Model Tests of Catastrophic Initiation Mode and Transport Mechanism of Viscous Mudflows

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Abstract: Most previous studies on the initiation mechanism of debris flows have achieved some significant results by means of traditional linear methods, statistical analyses, and qualitative and single-factor analyses. In fact, however, a large number of field observation analysis indicate that the initiation of debris flows may be a complicated nonlinear process subject to many influencing factors, with its initiation mode showing typical and complex characteristics such as sudden happening and slow happening and so on, which we could not explain clearly till now. In other words, if the initiation conditions could be regulated and controlled, the prevention and control of debris flows should achieve the practical effect. Based on catastrophe theory, the characteristics and mechanisms of the initiation, transport, and sedimentation associated with viscous mudflows, which can be taken as representative of natural debris flows, are analyzed, described, and verified using flowing model tests on the well-designed test apparatus. The results show that not only does the initiation mode of viscous mudflows belong to the slow-starting mode, but also its transport mechanism is in accordance with the general characteristics of the cusp catastrophe model. This is of great significance not only with regard to the forecasting and controlling of viscous debris flows that occur frequently in mountainous areas, but to the enriching of the nonlinear theoretical system of debris flows initiation mechanism as well.

Keywords: Catastrophe theory, characteristics and mechanism, cusp catastrophe, initiation mode, nonlinear theory, viscous mudflows.

1. INTRODUCTION

Debris flows are a specific type of fluid composed of mixed water and soil, which lie between mass landslides and sediment flows. They constitute a common disaster in mountainous areas, occurring in small watersheds with viscous laminar flow or dilute turbulent flow morphologies. There are three fundamental conditions necessary for their occurrence: suitable topography, certain source materials, and rainfall. Among the various types of debris flow, viscous debris flows tend to be the most common and most destructive. It is proven that many debris flows that lead to considerable economic losses and casualties are viscous debris flows [1]. Therefore, research on the fundamental laws governing the process of initiation of viscous debris flows is crucial for developing the theoretical basis for forecasting and controlling debris flows.

Most previous studies on the initiation mechanism of debris flows have achieved some significant results by qualitative and single-factor analyses, based on means of traditional linear methods, statistical analyses, and experimental research into changes in soil structures and soil liquefaction under the effect of water. Takahashi [2] described the interaction among soil particles and the fluidization phenomenon in the initiation process of viscous debris flows in mountainous areas using particle flow theory. Iverson [3-7] explained the debris flow initiation process with regard to pore water pressure and soil mechanics, the results of which promoted significant research on debris flow initiation.

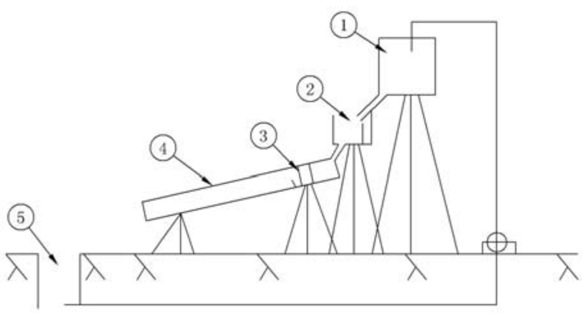
In terms of theoretical study, Qi [8] performed research into the initiation mechanism of rain-induced debris flows based on unsaturated soil mechanics. Klubertanz [9] discussed the process for the movement of loose solid masses to debris flows using tiny transformation elastic–plastic theory. Chen performed several studies [10-12] and found that the content of clay had considerable impact on the process of debris flow initiation. However, the transformation from a static situation to motion is actually a nonlinear process controlled by multiple factors.

The development of the nonlinear discipline has led to many nonlinear methods suitable for application in this field. For example, Cui [13] applied catastrophe theory to study the initiation of debris flows. In this paper, physical model flowing tests were conducted to provide preliminary results for analysis of the initiation mode and transport mechanism of viscous mudflows based on catastrophe theory. The test material was viscous mud without bulky grains, and an indoor generalized model test system with a straight flume was designed and built to simulate the basic conditions for flow occurrence and development, and to control the boundary conditions.

2. MATERIALS AND METHODOLOGY

2.1. Test Apparatus

The indoor generalized model test system comprises systems for mud mixing, transport, and storage, a pressure stabilization system (flow control valve included), and test flume system for mudflow (open straight flume with adjustable slope that is convenient for observation). The simulation tests of the flow characteristics of viscous mudflows were repeated under different conditions (four different mud densities, four different flow discharges, and five different slopes). The test apparatus is shown in Fig. (**1**).



Notes: (1) Mud storage tank; (2) Pressure stabilizing tank; (3)Energy dissipation fence; (4)Straight flume; (5)Mud mixing pool.

Fig. (1). Diagram of model test apparatus.

The test flume, which is 700 cm long, is the principal part for the flow simulation tests. However, because the initiation section of debris flows is always located in a shorter channel in the upper stream with weaker hydrodynamic forces, the 150-cm section behind the 50-cm energy-dissipating section, used for reducing hydraulic scour in the upstream of the test flume, is recognized as the initiation section. Thus, the effective length of the flow test section, which has a wood and bamboo veneer laid on the steel bottom, is 500 cm. The flume section is 20 cm wide and 20 cm high (B×H=20×20 cm), and the flume sidewall is toughened glass with a thickness of 10 mm.

2.2. Test Materials

The soil used in the test is loess, excavated from a construction site in the School of Energy and Power Engineering, Lanzhou University of Technology, China, where our place of work is located, and where a pool had been designed and built for water storage. The original plans for the sampling site were for a pump laboratory, and as no endangered or protected species were affected, no specific permissions were required for the sampling. The soil sampling was conducted as the pool was being excavating because the soil exhibited good representation of the sedimentary sequence. Nevertheless, all efforts were made to minimize any other possible impacts during the sampling process.

Samples of undisturbed soil (Lab No.: 2004-T912) and disturbed soil (Lab No.: 2004-T913) were acquired for the physical index experiments to measure their natural moisture content, volume weight, liquid and plastic limits, and particle size distribution. According to the standard of the People's Republic of China GB50021-2001, the soil is described as Silty Clay and its characteristics are shown in Table **1**.

3. TEST RESULTS

The four different mud densities (γ) used are 14.0, 15.0, 16.8, and 17.5 KN/m3. The four different flow discharges (Q) used are 0.15, 0.50, 0.75, and 1.50 l/s, and the test flume slopes (i) used are 0%, 5.5%, 10.9%, 14.0%, and 19.0%. Observation of the repeated flow tests, demonstrating the processes that mudflows experience from initiation, to wavelike intermittent flow and steady flow, and ultimate sedimentation under different combinations of the conditions mentioned above, reveal a number of principal features.

(1) Under the condition of continuous mud supply, viscous mudflows can start slowly while accumulating source material. Over one hundred tests indicate that as long as any two of the variables mentioned above keep pace with each other, while the third variable is changed, the role of water is shown to be one of the decisive factors influencing the initiation of viscous mudflows. In his research into the initiation conditions of debris flows, Cui [14] used water saturation ($S_r = \text{water volume} / \text{voids volume}$) to reflect the effect of water. He found that the initial slope (α) lessens as water saturation increases and that the relationship conforms to hyperbolic law. Furthermore, particle composition is another critical determinant because the content of fine particles determines the structural features and connection strength of the debris flow. Cui's work [14] presented the initiation conditions based on field data. His test results indicated that water saturation (Sr), initial slope (α), and the content of fine particles (C) constitute the three determinants for the initiation of viscous mudflows and debris flows, which further confirms the abovementioned three basic conditions for the occurrence of natural debris flows in mountainous areas.

(2) The flow state of viscous mudflows in a straight flume is wavelike and intermittent, which is the same as flows in natural channels. A large number of flume flow tests indicate that when a mudflow is initiated in the flume, its flow state is wavelike; i.e., one surge follows another surge. In the initial stages of a mudflow, the first wave of mud adheres to the flume bottom (channel bed) and it then is consumed. The flow stops upon reaching a certain thickness because the first wave spreads and distorts during the process. Then, the second wave adheres to the previous channel bed when flowing through the bed surface until it reaches the end. This process is called "bed making". The thin mud layer is termed the "static layer". The morphologies of mud flowing under different test conditions are shown in Table **2**.

The flow states in Fig. (**2A**) and (**2B**) demonstrate the flow morphologies of viscous mud in the test flume, which can be taken to represent the actual flow state for gentle and

Table 1. Characteristics of the soil samples.

Laboratory serial number	Moisture content (%)	Density (g/cm^3)	Liquid limit (%)	Plastic limit (%)	Plastic index	Liquidity index	Particle composition (%)			
							Particle size distribution (mm)			
							>0.05	0.05 – 0.01	0.01– 0.005	<0.005
2004-T912	7.5	1.41	30.6	15.5	15.1	-0.5	14.0	66.0	13.2	6.8
2004-T913	6.7	-	28.6	15.1	13.5	-0.6	19.0	62.0	9.0	10.0

Notes: 1) "-" means no data; 2) soil is defined as Silty Clay according to the standards of the People's Republic of China GB50021-2001.

Table 2. Mud flowing morphologies under different test conditions.

i (%)	*Q* (l/s)	0.15				0.5				0.75				1.5			
	item	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5.5	Velocity (m/s)	0.05	-	-	-	0.23	-	-	-	-	-	-	-	0.29	0.3	-	-
	Flowing morphology	W	W	W	Z	W	W	W	S	W	W	W	S	W-U	W	W	S
10.9	Velocity (m/s)	0.24	-	-	-	0.28	-	-	-	0.51	-	-	-	1.56	-	-	-
	Flowing morphology	W	W	W	W	W*	W	W	W	W*	W	W	Z	W-U	W	W	Z
14.0	Velocity (m/s)	0.33	-	-	-	0.39	-	-	-	0.81	-	-	-	1.67	-	0.39	-
	Flowing morphology	W	W	W	W	W*	W*	W	W	W-U	W*	W*	W	W-U	W-U	W*	Z
19.0	Velocity (m/s)	0.38	-	-	-	0.44	-	-	-	1.09	-	-	-	1.75	-	-	-
	Flowing morphology	W	W	W	W	W*	W*	W	W	W-U	W-U	W-U	W	W-U	W-U	W-U	Z

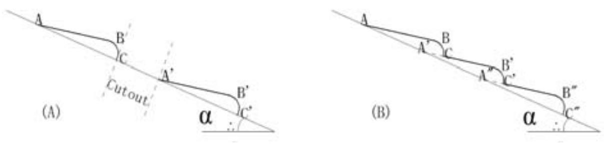
Notes: 1) Float method is adopted to measure velocity, i.e., surface velocity; 2) flow supply is controlled by orifice at the exit of valve of pressure stabilizer; 3) the slope of the test flume is adjusted by the lever block fixed at one end; 4) the numbers 1, 2, 3, and 4 represent mud densities of 14.0, 15.0, 16.8, and 17.5 KN/m^3, respectively; 5) W represents wavelike flow, W* represents the situation of the previous wave being chased and surpassed by the latter, W-U represent the transformation of wavelike flow into steady flow, S represents the test flume becoming filled with mud and the experiment ending, Z represents mud moving slowly down the channel; 6) the marked flow velocities in the table are representative measured values; 7) "-" means no measured data

steep natural bottom slopes, respectively, with high levels of fine particles. In this case, the flow velocity of a viscous mudflow drops and it exhibits the form of "quasi-laminar flow" with no sharp changes on the morphology of the mud surface. Except for the gradually changing mud depth around the front position, the majority of the central part shows a steady flow state. As long as the mud is supplied continuously upstream, the wavelike intermittent flow gradually turns into a continuous steady flow [15].

Tests show that in the early stages of mud supply, the flow discharge is comparatively small and the mud stays at the flume end. As the mud supply continues, the mud will slowly "hunch up", become wavelike, and then flow down the test flume. The flow state changes from the initial intermittent and isolated surge, to overlapping and continuous surges, before the final steady flow develops. The transition process of flow state is shown in Fig. (**3A**) and (**3B**) (for simplicity, the static layer used for bed making is not shown).

Notes: (A) Fixed bed and gentle slope (i = 5.5%, γ = 16.8 KN/m3); (B) Fixed bed and steep slope (i = 5.5%, γ = 16.8 KN/m3).

Fig. (2). Flow state of the front position.



Notes: (A) Intermittent wave flow; (B) Continuous wave flow.

Fig. (3). Transition process of the flow state.

(3) The surface of the viscous mudflow accumulating in the test flume is normally not a uniform plane, but is a nonuniform parabola accompanied by fractures on the mud surface. The typical fracture state is shown in Fig. (**4**).

Notes: Fracture state of mud surface (γ = 17.5 KN/m3, i = 14.0%, Q=1.50l/s).

Fig. (4). Fracture state of mud surface.

4. THEORETICAL ANALYSIS

4.1. Initiation Model

As is proven repeatedly by the tests in this study, corroborating the results achieved through a large number of previous tests and analyses [14-16], water saturation (Sr), initial slope (α), and content of fine particles (C) comprise the three principal determinants for the initiation of debris flows. The general formula for the critical conditions necessary for debris flow initiation is given as follows:

$$D\alpha + A_1 S_r^2 + A_2 S_r + \frac{B_2}{C - B_1} + F = 0 \tag{1}$$

Where D, A1, A2, B1, and B2 are coefficients and F is the constant determined by the boundary conditions. As both viscous debris flows and viscous mudflows belong to Bingham-type fluids, we think that the model for the initiation of viscous mudflows can also be described by Equation (1).

If

$$\frac{B_2}{C - B_1} = BU \tag{2}$$

Then

$$C = \frac{B_2}{BU} + B, \tag{3}$$

Where U is the parameter reflecting the content of fine particles, which is in a reciprocal relationship with C. If we introduce Equation (2) into Equation (1) and multiple it by Sr, then we obtain

$$D\alpha S_r + A_1 S_r^3 + A_2 S_r^2 + BUS_r + FS_r = 0 \tag{4}$$

Note that the relationship of saturation Sr and slope α conforms to a parabolic equation:

$$(S_r - a)^2 = 2P(\alpha - b), \tag{5}$$

Where a and b are the vertex coordinates of the parabola and 2P is the parameter reflecting the focus of the parabola. Then, by introducing Equation (5) into Equation (4), we obtain

$$\begin{aligned}&(\frac{D}{2P} + A_1)S_r^3 - (\frac{Da}{P} - A_2)S_r^2 + BUS_r \\ &+ \frac{D}{2P}(2Pb + a^2)S_r + FS_r = 0\end{aligned} \tag{6}$$

By arranging equation (6) in order, we have

$$\begin{aligned}&(\frac{D}{2P} + A_1)S_r^3 + BUS_r - \frac{aD - PA_2}{P} \\ &\left\{\left[S_r - \frac{D(2Pb + a^2) + 2PF}{4(aD - PA_2)}\right]^2 - \left[\frac{D(2Pb + a^2) + 2PF}{4(aD - PA_2)}\right]^2\right\} = 0\end{aligned} \tag{7}$$

Adopting Equation (5) in the calculation of Equation (7) leads to

$$\begin{aligned}&(\frac{D}{2P} + A_1)S_r^3 + BUS_r - \frac{aD - PA_2}{P} \\ &\left\{2P'(\alpha - b') - \left[\frac{D(2Pb + a^2) + 2PF}{4(aD - PA_2)}\right]^2\right\} = 0\end{aligned} \tag{8}$$

P' and b' will be determined and then

$$-2P'b' - \left[\frac{D(2Pb + a^2) + 2PF}{4(aD - PA_2)}\right]^2 = 0 \tag{9}$$

When Equation (7) is determinable, Equation (8) can be written as

$$(\frac{D}{2P} + A_1)S_r^3 + BUS_r - \frac{2P'}{P}(aD - PA_2)\alpha = 0, \tag{10}$$

If we assign

$$\frac{D}{2P}+A_1=A \tag{11}$$

And

$$\frac{2P'}{P}(aD-PA_2)=-Q, \tag{12}$$

then Equation (10) can be written as:

$$AS_r^3+BUS_r+Q\alpha=0. \tag{13}$$

Based on [17], Equation (13) is actually a manifold function of the cusp catastrophe model. The potential function of this mode will be gained by integration

$$V(S_r)=\frac{A}{4}S_r^4+\frac{B}{2}US_r^2+Q\alpha S_r, \tag{14}$$

Where A, B, and Q are equation coefficients. Equation (14) is the potential function of debris flow initiation; however, the function is equally suitable for the viscous mudflows that are the focus of this paper.

4.2. Catastrophe Theory

Catastrophe refers to a situation in which the research system transforms from one stable condition to another stable condition, in a leaping mode, because of continuous changes of external controlling parameters. In other words, the continuous and gradual changes of some variables cause a sudden change of the system during the system's evolution. The mathematical origin of catastrophe theory can be dated back to Poincare in the early 19th century, when he identified that the solution of ordinary differential equations depends on three principal factors: structural stability, dynamic stability, and a critical set [17]. However, his thoughts were not accepted by other mathematicians at that time. Morse's [18] proposal in 1930 was considered a significant contribution to the mathematical foundation of catastrophe theory, but the biggest impetus was provided by the paper "Mapping from a Plan to a Surface" published by American mathematician Whitney [19] in 1955, which is considered another seminal work on the mathematical foundation of catastrophe theory. In the 1970s, Thom [20] proposed a theory of "primary catastrophe", which marked the popularization and application stage of mutation theory. At present, there are seven types of basic catastrophe mode in applied primary catastrophe theory [17], among which the standard potential function of the cusp catastrophe model is

$$V(x)=x^4+ux^2+vx. \tag{15}$$

The great importance of this model is the critical point determined by the first-order derivative $V'(x)=0$, i.e.:

$$4x^3+2ux+v=0. \tag{16}$$

Equation (16) is a cubic equation with one unknown and the number of its roots is determined by its discriminant

$$\Delta=8u^3+27v^2. \tag{17}$$

When $\Delta > 0$, there is a real root; when $\Delta < 0$, there are three diverse real roots; and when $\Delta = 0$, there is a double or triple root.

In the cusp catastrophe model, surface M determined by Equation (16) is called the catastrophe manifold. The following is based on Equation (16) and the second-order derivative $V''(x)=0$, i.e.:

$$12x^2+2u=0 \tag{18}$$

If we eliminate x, then curve B determined by the parameter equation of a plane will be obtained simultaneously and can be expressed as:

$$8u^3+27v^2=0, \tag{19}$$

Which is called a bifurcation set.

When comparing Equations (14) and (15), it is easy to establish that the initiation mode of viscous mudflows belongs to the cusp catastrophe model. Corresponding graphs of viscous mudflow M and viscous mudflow B are illustrated in Fig. (**5**). When $\Delta=0$, bifurcation set B is shown as the projection of the fold of the catastrophe manifolds on the surface of the fine particles content parameter (nondimensional parameter) U—bottom slope α, where Sr is the state variable, while U and α are control variables.

What must be explained again is that the variables are determined according to the principles of "part lemmas" in catastrophe theory. The so-called "part lemmas" actually classify all the variables into related real variables and unrelated unreal variables associated with structural instability and ignore the latter. In other words, in catastrophe theory, it is supposed that the number of possible catastrophe modes only depends on the number of real variables, which means that only a few control variables can predict the qualitative and quantitative status of the system. With regard to the mudflows or debris flows in this paper, only water saturation Sr, initial slope α, and the content of fine particles U are used to represent the initiation conditions. Among these factors, U and α are planar and called control variables, whereas Sr is unidimensional and it is considered a control variable that represents the qualitative and quantitative changes of substances.

4.3. Initiation Mechanism

The upper, middle, and lower lobes in Fig. (**5**) are the three possible equilibrium positions, of which the upper and lower lobes are stable and the middle is not. The upper lobe represents the status of the source material storage before initiation; the middle lobe represents the initiation process, and the lower lobe represents the debris flow after initiation. As there is one real root or three dissimilar roots in Equation (13), there are three corresponding initiation situations for the debris flow, which are shown as paths I, II, and III in Fig. (**5**). Each of the initiation situations is described below.

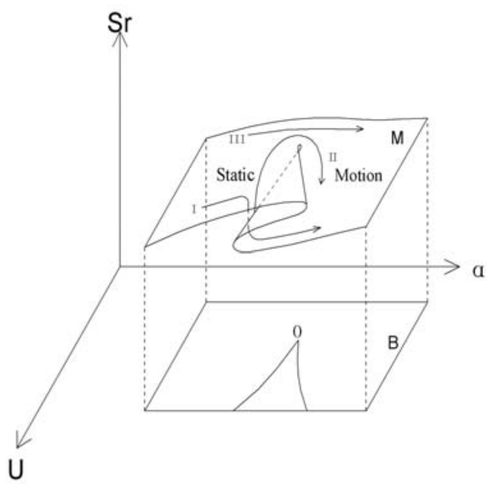


Fig. (5). Catastrophic manifold of debris (mud) flows.

(1) Path I represents the forepart of the cusp. This area denotes the condition where there is lower content of fine particles and water in natural debris flow. Elastic failure occurs mainly when debris with elastic, plastic, and viscous features approach initiation. In particular, because of the lower content of fine particles, the connections between particles are weakened. Therefore, solid matter approaching the yielding fracture surface will recover its deformation abruptly and accelerate instantly in the form of an elastic impulse at the critical point of initiation. This is considered the “catastrophe” feature of initiation, i.e., the characteristic of the sudden occurrence of debris flows in mountainous areas. Cui [14] named this physical process the “acceleration mechanism” of debris flow initiation.

(2) Path II represents the middle section of the cusp. This area denotes the condition where the content of fine particles increases and connections between particles are boosted. The elasticity weakens while plasticity and viscidity increase, and the separation effect accelerates. Thus, the destruction process of debris develops gradually from the front to back causing staged initiation at a constant speed. The initiation of most natural viscous mudflows is as described above, which is termed the “separation mechanism”.

(3) Path III represents the back of the cusp. This area denotes the condition of natural viscous mudflows. When the content of fine particles increases further, the connection effect becomes dominant, structural strength increases sharply, and the initiation process develops slowly. This exhibits the features of “gradual change” in the initiation of viscous mudflows, which is named the “connection mechanism”.

4.4. Characteristics Description

Based on catastrophe theory, theoretical analysis, description, and verification of the entire process of natural debris flows, the characteristics of the initiation, transport, and sedimentation of viscous mudflows, described in the “Test results” section, are discussed in the following.

4.4.1. Initiation Characteristics

As described in the tests, the initiation of viscous mudflows shows typical gradient features at a constant or low speed with its initiation mode usually the same as that stated in Paths II and III. Large numbers of tests show that viscous mudflows can start moving on the five kinds of slopes set in the experiments of this study. When the content of fine particles exceeds 50%, the fine particles wrap and separate coarser particles completely. Thus, the connections between fine particles increase continuously and new connections between fine particles appear, counteracting or even exceeding the structural damage caused during the shear process. Consequently, the critical initiation slope lessens and the initiation process shows significant slow and gradient features.

4.4.2. Flow Characteristics

The tests indicate that viscous mudflows move in a surge after initiation, when variables such as the slope of the test flume and mud density (indirectly reflecting water saturation and content of fine particles) change or are in certain combinations. This phenomenon can be explained by catastrophe theory. As mentioned earlier, when the content of fine particles and water increase, the initiation of viscous mudflows is in accordance with Paths II and III at a constant speed or in stages. After initiation in stages, the mud should form many isolated surges and flow down the channel as its flow morphology changes from pause and flow, to spreading and distorting, and finally to wavelike intermittent flows. When certain conditions of the slope of the test flume and mud density are satisfied, the situation in which the previous wave is chased and surpassed by a latter one is possible, and finally the wavelike intermittent flow turns into a steady flow.

4.4.3. Accumulation Characteristics

The entire process of the flow tests in this study was recorded by camera and one typical phenomenon was observed, which was that the mud surface exhibited fracture features when the mudflow in the flume stopped moving and began to accumulate. A description of this based on catastrophe theory is given in the following.

As shown in Fig. (**5**), the surface is divided into three sections. The upper lobe represents the stationary state, the lower lobe represents the state of motion, and the middle lobe indicates the unstable state. The initiation process of viscous mudflows is a sudden jumping process from the upper lobe to the lower, whereas the accumulation process is a shifting process from the lower lobe to the upper. Based on the parameter plane, the cusp curve in Fig. (**5**) is the counteracting area of driving force and resistance of viscous mudflow initiation, where the right branch is the critical initiation condition and the left is accumulation. When the control variables exceed the critical conditions, the viscous mudflow will transform slowly from the motion state to the stationary state. However, when the resistance reduces during the motion process, which means returning to the critical initiation curve, the mud will not deposit quickly. Only when the critical conditions for accumulation are satisfied (i.e., the left branch) will the mudflow stop. Undoubtedly, the previous accumulation prepares for the subsequent initiation.

Although within the same test the slope of the test flume is fixed, after experiencing an entire motion process, the density of the viscous mudflow could alter for various reasons, e.g., mixing with gas. Thus, we believe that around the critical point, any subtle variations of the control parameters could cause considerable changes in the variables of the motion state. For example, adjacent viscous mudflow bodies in the test flume might move along two similar but individual paths while reaching different equilibrium positions (upper and lower lobes, or in other words, the two sides of the cusp), causing the hysteresis effect and ultimately, leading to fracture along certain sections. In physical process, the instability of the path perturbation of the control parameters is called "divergence", which indicates the divergence of the cusp catastrophe model.

CONCLUSION

Based on catastrophe theory, the characteristics and mechanisms of the initiation, transport, and sedimentation associated with viscous mudflows, which can be taken as representative of natural debris flows, were analyzed, described, and verified using flowing model tests. This is of great significance with regard to the forecasting and controlling of viscous debris flows that occur frequently in mountainous areas.

(1) The initiation mode of viscous mudflows conforms to and is in accordance with the general characteristics of the cusp catastrophe model, where the initiation characteristics are the same as the constant or low-speed initiation described in Paths II and III.

(2) The entire process of a viscous mudflow, including its initiation, transport, and accumulation, can be explained theoretically and reasonably by the cusp catastrophe model. It possesses multiple modes including "catastrophe", "gradual change", "hysteresis", and "divergence" and thus, to a certain extent, its occurrence and development could be prevented and controlled by adjusting the dominant parameters controlling its motion.

(3) Research on the initiation and transport of mudflows (debris flows), based on nonlinear science, are comparatively rare. Further related studies are necessary to enhance the theoretical system because of the complicated motion mechanisms involved.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This article and the whole tests were funded and supported by the National Natural Science Foundation of China (No. 51269009) and the Science and Technology Project of Western Transportation Construction, Ministry of Transport of the People's Republic of China (No. 2002 318 000 36). The physical index of the soil samples were analyzed by Northwest Research Institute Co., Ltd of C.R.E.C. and great thanks to the related organization and the personnel here.

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Received: July 8, 2014 Revised: October 3, 2014 Accepted: December 20, 2014