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ABSTRACT: This paper has discussed the problem proposed about multiple stroke of high-speed landslides its multiple strokes, change of energy, and overstepping gas billows spattered with mud.

INTRODUCTION

This paper for the first time puts forward the problem of multiple-stroke and high-speed landslides in bedrock, and the problem of over-stepping gas billows spattered with mud and made theoritical discusson about them so that much attention should be paid to protected slope environments from the point of view of engineering geology and to improving its quality to prove landslides in theory and take appropriate measures for prevention and management.

PROBLEM PROPOSED IN THIS PAPER

Leng-shui-gou, Shi-jia-po landslide in Sang-su-wan village in Ning-qiang county is a typical one first proposed with multiple-stroke, , intensely-moving and high-speed. Shi-jia-po multiple-stroke, intensively-moving and high-speed landslide iies on the left bank(Shi-jia-po) of Leng-shui-gou branch of upper reaches of JIANG HAN River. The place near Leng-shiu-gou is very dangerous. At about 10 o'clock at that noght,on 23, August, 1981, rock soil of bulk 480,000 m^3 in all on the left bank of the slope rapidly and intensively dived and slid down from the elevation of 925 m., accompanied by boom amd great noise, suddenly stopping up rivers. And the body slide under enormous impulsive forces crossed the valley floor in length if 50-100 m., and upthrusted valley slope on the right bank, lifting up the 40m.. What is more, in the front part of the landslide took place the secondary slide bed plane which dived and slid down from the elevation of 40m. to the opposite direction and after turning to the former left bank, upthrusted lifting up to 20m.. From here, it mixed with large amount of stream water and rains, continously made up three moving strokes in the form of fluids from the left to the right, and then from the right to the left, and stopped in the regious Shan-tand-su and Long-wang-miao. The whole course is about 1,060m. long, which spent less than 10 minutes sliding. It is emphasized that damages made by Shi-jia-po multiple-stroke landslide is rare in our country. At the left bank of down. stream which is 600 m. away from the starting place landslides overturned a mountain to a farmar household in the village Qing -gang-su- wan and thirteen farmers were died of sliding fluids and no one is alive.

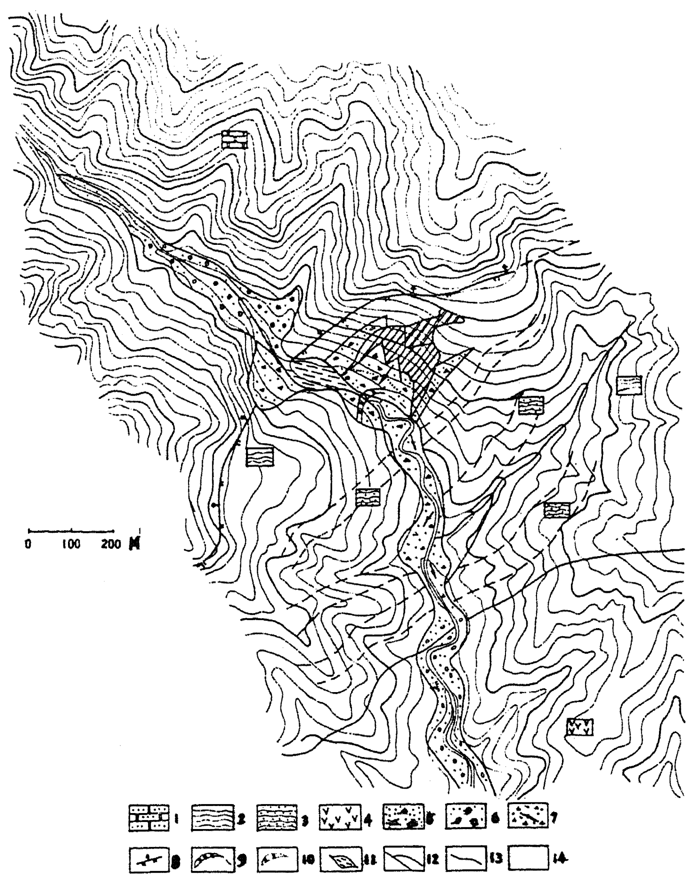

Fig. 1. A geological map of Shi-jia-po section in Ning-qiang county, Shaanxi Province
1.quartzite, 2. phyllite, 3. chlorite-schist, 4.basalt-andesite, porphyrite, 5. slope wash, 6.alluvial soil, 7.sliding accumulation, 8. fault.

MULTIPLE STROKES

High-speed landslides in the southern part of Shaanxi Province have been well known for a long time. However, Shi-jia-po landslide is a typical and multiple-stroke and high-speed landslde. From the beginning of sliding, in a matter of several minutes, there appear five grades of strokes in the whole sliding course as long as 1,060 m., each having more oe less double strokes--"dive" and "upthrust" ,that, a pair of strokes which dive from higher places to lower, and then from lower to higher. The first two strokes are typical sliding ones of body slides, while the last three strokes are moving ones appeared under particular conditions of that time (Fig. 1, 2).

The first grade stroke (A) of Shi-jia-po landslide --Shi-jia-po-- begins from the left bank of Leng-su-gou river in Shi-jia-po where landslides take palce(TABLE 1). This grade stroke is the consequent sliding stroke of front dive and upthrust.

The secondary grade stroke(B) of Shi-jia-po landslide--Shui-jing-wan stroke-- occurs upon the front slope bodies (sliding tuquer) of the former stroke of landslides.This is a especial and interesting problem about motive forces of land slides. This grade stroke is a contrary sliding stroke of reverse dive and upthrust.

The third grade stroke (C) of Shi-jia-po--Tong-guan-wan stroke-- also happens on the front edge of sliding bodies of the former stroke, but this stroke is different from the former stroke in features of motive forces and changed greatly. After Shi-jia-po landslides, there appear one month's rainy days and flood, so the level of river bed rises high enough to make larger discharge. In the first grade stroke, because its front edge (sliding tuquer) is mixed with large amount of rains and water of river, sliding bodies having fragments in a moist saturated state and mixed with sticky soil further disintegrate and break out. This stroke is a turned and consequent moving stroke of dive and upthrust.

The fourth grade stroke(D) of Shi-jia-po landslide is a a Shan-tang-su stroke. This stroke ia also a turned and consequent moving stroke of dive and upthrust.

The last-- the fifth-- stroke(E) of Shi-jia-po landslide is a Long-wang-miao stroke near Sha-tang-su village, the characters of which are similar to those of the former. In this case, Shi-jia-po multiple-stroke landslide has finished its activities if five grades of strokes in all. It may take several minutes to finish the whole process of sliding.

Table 1 The situation of "dive" and "upthrust" Shi-jia-po multiple-stroke landslide (elevation of the back edge 925 m.)

stroke	the lowest elevation (m)	the highest elevation (m)	the direction of stroke	dive (m)	upthrust (m)	angle of inter ection with the former	disdance	remark
A Shi-jia-po stroke	800	840	SW225°	125	40		340	sliding stroke
B Shui-jing-wan stroke	800	820	SE102°	40	20	123°	160	sliding stroke
C Tong-guan-wan stroke	775	785	SE155°	45	10	50°	200	moving stroke
D Sha-tang-su stroke	767	775	SW206°	18	8	51°	200	moving stroke
E Long-wang-miao stroke	757	763	SE143°	18	6	63°	160	moving stroke

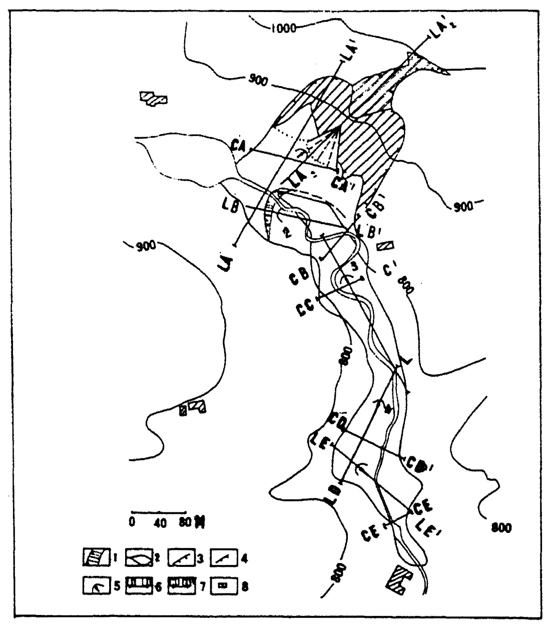

Fig. 2 A plane of multiple-stroke landslide of Shi-jia-po in Ning-qiang county, Shaanxi Province
1. landslide, 2. lake and river, 3. the first landslide, 4. the secondary landslide, 5. the direction of sliding, 6. longitudinal profile, 7. cross profile, 8. village.

CHANGES OF ENERGY

Changes of energy in multiple- stroke landslides should be studied from a complete stroke (dive, upthrust). For this reason, first, a typical energy system of multiple-stroke landslides must be chosen (Fig. 3) -- just as "ABCDE" system. It must be stated that it is difficult in proving clearly, generally such a complex theory in practice without some supposition, imagination and simplification providing that this may not affect changes of energy studied in this paper. Therefore about forms of the slide bed plane on the landslide profile intruduced in the paper we will not discuss.

This is not significant for the problem discussed in the paper. There only according to the lines of basic slide bed planes ($A_1B_1C_1D_1$) which are existing in Shi-jia-po multiple-stroke landslide and their developing characters, slide bed plane may be properly repaired and simplified. So they are intruduced to be well-kmown slide bed planes ($A_1B_1C_1D_1$) in a form of circle and are lines which may generally correspond to most conditions and actually accepted by scientists. Actual slide bed planes ($A_1B_1C_1D_1$) are essentially similar to simplified slide bed planes ($A_2B_2C_2D_2$). The section A_1E is quite different from the section A_2E. But in fact the former (slide walls) is rebuilt from the original slide bed plane by bursting apart (to form EB_1F colluvium). So it must be much steeper and closer to the section A_2E. Otherwise, in spite of deviation, section EB_2C_2 are close to EB_1C_1. Reversed and turned-back body slides ($A_2B_2C_2F$) are in the states of body slides deformed after sliding. Although they do not entirely correspond to lines of the former terrain before sliding, they are approximate to each other. Besides, it is supposed to be a problem of plane and this means that in different planes and during the whole sliding process, the strength of shear- resistance of slide bed planes is equal and unchanged, the whole slide bodies at a definite speed. These may not affect the essence of problems discussed in this paper.

At any time (t) in sliding of high-speed landslides, the parts beyond sliding bed planes should be taken as an energy balance system while the others do not belong to it. When taking point M as the centre of conversion, slide bodies slide at a definite speed (V) , the interion energy of this system is regarded as potential energy (EP) of slide bodies. Slide bodies in motion possess sliding kinetic energy (EK). Besides, for overcoming shear-resistant strength of rock masses beyond the system energy wasted by friction and resistance in interior bodies and other resistance (such as air resistance) and ect. (t) for doing work is considered to be negative outer energy Ee. Therefore, according to relative elevation 0 line--basic line-- shown in the Fig. and energy balance principles, we suppose the total weight of slide bodies to be W, and can clearly see all kinds of energy stated above:

$$Ep = HW \qquad (1)$$

$$EK = \frac{WV^2}{2g} \qquad (2)$$

$$Ee = \tau L \varepsilon \qquad (3)$$

where: L= the total length of a slide bed plane ($A_2B_2C_2D_2$ or $B_2C_2D_2$);

ε = the distance of sliding (C_2D_2);

The shortened thickness is equal to 2^{1}. On the basis of energy law of thermodynamics or the law of conversion of energy and from formulas (1), (2), (2), we may make energy balance formulas of whole processes of dive and upthrust in high-speed and intensively-moving landslides, but outer energy is usually regarded as negative outer energy (-Ee):

$$Ep + Ee + EK = U \qquad (4)$$

$$HW + \tau L \varepsilon + \frac{WV^2}{2g} = U \qquad (5)$$

the total energy (U) of slide bodies system in sliding keeps some balance. In the same way, at the moment when body slides have just started or will stop, we may write the following formulas:

$$W(H_1 - H_2) = \tau L(\varepsilon_1 - \varepsilon_2) = \frac{W}{2g}(V_1^2 - V_2^2) = 0 \qquad (6)$$

Thererfore, in order to prove in detail or partly to investegate the relationship of energy conversion among slide bodies we may divide slide bodies into many strips in definite size and make up formulars for energy balance in complete dive and upthrust processes of high-speed and intensively-moving landslides From formulars (1),(2), (3), we may write the following formulars:

$$\sum_{n=1}^{i+1} w_n h_m + b_1 \sum_{n=1}^{i+1} \tau \Delta L \varepsilon + \frac{WV_1^2}{2g} = U \qquad (7)$$

$$\sum_{n=1}^{i+1} w_n h_m + b_2 \sum_{n=1}^{i+1} \tau \Delta L \varepsilon + \frac{WV_2^2}{2g} = U \qquad (8)$$

$$\sum_{n=1}^{i+1} w_n (h_{1n} - h_{2n}) + (b_1 - b_2) \sum_{n=1}^{i+1} \tau \Delta L_n \varepsilon + \frac{W}{2g}(V_1^2 - V_2^2) = 0 \qquad (9)$$

From basic formulars of energy balance (6) and (9), it is not difficult in seeing that-in the total energy of slide bodies potential energy, kinetic energy and nagative outer energy may converte to each other in the whole dive and upthrust process of high-speed and intensively-moving landslides, or straightly speaking, the energy is completed by arranging and converting the difference of elevation of gravity centre, the speed of sliding and the difference of migration of sliding. There is a clear and strict conversion relationship among them.

According to the former formula and formulars stated above, it is not different in proving laws of energy conversion of multiple-stroke landslides(Fig.4,5).

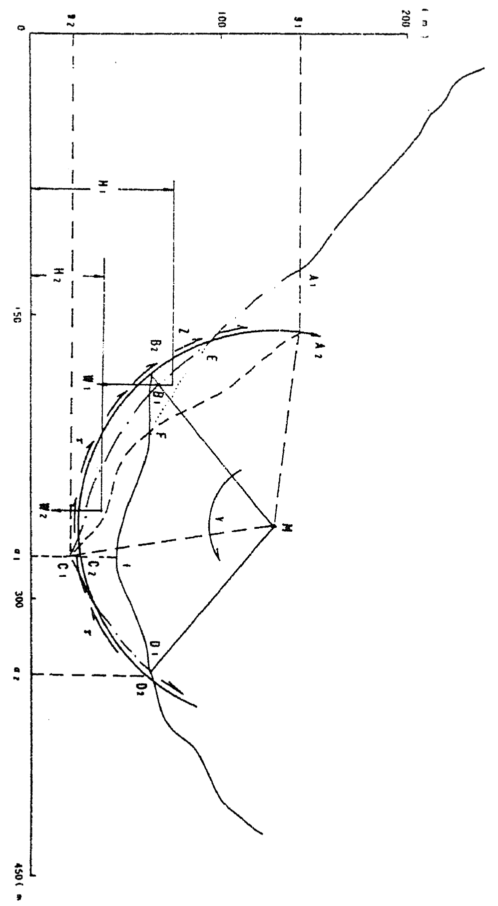

Fig.3 An analysis map of energy balance of Shi-jia-po landslide

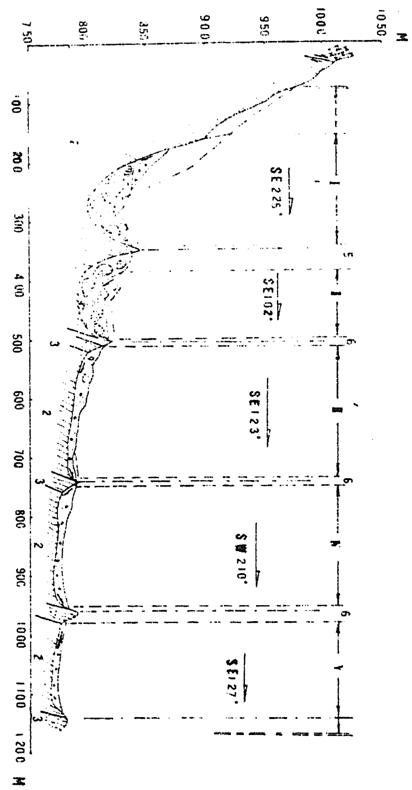

Fig. 4 A process map of multiple- stroke dive and upthrust of Shi-jia-po landslide
I. the first(sliding) stroke,II. the secondary(sliding)stroke,III. the third(moving) stroke,IV. the fourth(moving) stroke, V. V. the fifth(moving) stroke, 1. quartzite, 2.sericite,3.chlorite-schist, 4.fault. 5.line of former terrains, 6. links.

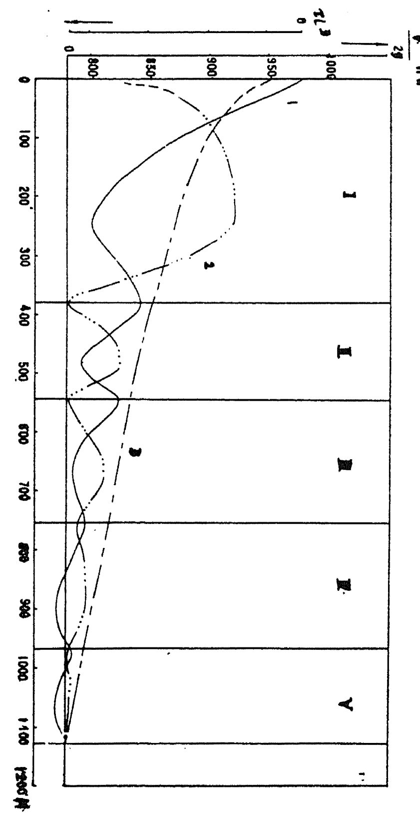

Fig. 5. An inferred map of energy conversion of multiple-stroke Shi-jia-po landslide 1. curve Of potential energy, 2. curve of kinetic energy, 3. curve of energy wasted by friction and resistance.

OVERSTEPPING GAS BILLOWS SPATTERED WITH MUD

Shi-jia-po landslide has its own characters and a new phenomenon different from that of common landslides. This is overstepping gas billows spattered with mud of active slide bodies. They may bring us extraordinary disasters that are difficult in imagining. Overstepping gas billows spattered with mud may damage building and installation , break trees, burst the surface soil and even may break and lift quite far objectes away. For forming overstepping gas billows spattered with mud, it is necessary to have sufficient high speed. Slide bodies at high speed have enormous kinetic energy,thus causing gasses in front parts of body slides to press swiftly, expand and then suddenly burst out under proper conditions. If in a region there may exist a suitable distance, very different rocks-- soft and hard, a proper fracture belt in structure or the combination of the former two, there would be formed wide or narrow, and winding river valleys, obvious projected mountain spur and whetstones which can stop slide bodies to turn. Therefore, it makes parts of kinetic energy of body slides be changed into an enormous impulse. So this is important objective conditions under which overstepping gas billows spattered with mud are formed(Fig. 6, 7).The projected mountain spur must have steep slopes(about45-75^{0}) so as to cause parts of pressed air and converted enormous impulse to break out swiftly and violently, thus forming the maximum height (hmax)and distance (lmax) of gas billows spattered with mud. Obviously, slide bodies at a high speed must possess sufficient weak rock masses and developed fractures (weathered rocks or low-strength rocks) or loose soil for rapidly disintegrating, breaking out and grinding. In this way, the front or the side part can be changed into mud. This is material conditions for making up gas billows spattered with mud. At last, there must be large amount of underground water and surface water to take part in forming overstepping gas billows spattered with mud. The humid weather, rains, especially, flood season provide enough materials for overstepping gas billows spattered with mud.

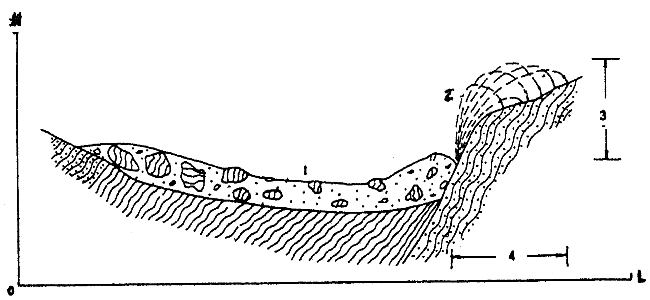

Fig. 6 A sketch map of overstepping gas billows spattered with mud of Shi-jia-po landslide 1.body slide, 2. overstepping gas billows spattered with mud, 3. the maximum height of spattering (hmax), 4. the maximum distance of spattering.

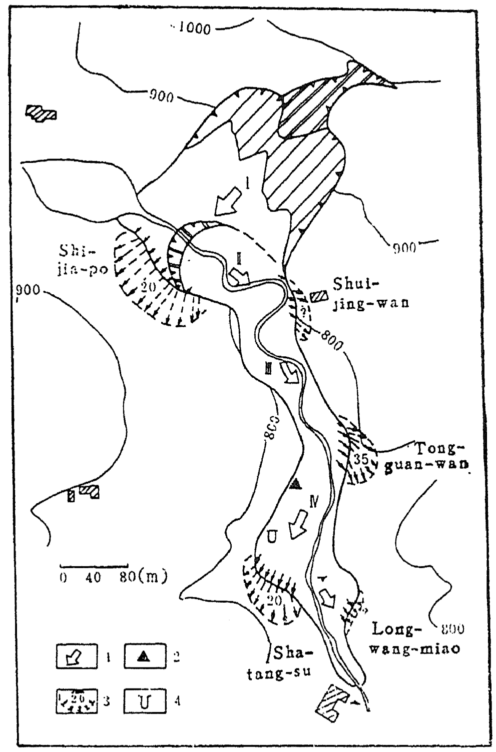

Fig. 7. Overstepping gas billows spattered with mud of Shi-jia-po landslide 1. sliding,moving stroke and its direction, 2. overstepping gas billows spattered with mud and their height(m), 3. houses damaged (thirteen people were buried) 4, boulder (stone tablet overturned)

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