Experimental Study on the Formation and Evolution of Granular Mixtures Slope Selection Result

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Abstract

The experiment simulation which was carried out in the slope model of our own reproduces the movement process of granular slope particles and the accumulation process, studies its movement, accumulation and its fractal characteristics. It was found that the average rules of a single particle migration distance is bigger than irregular particles, particles migration distance and particle size of itself does not present a clear relationship, and the morphology of particles in contact with the ground when one of the main factors influences the particle migration distance; the worse the grain composition is, the greater failure the slope angle of slope is, and vice versa; the side slope unstable particles controls the critical angle; grain quality—particle size distribution fractal dimension increases with the content of fine particles, and the fractal dimension decreases gradually since the slope body is composed by an upper and a lower, suggesting that slope body evolution through the process of self-organization spontaneously and showing the self-organized criticality.

Keywords: grain body slope, movement characteristics, accumulation characteristics, fractal characteristic

Preface

In the first slope zone of the Sichuan Basin transition to the Qinghai-Tibet Plateau and the hinterland of Tianshan Mountain, Qilian Mountains, formed a large number of grain body slopes by scattered debris, commonly known as "slip sand slope." Especially in cold, drought, severe physical weathering western region, this phenomenon is particularly prominent. In the mass transportation of western region, "slip of sand slope" is often existed as road slope. Since the "mess" feature, Granular Slope is sensitive to disturbance, so the Granular Slope on the both sides of the road often caused silt buried hazards to the road, usually with amazing speed forward.

Foreign scholar study of sand-sliding slope began in the middle of 20th century, it was limited to the naked eye on the surface characteristics of the observed slope, which made a number of inconclusive or even contradictory opinions [1]. In the 21st century, Western scholars gradually from the perspective of Geomorphology and Quaternary Geology proposing a "Alpine mode ", which regards the formation of sand-sliding slope evolution as an evidence of Quaternary climate change in the Alpine high altitude. Through a variety of advanced geophysical methods (GPR) to detect the internal interbedded structure of coarse particles, predicting the rate of the rock weathering, then putting forward the formation and evolution of sand-sliding slope model [2-5].Domestic study of sliding sand disasters was only in its infancy and in the traditional geomorphology it was classed as general weathering debris deposits, yet the dedicated research haven't been conducted. With the great western development , sand sliding hazard effects on the highway construction is increasingly apparent, Liangguangmo et al [6-9] studied the evolution of the formation of sand -sliding slope , granular structure characteristics , factors and particle motion model from the perspective of disaster science through field visits and laboratory model test .Jiang Wei Liang et al [10-12] continued the research ideas of foreign scholars' from the perspective of self-organized criticality, having indoor systematic experimental study about its dynamics, proposing sand granular layer and rub blocking layer dual structure model [13].

1.Experimental Design

According to preliminary field investigation combined with the actual situation of indoor venues designed test platform dimensions with length 3.5m, width 7m, height 3m, see Figure 1.

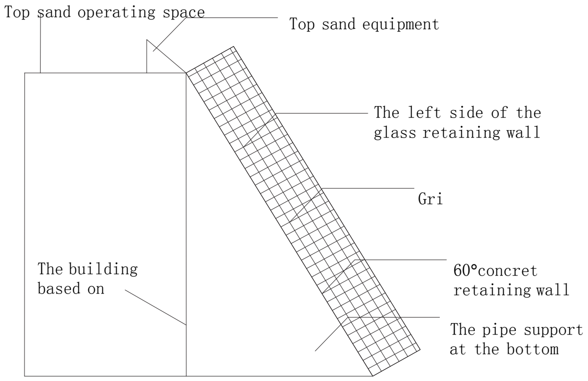

Figure 1 Schematic Diagram of Bulk Solid Stacking Test Platform

In this experiment, the material takes from the uniform of a Granular Slope in WenChuan County, three kinds of materials was prepared, including the small gravel particles(1#) with non-uniformity coefficient of 3.8, the curvature coefficient of 1.24, The gravel particles (2#) with the particle size of about 6 ~ 10cm and the mixing gravel particles (3#)with the uniformity coefficient of 7, the curvature coefficient of 1.16. The particle size distribution of various materials showed in Table 1. Three different graded granular materials test was repeated nine times.

Table 1 Test sample of particle size distribution

Serial number	<80	<60	<40	<20	<10	<5	<2	<1	<0.5	<0.25	<0.074
1#	100	89.47	64.31	27.63	10.67	3.51	0.82	0.61	0.22	0.15	0
2#	100	17.27	12.31	9.28	6.50	4.21	1.56	0.52	0.25	0	0
3#	100	69.72	55.39	29.67	15.93	7.12	2.40	1.18	0.93	0.59	0

2 Experimental Results and Analysis

2.1 Characteristics of particle motion study

Experimental design in this large-scale simulation platform Granular Slope (through field observations and experimental studies , combined with previous research shows that granular particles in the plane mainly have three kinds of movement, including slipping, rolling and slip - scroll alternately [14]. In order to further analyze the movement of sand particles slip characteristics, we selected four groups of single particle rolling materials. By testing, we got exercise time, the quality of the state of motion and the particle shape characteristics of particle motion. On this simulation platform, the test platform size in Figure 1 changed to 9.6m in length, 3m in width, 6.8m in height, with slope of 45 and on the surface of the slope covered with mortar cement in advance). A total number of 24 particles selected form former materials with grain diameter of 3cm and 8cm. each species take 6 caps regular in shape and 6 irregularity in shape.

In slope movement, the time when the particles reach the slope toe and the time of stop is different, which is depends on the particle's mass, shape, path differences. Table 2 gives each particle arrival time at the foot of the slope.

Table 2 Time Comparison Table of Particles Reach the Slope Toe

Particle number	The least time (s)	The average velocity (m/s)	The longest time (s)	The average velocity (m/s)	The total average time (s)	The total average speed (m/s)
3cm Rules of particle group	2.55	3.79	2.68	3.63	2.58	3.73
3cm Irregular particle group	2.62	3.68	2.72	3.57	2.66	3.65
8cm Rules of particle group	2.85	3.39	2.93	3.32	2.91	3.35
8cmIrregular particle group	3.01	3.21	3.1	3.14	3.06	3.43

For a better comparison, each group of particles are carried out free-fall tests, for free-fall campaign, there is,

$$\mathrm{H}=\frac{1}{2}at^2 \quad (1)$$

$$\mathrm{E}=\frac{1}{2}mv^2=\frac{1}{2}ma^2t^2=\frac{1}{2}m\left(\frac{2H}{t^2}\right)^2t^2=2m\frac{H^2}{t^2} \quad (2)$$

Among them: H is the height of free fall ; t is time ; a is the acceleration ; E is the kinetic energy ; m is the particle mass

Calculate the kinetic energy of each group particles when they arrived at the bottom: the kinetic energy of the 3cm rules particles is about 0.347J; the kinetic energy of the 3cm irregular particles is about

0.196J; the kinetic energy of the 8cm rules particles and the 8cm irregular particles were 1.638J and 1.501J respectively. Visible, for the same kind of particle size of particles, the kinetic energy of the rules particles when reaches the bottom is larger than the irregular one; for different size particles, the kinetic energy of the bigger particle size when reaches its bottom is larger than the small one. Because irregular particles use more energy when contact with the slope, so the kinetic energy arriving at the end is smaller.

The time and speed for each group of particle free fall showed in the table 3.

Table 3 The comparison table for particles free fall stop time

Particle number	The total average time（s）	The total average speed（m/s）
3cm rules of particle group	1.15	5.91
3cmirregular particle groups	1.20	5.67
8cm rules of particle group	1.10	6.18
8cm irregular particle groups	1.25	5.44

Compare Table 2 with Table 3, the fastest time that the particles move to the slope toe is about 2 times faster than free-falling. The kinetic energy of 4 groups particles when they move to the slope toe through free-fall were 1.748J, 0.963J, 11.464J, 8.996J(height of 6.8m), visibly，the kinetic energy of particles when arrive at the slope toe through the slope movement is about 0.143 ~ 0.204 times than free-falling.

Through the test data, found a certain relationship between particles in slope movement time and distance, with expression is as follows:

$$s = xt^2 + yt + z \quad (3)$$

Among them: **s** is the movement distance;

x, y, z for sports-related parameters ;

t is the exercise time .

The expression regression curves of the distance-time curve of each group particles, as is shown in the Figure 2 and 3, were consistent with the formula 3. Visibly, the distance and the time of particles movement on the slope shows a parabola relationship, and coefficient of determination reached 0.99. The constant x in the equation values is between 0.0027 ~ 0.3554, because $v = ds/dt = 2xt + y$, so the particle motion acceleration value is the 2x, namely the acceleration valueis between 0.0054 ~ 0.7108, approximation for uniformly accelerated motion.

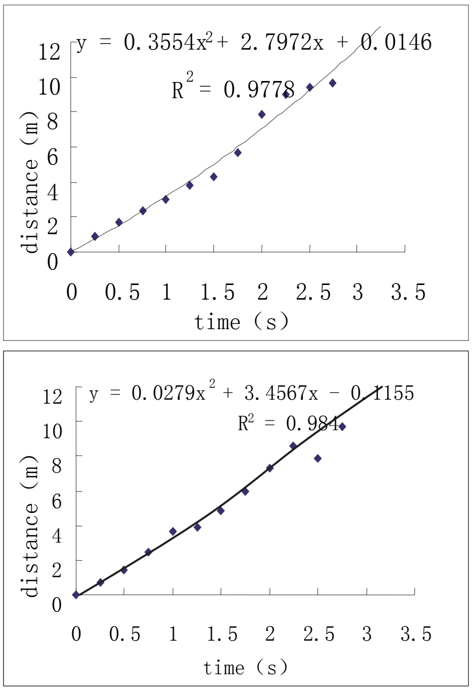

Figure 2 Distance - time curve of particle movement (above is 3 cm rule particles, below is 3 cm irregular particles）

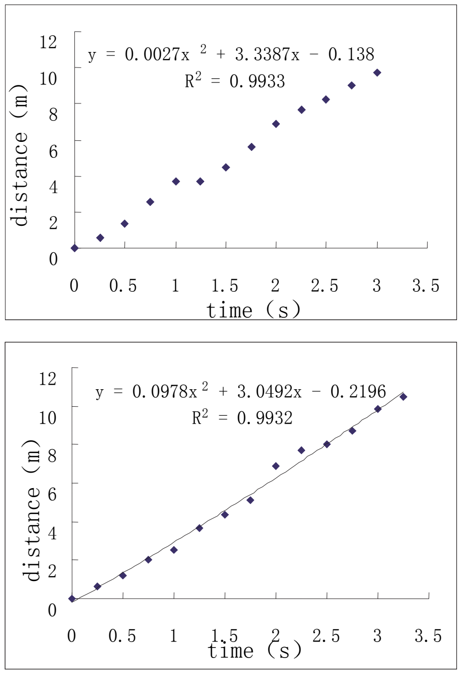

Figure 3 Distance - time curve of particle movement (above is 8cm rule particles, below is 8cm irregular particles）

The figure shows the connection for each data pointed in the local regression equation. There is a certain shift indicated sometimes, the move velocity of particle changes a lot, namely the acceleration is large. During this time, the particle jumping motion may be occur.

In addition, the test also observe and record the movement of the particles when they arrived at the slope toe, found that the placement is located between 1.55 ~ 9.95m away from the foot of the vertical distance. Most of the particles are concentrated to stop near the central axis, but the placement of the rule particles appears more dispersed than the irregular particles.

Statistical results showed that the average distance that rules 8cm particles move from the foot to the static of the slope is 6.09m, the maximum average migration distance of rules 3cm particles is 6.21m, corresponding to the particle size of the average transport distance of irregular particles is 4.69m and 5.53m respectively. Thus, the average transport distance of rule granules is larger than irregular granules. But test data shows that migration distance of particles and particle size in itself does not show a clear link. Perhaps the reason is that the slope is steep, particles fell on the ground after collision with slope in the process of movement. Before the collision with the ground, the tangential velocity is small. Watch the video replay showed that Shape of particles in contact with the ground is one of the main factors affecting the particle migration distance.

2.2 Study on accumulation characteristics of slopes

(1) The accumulation process change in slope angle slope analysis

By large-scaled physical simulation experiments, got the slope angle of upper, middle, and lower part of 1 #-3 # test materials slope in the process of accumulation before and after the collapse, the change of the typical as shown in figure 6, 7.

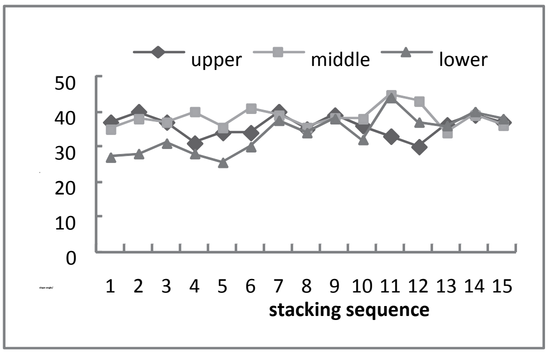

Figure6 1# Angle changes before the collapse

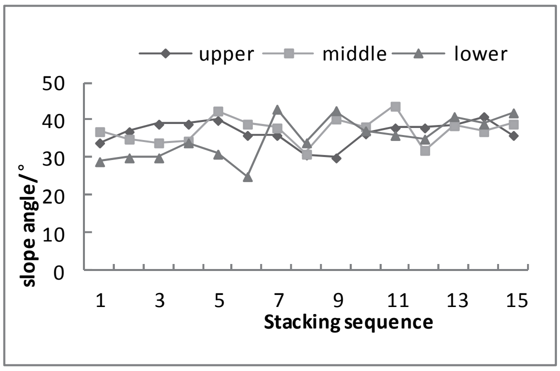

Figure7 3# Angle changes before the collapse

The average slope of 1# sample's upper , middle and lower part before slumping was 35.88 ° , 38.27 ° , 33.73 ° , the total average gradient was 35.96 ° ; the average slope of sample's upper , middle and lower part after slumping was 36.66 ° , 37.34 ° , 35.25 °, the total average gradient is 36.42 °, which increase 0.46 ° than it before slumping.

The more uniform the sand grain particle is, the wider the slope angle of the slope destruction becomes; the less uniform the sand grain particle is, the smaller the slope angle of the slope destruction becomes; on the whole, the angle of slope changes little before and after the collapse.

(2) Analysis of influence factors

By a single curve analysis, the slope angle of the same parts in the accumulation process constantly ups and downs. The angle fluctuation after the collapse was larger than before the collapse, which is consistent with the observation of the test site.

Judging from stacking on slope, the large and small particles are not evenly distributed. Some regions only spread with large particles, while some other regions with fewer large particles. The nonuniformity of their distribution makes the instability of side slope. Under the same condition of the disturbance, the stability of the large particles area is better than the area composed of fine particles for the large particles can deeper embedded into the slope, particles. The heavier the non-uniform degree of the particles is, the more diversity and complexity of the slope stability is. Large particles can form the skeleton effect supporting pressure from external while Small particle have the filler effect improving the density of sand pile. The Smaller the granular is, the higher compactness of the sand heap becomes and then the greater shear strength is. More Large grained materials mean higher compressive strength. The less large particles contain, the more small particles in the same volume, causing more space and poorer stability; when the large particles content is more, the sand is more dense and the weight of unit volume is greater; when the size of the particles volume arrive at a certain ratio, the gap in sand will be filled with small particles, the density can reach maximum .The results that Jiang hongying got through the different ratio of compressive strength test also verified this point of view.

When the slope is large-scale instability, the majority of the subsequent slump occurred in the fine particle level which is formation after the first large-scale instability, suggesting that the fine particles play a controlling role in the stability of sand-sliding slope. The fine particle level in the slope is formed by the separation of the fine particles which cause the fine particle gathered and infiltrated to under part of the slope. With the stacking of fine particles, the content of fine particles also constantly increases. When the slope collapse on a large scale, slipping particles can bring fine particles out of the slope, the fine particles content of slope would reduce at this time, when reduces to a species degree (When the regulatory role of the fine particles severely weakened), the sand stacked again, and repeat above processes.

2.3 Study on fractal characteristiccs of particle

Sampling from different parts of the accumulation body during the process of experimental, followed by a screening test and weighing, to study sand particles' fractal characteristics by use of the fractal model of particle size distribution which raises by d Yler et al under the assumption that particle density is under the same conditions.

$$\frac{\mathrm{M(r < R)}}{\mathrm{M_T}} = \left(\frac{R}{R_L}\right)^{3-D} \qquad (4)$$

Among them: R is the particle size;
M (r<R) is particle size less than R pellet quality;
R_L is the maximum particle size;
M_T is the total mass of particles;
D is the dimension.

Calculating the fractal dimension of different parts of the slope in this experiment , sampling a total of 13 groups, sampling in each set of upper, middle, lower part of the three parts of the slope, sampling a total of 39 times. The specific fractal dimension are shown in table 3, figure 8.

1. The quality of particles soil slopes deposits -- the distribution of particle fractal dimension

Fractal dimension values in Figure 8 were between 2.0 and 3.0, and the fractal dimension increases with the increasing of the slope height, the fluctuation difference of the lower part of the curve is bigger, the upper is small. The average fractal dimension value of the upper slope is 2.3706; the average fractal dimension value of the central measurement point is 2.3607. Fractal dimension are all above 2.2377, indicating that the heap size composition of the sand has a good fractal structure, the structure of the sand conforms to the fractal distribution.

2. Distribution of Granular Slope deposits granularity

Granular Slope particle buildup is obvious distributed, although the accumulation distribution along its height direction is quite different. The content of fine particles decreases from top to toe of slope, while coarse particle content gradually increases.

3. Quality of the particles slope debris - relevance between particle size fractal dimension and granularity

Heap fractal state during the test is as shown in the figure 8, the fine particles gradually reduce from top slope to bottom while the coarse particles is increasing. Particles presents sorting characteristics in the process of accumulation, Thus the quality of the particles slope debris -- particle size fractal dimension increases with the increasing of the content of fine particle. Fractal dimension decreases from top to bottom, indicating that the slope evolved through process of spontaneous self-organization, embody the self-organized criticality. Particle composition of the slope deposits can be characterized by the fractal dimension value of size, the higher the dimension points is, the more accumulation of fine particles in composition have, whereas the smaller the fractal dimension is, the smaller the fine grains are. Test each measuring point data basically reflect this rule, see Table4.

Table 4 The fractal dimension and uneven coefficient of each part of the slope

Number	fractal dimension			coefficient		
	up	middle	low	up	middle	low
1	2.3441	2.3118	2.3049	0.9476	0.9615	0.9644
2	2.3084	2.3175	2.2933	0.971	0.9556	0.9636
3	2.3666	2.3874	2.3509	0.8822	0.9204	0.9356
4	2.3341	2.3179	2.3306	0.9545	0.9589	0.9305
5	2.3576	2.3883	2.3683	0.9335	0.8936	0.9308
6	2.3597	2.3274	2.3353	0.9371	0.9603	0.9542
7	2.4017	2.3824	2.3449	0.8943	0.9261	0.9332
8	2.3677	2.4059	2.2657	0.9249	0.9609	0.973
9	2.4082	2.3083	2.3887	0.8908	0.9591	0.9201
10	2.421	2.4025	2.36	0.8738	0.8984	0.9359
11	2.4004	2.3761	2.3544	0.8859	0.9329	0.9356
12	2.4009	2.394	2.44	0.861	0.9158	0.8224
13	2.3473	2.369	2.2377	0.9446	0.9233	0.9623

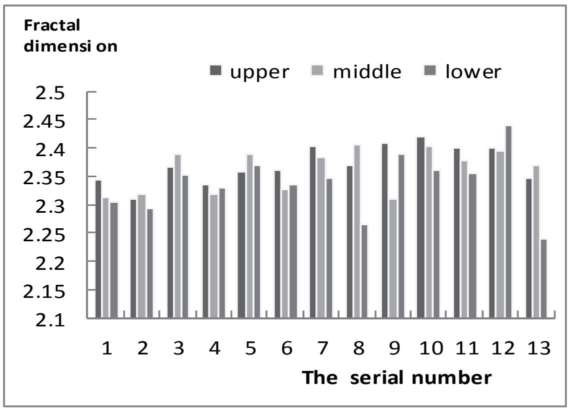

Figure 8 Granular fractal characteristics of the particles in the slope's each part during the accumulation process

3 Conclusions

1, The average transport distance of a single rule particles is larger than the irregular particles for irregular particles consume relatively more energy during movement after makes contact with the rear slope due to its irregular shape , so the kinetic energy is relatively small , its migration distance is even smaller .

Migration distance, the size of the particles and the particles themselves exhibit no obvious link. Maybe the reason is that slope was too steep, the particles collide with slope during movement, then falling on the ground, and its tangential velocity is small in front of collision with the ground.

Observe from the test, the horizontal offset direction is not keep the single constant, during its movement process, the slope conditions on the offset direction particles play a decisive role because of the different slope conditions affecting the offset direction of the particles. Also with the constant downward motion of the particles, the vertical displacement continues to increase.

2, Experimental data statistics showed the more uniform the particles were, the wider the slope angle of sand slope destruction becomes; and the more uneven the particles were, the smaller the slope angle of sand slope destruction becomes; the slope angle of the same parts sand slope constant ups and downs during the slope accumulation process.

3, During the accumulation process of particles, the most unstable particles in the slope controls the critical angle, therefore, the poor stability of this region is due to the particles of this part has reached a critical state; in addition, the area that has not yet reached the critical state of proportion also affects the overall stability of the slope, the overall stability of the slope body is composed of the sum of the partial ones.

4, Experimental observation shows that the fine particles gradually reduce from top slope to bottom slope while the coarse particles increasing.

Fractal dimension decreases from top to bottom, indicating that the slope evolved through process of spontaneous self-organization, embodying the self-organized criticality. Particle composition of the slope deposits can be characterized by the fractal dimension value of size, the larger the dimension points indicates more accumulation of fine particles in composition and smaller the ratio of the length of the particles shaft, whereas the smaller the fractal dimension is, the smaller the fine grains is and the bigger the ratio of the length of the particles shaft becomes.

References

[1]CAINE N. The texture of talus in Tasmania[J]. Journal of Sedimentary Petrology, 1967, 37(3) : 796–803.

[2] ALASTAIR M C , ROSS B. Structure , sedimentology and evolution of rock fall talus, Mynydd Du, South Wales[C]// Proceedings of the Geologists′ Association. [S. l.] : [s. n.], 2003 : 49–64.

[3] ALASTAIR M C, CHRIS J M. Lateglacial and Holocene talus slope development and rockwall retreat on Mynydd Du, UK[J]. Geomorphology, 2004, 58(1–4) : 85–106.

[4] SASS O. Bedrock detection and talus thickness assessment in theEuropean Alps using geophysical methods[J]. Journal of Applied Geophysics, 2007, 62(3) : 254–269.

[5] SASS O , KRAUTBLATTER M. Debris flow-dominated and rockfall-dominated talus slopes, genetic models derived from GPR measurements[J].Geomorphology, 2007, 86(1/2) : 176–192.

[6] LIANG GUANG MO, WANG CHENG HUA ZHANG XIAO GANG. The formation and countermeasures of the slip sand slope of the Sichuan-tibet highway dam [J]. The Chinese journal of geological hazard and control, 2003, 14 (4) : 33-38.

[7] WANG CHENG HUA ZHANG XIAO GANG, JUE YUN, etc. The formation of the granular clastic and basic characteristics research of the slip sand slope [J]. Rock and soil mechanics, 2007, 28 (1) : 29-35.

[8] WANG CHENG HUA, JUE YUN LI XIN PO, etc. The motion characteristics and dynamic numerical analysis of the granular detrital slip sand slope [J]. Rock and soil mechanics, 2007, 28 (2) : 219-223.

[9] WANG CHENG HUA, JUE YUN XU JUN, etc. The equation motion of the granular detrital slip sand slope and soil pressure calculation of the sandy slope [J]. Rock and soil mechanics, 2007, 28 (7) : 1 299-1 303.

[10] JIANG LIANG WEI, YAO LING KAN, LI SHI XIONG. Mechanism of self-organized criticality in Non-homogenous granular mixtures [J]. *Chinese Journal of Rock Mechanics and Engineerin g*, 2004, 23 (18) : 3 178-3,