physical and mechanical indexes of remolded soil samples

Natural moisture content%	specific gravity ds/(g/cm-3)	Liquid limit WL/%	Plastic limit WP/%	Plastic index IP	Severe γ(kN/m3)	Saturated severe (kN/m3)
11.3	2.72	26.2	16.6	9.6	18	20

4.1.2 Parameter selection and group number arrangement



(a) Profile map (b) Floor plan

Figure 2. Schematic diagram of sensor layout

First of all, group experiments were carried out with accumulation of thick of 10cm, 15cm and 20cm, and the critical gradient of soil slope under non-rainfall condition was obtained respectively. The slope of the simulated rainfall experiment will be set according to the critical slope value θ that obtained from the accumulation experiment under non-rainfall conditions. The slope gradient was set according to the critical Angle θ, and two groups of grouping experiments were carried out according to α and β respectively, θ > β > α.

According to the meteorological data of Sanmenxia city, the short duration of heavy rainfall in the region is concentrated in the rainy season (July to September), with the maximum daily rainfall of 69.4mm, the maximum hourly rainfall of 60mm, and the maximum 10 minute rainfall of 17.8mm. According to the meteorological data of the study area, the simulated rainfall intensity range is 20mm/ h-60mm /h. The duration of each rainfall is 20min - 60min, and the interval of rainfall is 20min - 60min. During the experiment, the simulated rainfall and intermittent time were adjusted at any time according to the specific process of the experiment.

The experimental sensor mainly includes moisture content and displacement sensors. Two survey lines are set up, and a group of soil moisture content sensors and displacement sensors are buried at different heights for each survey line. The humidity sensor is numbered TS-1 - TS-4, and the displacement sensor is numbered CH-1 - CH-4. Figure 2 shows the sensor positions.

4.2 Experimental Process

(1) Experimental procedure of critical slope value of shallow soil landslide under natural state: Building slope surface → Model filling → Seal for about 3 days to make it natural compaction → Slowly increase the slope →The slope becomes unstable with a slope value of θ1→ The slope is completely unstable with a slope value of θ2→ The experiment is over.

(2) Physical model test flow of incubation process of shallow accumulation soil landslide under simulated rainfall: Building slope surface →Model filling → Let it stand for more than 3 days to make it naturally dense →Conduct slope rainfall according to the specified rainfall intensity →The

Volume 7 Issue 9, 2021
DOI: 10.6919/ICJE.202109_7(9).0015

changes of water content and displacement during rainfall infiltration were measured →The slope begins to slide →The experiment is over.

4.3 Experimental results and analysis

4.3.1 Experiment on slope critical value of shallow soil landslide in natural state

According to the actual situation, the initial soil moisture content is controlled at 12.5%±0.5% when the model is filled, which is close to the natural water content to the maximum extent. Gradually and slowly increase the slope by adjusting the base plate until it stops when the slope begins to slide, the slope at this time is measured to obtain the critical value θ of soil slope sliding after disturbance of different accumulation thickness under natural state (Table 2), which provides the slope design basis for later rainfall simulation experiment.

Table 2. Instability slope of different accumulation layer thickness

Accumulation of thick/cm	Start to fail slopeθ1/°	Slope of complete instabilityθ2/°
10	52	55
15	49	54
20	46	48

4.3.2 Physical model experiment of soil landslide breeding process with different slope under simulated rainfall condition

The initial soil moisture content of the model was also artificially controlled at 12.5%±0.5%. Because the safety factor of unsaturated soil slope is inversely proportional to grade of slope, according to the experimental results of the critical value of accumulation layer instability under non-rainfall conditions, combined with the angle classification of open-pit mine slope in the relevant standard [11], finally, the experimental slopes are 35 ° (slope) and 45 ° (steep slope).

(1) Model experimental of slope with gradient of 35°

① Slope rainfall scheme and deformation process

Observe and record the changes of displacement and water content through the displacement and water content monitoring system until the landslide stabilized and stopped. The rainfall time and rainfall interval Were properly adjusted according to the actual situation, the final rainfall scheme is shown in table 3. When the model was filled, the water content was controlled at 12.5%±0.5%, and the rain intensity gradually increased from small to large.

Table 3. The rainfall plan of the slope model test with a slope of 35°

Rainfall sequence	Raininess(mm/h)	Duration(min)	Interval(min)	Starting-ending time
1	20	90	25	9:15-11:10
2	40	60	30	11:10-12:40
3	60	60	30	12:40-14:10
4	40	60	40	14:10-15:50
5	30	30	-	15:50-16:25

During the experiment, the slope failure mode is block sliding failure. The landslide mass mainly slides along the slope formed by maintenance, and the landslide mode is contact surface sliding, the slope deformation of the model is mainly divided into four stages. Fine cracks appear on the slope after a period of rainfall (0min -115min) →Crack expansion at the back edge (115min - 280min) → The slope foot appears drum fractures (280min - 355min) → Accelerated instability (355min - 425min). Figure 3 shows the slope shape change process.

Volume 7 Issue 9, 2021
DOI: 10.6919/ICJE.202109_7(9).0015

Embryonic period Puberty Maturity Accelerated deformation

Figure 3. The failure process of a slope with a slope of 35°

② Analysis of water content variation characteristics

Figure 4 shows the change of water content of slope model with simulated rainfall process. As can be seen from the figure, at the initial stage of simulated rainfall, the water content of each measurement point in the first 20min is relatively stable and basically remain unchanged. When the rainfall lasts for a certain period of time, the moisture content rises slowly at first. In the process of simulating rainfall infiltration, the wetting front forms an obvious interface with the underlying dry soil, and there will be a stable period after reaching the wetting front. With the rainfall accumulation breaking through the wetting front, the growth rate of water content increases, and finally reach a stable value.

When the simulated rainfall started 20min, the water content increased slightly, and reached a stable state about 40min; during the rainfall interval, the water content fluctuates slightly; the soil at the top of the slope reaches saturation earlier than that at the foot of the slope, and the water content changes slower; When cracks appear in the slope, the rainwater will accelerate to infiltrate along the cracks, which will cause a short peak fluctuation of the nearby water content sensor value, such as the band peak at 175min and 240 min of sensor 2; sensors 3 and 4 were gradually exposed in the destruction process of the slope foot around 375min, and the water content gradually decreased; After 225min, due to the consolidation settlement of the wet soil on the upper part of the slope model, the infiltration rate is slowed down, and the No. 3 and No. 4 moisture sensors are in a stable state for a long time. No. 2 sensor reaches the saturation state in about 310min, and the water content basically remains unchanged, the water content of sensor 1 decreases to a certain extent in the simulated rainfall interval after reaching the saturation state due to the influence of cracks. Therefore, the time to reach the final saturation state is later than that of No. 2 sensor.

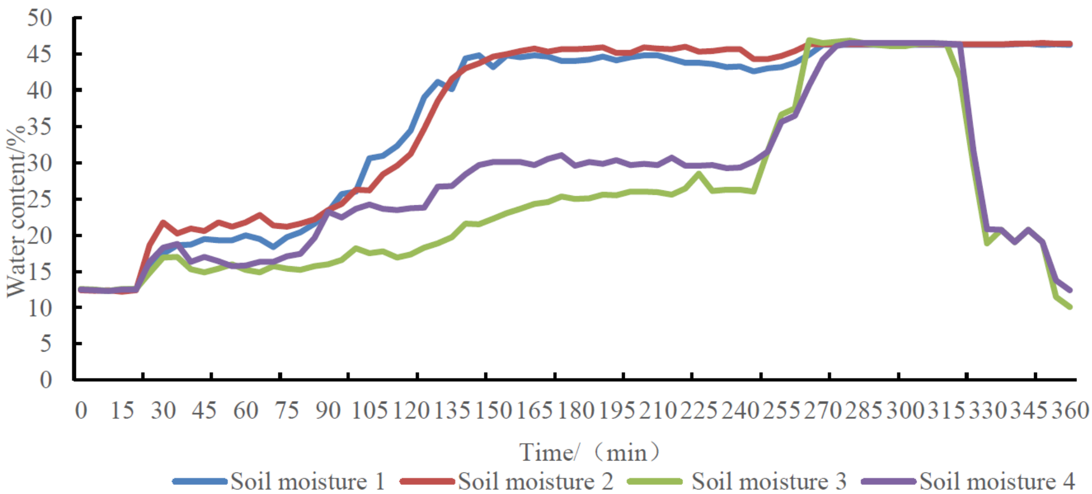


Figure 4. Variation of water content at 35° slope

ISSN: 2414-1895
DOI: 10.6919/ICJE.202109_7(9).0015

③ Analysis of displacement characteristics

In this paper, the strain displacement sensor is used to monitor the slope displacement (FIG. 5). As can be seen from the figure, the displacement of measuring point 1 and 2 at the top of the slope changed by a maximum of 8.68mm. After the slope is completely unstable, the sensors at measuring points 3 and 4 at the foot of the slope are exposed to the surface of the soil. At this time, the displacement reaches the maximum range of the sensor (100mm). The measuring point 3 and 4 at the foot of the slope began to be destroyed at 354min52s and 355min18s, respectively, and the displacement change accelerate. In about 20min, the slope appeared large scale fragmentation and gradually accelerated instability.

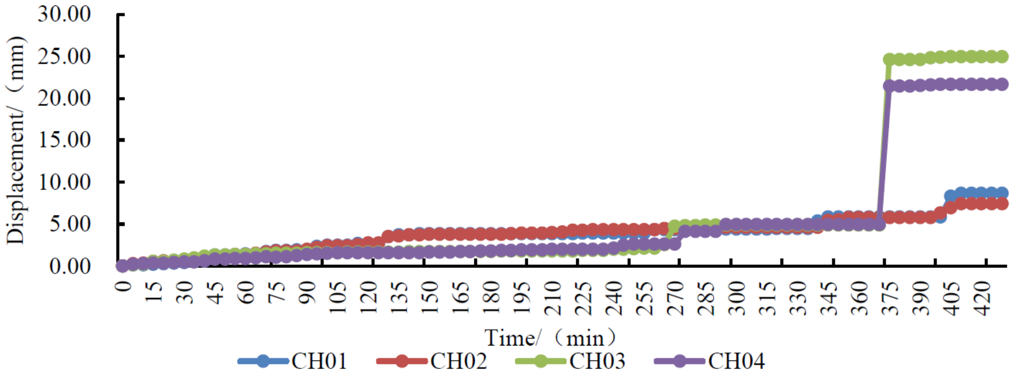


Figure 5. Slope 35° displacement change

(2) Model test of slope with gradient of 45 °

① Slope rainfall scheme and deformation process

The actual rainfall scheme of this experiment is shown in table 4. The initial water content of the model is controlled in 12.5% ± 0.5%, and the rain intensity increases gradually.

The failure mode of 45 ° slope experiment is multistage backward failure, which can be divided into four stages: Slight cracks appear at the slope toe (0min -- 105min); erosion-ravaged of slope toe (105min -- 195min); formation and destruction pull apart plane (195min -- 335min); form continuous sliding (335min -- 360min). The development process is shown in Figure 6.

Table 4. The rainfall plan of the slope model test with a slope of 45°

Rainfall sequence	Raininess(mm/h)	Duration(min)	Interval(min)	Start-stop time
1	20	90	30	9:20-11:10
2	40	50	90	11:10-13:30
3	60	60	30	13:30-15:00
4	40	24	-	15:00-15:25

Embryonic period　Puberty　Maturity　Accelerated deformation

Figure 6. Failure process of a slope with a slope of 45°

Volume 7 Issue 9, 2021
DOI: 10.6919/ICJE.202109_7(9).0015

② Analysis of water content variation characteristics

Figure 7 shows the change of water content with rainfall during the experiment. The moisture content of each measuring point basically remains unchanged within 20 minutes after the beginning of rainfall. After 20min, the water content appeared a small accelerated rising process, and then entered a relatively stable period. After 80min, the water content at the top of the slope began to climb. After 150min, the water content at the top and the foot of the slope entered the second stable period. After continuous rainfall for a period of time, it breaks through the wetting front, the water content at the foot of the slope increases sharply, and finally tends to be stable.

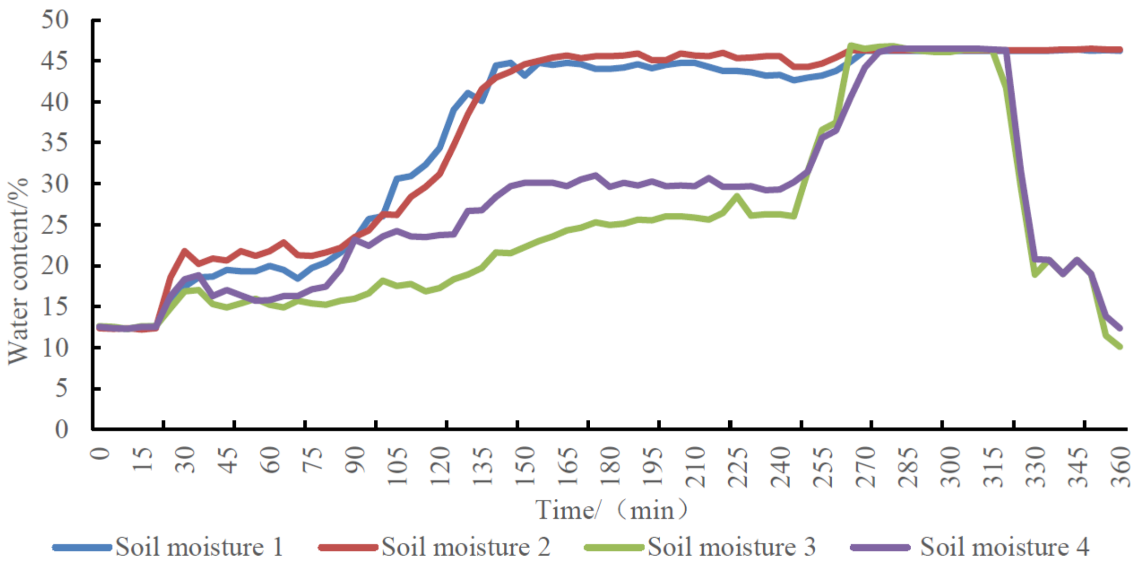


Figure 7. Change in water content with a slope of 45°

The simulated rainfall in the early stage is small, the water content is basically stable, and there is no significant increase. After 20 minutes of rainfall, the moisture content sensor changes one after another, and the soil moisture content increases slightly in the next 10 minutes, reaching a stable level in about 40 minutes. Before and after 150 min, the No. 1 and No. 2 sensor at the slope top gradually reach a stable state with rainfall infiltration, and the amplitude is relatively slow. Sensor 3 and 4 at the foot of the slope were stable before and after 170min, and sensor 4 was closer to the development of the crack, so the water content of sensor 4 was slightly higher than that of sensor 3. It began to climb significantly around 245min and 250min respectively, and reached the fourth stability state at about 280min. Around 300min slope foot began to be destroy, around 325min No. 3 and No. 4 sensor exposed, water content gradually decreased.

It can be seen from the figure that the maximum displacement change of measuring point 1 and 2 on the slope top is 8.68mm. After the slope is completely unstable, the sensors at measuring point 3 and 4 at the slope toe are exposed to the soil surface, and the displacement reaches the maximum range of the sensor (100mm).Among them, the measuring points (3 and 4) at the foot of the slope began to be damaged at 354min 52s and 355min 18S respectively, and the displacement change accelerated. About 20min, the slope gradually accelerated instability in large blocks.

③ Analysis of displacement variation characteristics

Figure 8 shows the changes of soil slope deformation and displacement measured by sensors during the incubation process of simulated soil landslide.It can be seen from the figure that the initial displacement change of measuring point 1 and 2 on the slope top is small, and the final slide occurs at 335min, and the maximum displacement is 28.93mm and 27.86mm respectively. Around 275min, the slope toe began to be damaged, No. 3 and No. 4 sensor were exposed to the soil surface, and the displacement reached the maximum range of the sensor (100mm).

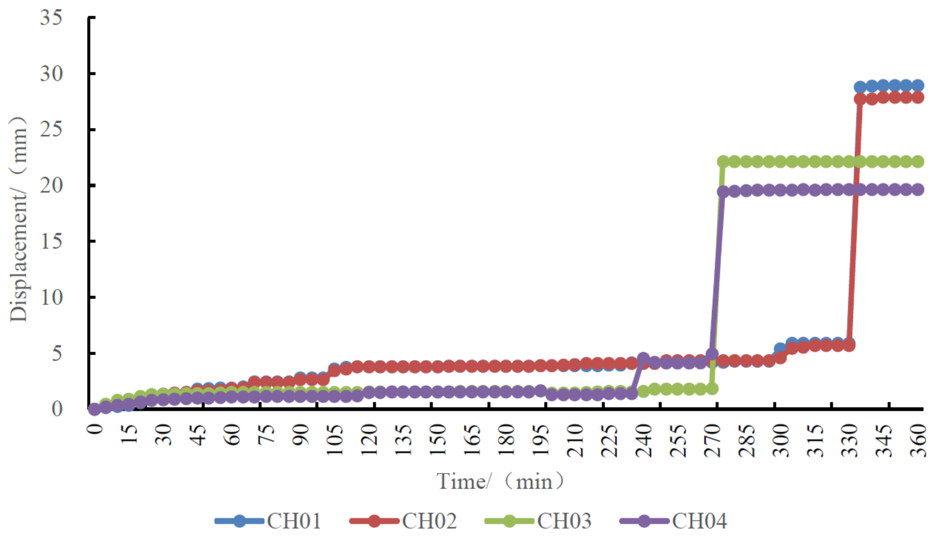


Figure 8. Displacement change with a slope of 45°

4.3.3 Physical model test on incubation process of soil landslide with different slope types under simulated rainfall

Based on the above experiments, combined with the ecological environment restoration of open-pit mines and the actual process of soil slope retention and treatment in the actual production process, take the slope shape as the variable, by comparing the bedrock floor in different experiments, the stability is better when the gradient of slope toe is 35 °. Therefore, 35 ° is selected as the bedrock floor slope, and the rainfall scheme is the same as the 35 ° slope experiment in the previous section. The slope shapes of "thick at the top and thin at the bottom", "linear" and "thin at the top and thick at the bottom" are used for simulation experiments. By summarizing the variation law of water content, displacement and failure during the preparation process of landslide model, the influence of soil slope on the failure mode under different slope shapes is judged, and contrast the instability duration of the above three slopes under the same rainfall condition, To achieve the purpose of comparing the stability of different slope shape, so as to provide a theoretical basis for the design and treatment of soil slope in the actual production process of open pit mine.

The moisture content and displacement change data of different slope shapes under the same conditions were obtained through the simulation experiment. By comparative analysis, the instability duration of "upper thick and lower thin", "linear" and "upper thin and lower thick" slope shapes was 390min, 420min and 445min respectively, and the stability increased successively. The failure modes are monolithic push sliding, block graded sliding and traction sliding.

4.3.4 Analysis on instability mechanism of soil landslide induced by rainfall

By observing the experiment phenomenon and integrating the experiment results, the deformation failure process of the landslide breeding model experiment is divided into: Changes in external conditions such as rainfall →Start of inoculation phase,rainfall infiltrates, the water content of slope changes, and cracks begin to develop →In the development stage of local deformation, the soil fabric changes, the water content changes, the slope begins to have slight deformation, crack expansion and partial saturation→In the accelerated instability stage, the failure strength of soil increases, and the failure area change from small to large, from local to overall →Return to stability phase,the accumulation body forms and tends to be stable, forming stable seepage.

(1) Fracture development and slip promotion

Affected by the loose and collapsible characteristics of the soil itself, the slope cracks are relatively developed, which is conducive to rainfall infiltration, rainwater infiltration increases the bulk density of the soil, causes the cracks to deepen, widen and breed new cracks. The heterogeneity of disturbed soil will produce differential infiltration, and the stress of slope will be continuously redistributed during rainfall. Therefore, the degree of stress variation in different positions of the slope is different during the experiment, which leads to the random development of cracks in the soil slope.

Precipitation infiltration causes cracks on the surface of the soil slope, which accelerates the infiltration rate of water, so that the surface of the slope in a state of high water content, and rainwater accumulates in the relative water-proof layer of the slope, forming a water-saturated zone. The surface of the potential sliding zone forms lubrication and buoyancy, which greatly reduces the tensile strength between the potential sliding surface and the stable soil. When the sliding force is greater than the anti-sliding force, the equilibrium state of the slope will be destroyed, and then deformation and instability will occur.

The edge position of sensors in the model experiment is quite different from the surrounding soil, and there are gaps, which is more conducive to rainwater infiltration. Therefore, during the experiment, the saturated area will first appear around the sensor with poor compactness. Water will also rapidly infiltrate along the weak surface, reduce the surrounding shear strength and cause crack development.

The deeper the crack depth of the slope, the smaller the development interval, and the shorter the rainfall time required for slope instability [12]. Therefore, after the slope toe is unstable or the slope body gradually tends to be saturated, the stress of the slope body changes, and the crack depth and density are gradually developed, which accelerates the occurrence of large-scale sliding.

(2) Moisture content response process

According to the experiment, because the collected soil sample is mining disturbed soil, the soil structure is loose, In the early stage of infiltration, the rainfall intensity is small the permeability is greater than the rain intensity, and the water constantly fills the soil gap, resulting in the natural consolidation and settlement of the surface soil. Compaction reduces the soil pores of surface wet soil and bottom dry soil. Under the action of continuous rainfall, the pores of surface soil are filled with water, forming a water film layer that can prevent the rapid infiltration of rainfall under the action of soil surface tension, which can isolate the exchange between bottom soil and external air. It is difficult to discharge the air in the lower part of unsaturated soil pore, new rain does not seep in easily not easily, reduce soil infiltration capacity, the surface of a soil to achieve transient saturation line, also known as the wetting front, Water content will form a long equilibrium state during the experiment. Continuous rainfall accumulation will promote fracture development, and then local damage will occur. The slope toe will gradually collapse and cause overall sliding.

As the simulated rainfall process proceeded, the stability rate of sensors at different locations is different. The moisture content in ideal state only controlled by the rainfall intensity and rainfall infiltration rate, but the actual soil moisture content change is not only influenced by rainfall intensity and rainfall infiltration rate, also is influenced by the local sliding slope failure state, uniformity of soil and other factors. In addition, according to the simulation experiment results, the water content threshold of soil landslide in the study area is about 47%.

The experimental simulation process shows that there is a clear response relationship between the soil displacement and the cumulative change of water content in the model of the slope. After the arrival of the wetting front, the displacement increases continuously and becomes stable after reaching the peak. When the cumulative water content of the experiment reaches a certain degree, the soil gradually becomes saturated, the slope stress changes, the soil slope model is initially damaged (The first visible sliding body begins to slide) and a large displacement mutation occurs. With the continuous intermittent rainfall, the soil slope model gradually saturated, completely destroyed and the displacement reached the maximum. There is an acceleration process of soil displacement at the moment of slope failure, which is consistent with previous research results [10][13].

5. Conclusion

(1) During the experiment, each incubation stage has different deformation characteristics. Embryonic period: Influenced by the collapsibility of soil itself, fine cracks first develop in

ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0015

somewhere; Development stage: surface slope erosion, crack development, from the top of the slope to toe erosion degree gradually increased; Maturation stage:The internal and external cracks are fully developed, forming a pull crack surface, and the local small collapse leads to international airport of soil in front of the slope foot; Accelerated deformation period: the tensile crack surface develops constantly, and the slope gradually forms landslides. The scale of the collapse increases from small to large until the tensile crack surface is fully developed and finally completely destroyed.

(2) Slope shape will also affect the stability of the slope body. The stability of different slope shapes: "thin on top and thick on bottom" > "linear" > "thin on top and thin on bottom".

(3) The experiment restores the breeding process and failure mode of soil landslide formed by reaccumulation after mining disturbance in the study area under different conditions to the maximum extent, and the water content threshold of such landslide breeding is about 47%, which is of reference significance to the prevention and control of landslide geological disasters in the study area.

References

[1] XU Qing. Study on Landslide Stability and Disaster Evaluation of Water Conservancy and Hydropower Project [D]. Hohai University,2005.

[2] ZHANG Shuai, ZHANG Shuai, ZHANG Shuai, ET al.Geological Characteristics and Prospecting Potential of Xilaokou Gold Deposit, Shandong Province [J]. Groundwater, 2017, 33 (3) 6:177-179.

[3] Chen Yang, Wang Xiping, Zhang Dongdong, Zhang Gang, Zhang Qingxiao, Li Zhe, Qian Yuwei, Pan Xiaoyu. Necessity and countermeasure of ecological protection and restoration of mountain, water, forest, field, lake and grassland in bauxite mining area of south bank of Yellow River in Sanmenxia city [J]. Environmental ecology, 2020,2(05):43-46.

[4] Zhang N. Study on landslide risk evaluation based on multi-source remote sensing data [D]. Central South University, 2009. (in Chinese with English abstract)

[5] Xi Shanfeng, Ouyang Zhaozhuo, Li Jianquan, Wang Zhongyu, Feng Feifan, Li Xun. Geological characteristics and ore-controlling conditions of sanmenxia bauxite in henan province [J]. Geology and resources, 2019, 28(04):339-344.

[6] ZHANG Shuai, ZHANG Shuai, ZHANG Shuai, ET al.Geological Characteristics and Prospecting Potential of Xilaokou Gold Deposit, Shandong Province [J]. Groundwater, 2017, 33 (3) 6:177-179.

[7] Chen Guangguo. Geological Characteristics of Caoyao Super large Bauxite deposit in Mianchi County, Henan Province [A]. Geological Society of Henan Province, Geological Survey Institute of Henan Province, Land and Resources Research Institute of Henan Province. Henan Earth Science Bulletin 2011 Volume (Vol. I) [C].: Geological Society of Henan Province, 2011:6.

[8] Wu Weijiang, Wang Nianqin. Basic types and active characteristics of loess landslide [J]. Chinese Journal of Geological Hazards and Control, 2002(02):38-42.

[9] Hu S. Spatial pattern of landslide and its influence on geomorphologic evolution in loess Plateau [D]. Northwestern University, 2019.

[10] XU Qiang, Tang Minggao, XU Kaixiang, et al. Chinese Journal of Rock Mechanics and Engineering, 2008 (06):1104-1112.

[11] Ministry of Emergency Management of the People's Republic of China. Technical Specification for safety monitoring of high and steep slope in metallic and non-metallic open-pit mines: AQ/T 2063-2018[S]. Beijing: Standards Press of China, 2018.

[12] YAN Jinkai, HUANG Junbao, LI Hailong, et al. Journal of geomechanics, 2020,26(04):481-491.

[13] Zuo Zibo, Zhang Lulu, Wang Jianhua. Journal of geotechnical engineering, 2015,37(07):1319-1327.