Slope deformation failure and prevention in a high earthquake intensity area

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Abstract: The 1933 Diexi earthquake occurred and affected an area upstream of the Minjiang River. This earthquake led to a number of surface geological effects. Recent research has systematically analyzed the distribution characteristics of slope deformation-failure at Diexi high earthquake intensity area. A summary of the spatial development and distribution characteristics of slope deformation-failure was investigated. Four mechanisms of slope deformation-failure were identified in the Diexi area. Finally, it mainly analyze and study the relationship between the distribution of the slope deformation-failure, the mechanism of the earthquake and stress fields in the Diexi area, and suggest the prevention and control methods.

Résumé: La destruction de déformation inclinée due à la propagation de séisme a été rarement étudiée, donc les recherches du mécanisme et de la prévention sont un nouveau secteur de recherche. En 1933 le séisme Diexi est arrivé et a affecté la région en amont de la rivière Minjiang. Le séisme provoque un certain nombre de désastres géologiques superficiels. La recherche récente a systématiquement analysé les caractéristiques de distribution de destruction de déformation incliné à Diexi où il y a une haute intensité de séisme. Un résumé du développement spatial et les caractéristiques de distribution de destruction de déformation inclinée a été examiné. Quatre mécanismes de destruction de déformation inclinée ont été identifiés dans la région Diexi. Finalement, il analyse et étudie principalement le rapport entre la distribution de la destruction de déformation inclinée, le mécanisme du séisme et les domaines de stress dans la région Diexi•et suggère les méthodes de prévention et de contrôle.

Keywords: Minjiang-Diexi country, Seismic landslide and falling, Slope deformation-failure, Distribution characteristics, Prevention and control

1. INTRODUCTION

Instability of mountain slopes during shaking is a common problem, which is even more common regions where earthquakes likely. Earthquake-induced landslides, due to their wide range, large scale and potential to cause damage, often result in heavy economic losses. The Diexi Earthquake (M=7.5) occurred on August 25, 1933 in the upper reaches of Minjiang River in Sichuan China induced a number of surface geological effects including landslide and falling, and the Diexi landslide in the meizoseismal area ultimately formed a debris flow which struck ancient Diexi Town and 'buried the town under riprap'. The thousand-year old town was destroyed and more than 500 lives were lost. Furthermore, the Yansai Dam located downstream of Diexi Seismic Area burst and the resultant flood peaked with a wave more than 60 m high which rushed to Guanxian County 200 km downstream, and washed away more than half of the villages and towns along the river claiming about 2500 lives. And at the same time, mountain hazards such as falling, landslide, debris flow etc. in different scales also occurred concurrently nearby the meizoseismal area and formed Yansai Lake with unique landscapes. Another example is the earthquake (M=8.5) occurred in Zayu Tibet on August 15, 1950 a landslide blocked the river and formed a lake. The river in the lake burst the bank 8 days after the earthquake and the 7-meter-high angry wave submerged hundreds of villages, which claimed one time more lives than the earthquake itself (Wang Yaowen, 1960). During the earthquake (M=7.7) that occurred in Peru on May 30, 1970, the massive landslide from the north peak of Mount Huascaran buried the towns of Yungay and Ranrahirca and claimed 18000 lives (Plafker et al., 1971). In addition, the landslides caused by large earthquakes (M=6.5) in Chile in 1960 and the Alaska earthquake (M=8.6) in the USA in 1964 have resulted in huge lose of lives and property. According to statistics, the loss due to deformation, failure and destabilization of mountain massifs caused by earthquakes accounts for significant losses and in some cases, such loss even far exceeds that caused by the earthquake itself (Keefer, 1984).

As a seismically active country, China has had many strong earthquakes in its history, especially in its western mountainous areas where earthquake remains more active and earthquake-induced geological disasters occurred more frequently. The problem of earthquake-induced slope failure is rather signifcant in the construction of major projects, the protection of ecological environment, the prevention and control of geological disasters as well as the sustainable development process of the resources and the environment in the western part of China. The deformation-failure and stability of mountain massif under the effects of strong earthquakes has always been the top concern of domestic and international researchers in the fields of engineering geology and rock mechanics, and the complexity of this issue has been fully recognized. This paper takes the development and distribution law of the surface geological disasters induced by Diexi Earthquake occurred in 1933 as the main research subject, and the research area is in the upper reaches of Minjiang River located in Jiaochangba of Maoxian County and its tributary in Songping Valley. The surface geological disasters induced by Diexi Earthquake in 1933 have the following typical characteristics and research significance:

- The earthquake-induced slope failure has important distribution characteristics, which were obviously under the control of earthquake mechanism and stress field;
- There exist several types of typical slope deformation-failure mechanisms, for instance, rock slope instability, debris flow formed due to the falling of the upper decomposed and decompressed rocky slope, landslide induced by sharp water pressure increase in pores on the deep overburden of grooves, etc.;
- The extent of slope deformation-failure and the way of instability failure vary in areas with different earthquake intensity;
- The precious natural resources left from Year 1933 Earthquake are being used for construction of Tianlonghu Hydropower Station and the development of Songping Valley Scenic Spot.

2 GEOLOGICAL BACKGROUND AND FEATURES OF THE DIEXI EARTHQUAKE AFFECTED AREA

The Diexi earthquake affected an area located in the middle section of the famous ‘seismic-tectonic zone oriented in S-N direction’. Geotectonically this area belongs to the northeast edge of Tethys Himalayas, namely, located in a triangle formed by the east of the geosyncline fold belt in Songpan-Ganzi NWW direction, the south of the geosyncline fold belt in EW direction in the west of Mount Qinling and the fault zone in NE direction on Mount Longmen, and consists of a series of dense line-like, arc-shaped and inverted folds and the accompanying thrust faults. The exposed bedrock in the area include outcrops in Devonian Weiguan Formation (Dwg), Carboniferous (C), Permian (P), Triassic Bocigou Formation (T_{1b}) and Zagunao Formation (T_{2Z}), most of which are regionally metamorphosed to varying extents to rocks such as metasandstone, limestone, phyllite and slate (see Fig. 1). In Jiaochang and Longchi areas, there rocks are covered by thick Quaternary deposits.

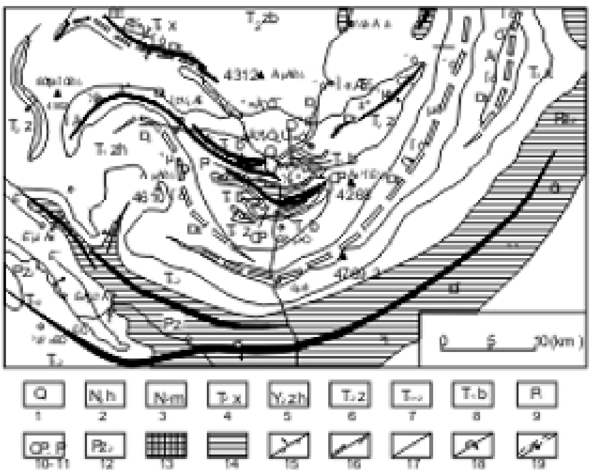

Figure.1. Geological tectonic in Diexi Seismic Area
1. Quaternary; 2. Neogene-Piocene Laterite Formation; 3. Neogene-Piocene Maladun Formation; 4. Upper Triassic Xinduqiao Formation; 5. Upper Triassic Jurassic Formation; 6. Middle Triassic Zagunao Formation; 7. Middle & Lower Triassic; 8. Lower Triassic Bocigou Formation; 9. Lower Permian; 10. Carboniferous-Permian; 11. Devonian Weiguan Formation; 12. Upper Palaezoic; 13. W-E tectonic belt on Mount Qinling; 14. Arc structure in Shidaguan; 15. Compression and torsion fault; 16. Torsion fault; 17. Fault with unknown nature; 18. Inverted anticline; 19. Syncline and inverted syncline

3. DISTRIBUTION CHARACTERISTICS OF SLOPE DEFORMATION-FAILURE IN DIEXI HIGH EARTHQUAKE INTENSITY AREA

Based on the distribution characteristics and the intensity of slope failure, the Diexi Seismic Area affected by slope movement is divided into the following 4 zones (Fig. 2):

- Diexi Jiaochang Zone (Zone A): with developed seismic faults and ground fissures, most of which belong to consequent rock slope instability and slope failure is intense.
- Songping Valley Zone (Zone B): most of the deformation-failure are due to falling of the decomposed and decompressed rock slopes, especially the upper steep parts of rock slopes.
- Longchi Zone (Zone C) on the right bank of Minjiang River: most of the deformation-failure are due to falling of the superficial and surface layers of the deep overburden.
- Tuanjie Village – Yuerzhai Valley Zone (Zone D): the deformation-failure are mostly seen in forms of quebrada, falling and landslide; a zone with relatively strong intensity of deformation, only second to Zone A.

3.1 Characteristics of slope deformation-failure in Diexi Jiaochang Zone (Zone A)

Diexi Jiaochang Zone (Zone A) was subject to very intense slope deformation-failure during the earthquake of 1933, which induced large scale slope movement. Using Mount Canling Fault Fracture, F1 (Jiaochang) Fault Fracture, F1' (Ganhaizi) Fault Fracture and F2 (Guancai Rive) Fault Fracture as the control border, Professor Wang Lansheng et al. divided the landslide groups into three subzones, namely, Jiaochang Fissure & Landslide Subzone, Canlingbei – Ganhaizi Landslide Subzone and Diexi Falling Subzone.

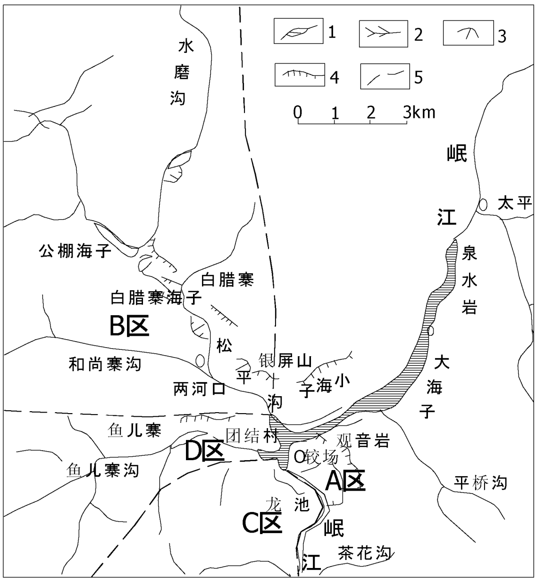

Figure 2. Zonation of slope's deformation in the area
1. Lake; 2. River; 3. Landslide; 4. Falling; 5. Border and serial number of zones

- The Jiaochang Fissure & Landslide Subzone is associated with extensive ground fissures in the shape of a crisscross crack network. According to the evidence of deformation of lake deposit, this subzone can be further divided into 4 parts, i.e., Jiaochangba subsidence Area, Liduishan Fracturing Area, Front Edge Landslide Area and Jiaochang River Landslide Area. Among these four parts, the Front Edge Landslide is the largest landslide in the research area, with a total area of about $3.6\times10^7 m^3$, and which forms the main body of Yansai Landslide Dam in Xiaohaizi. The landslide is composed of three sequentially sliding masses, forming platforms in three stages, and the overall sliding direction is S40°W. Exploration survey showed that the underlying slide face was developed and formed along the bedding surface of $T_{1b}+T_{2Z}$. The rock formation dips in the direction of the river valley (SW) at a dip angle of about 30°.
- Canlingbei – Ganhaizi Landslide Subzone consists of two landslides in Canlingbei and Ganhaizi. Both of the landslides are developed in the low-lying grooves in the former Jiaochang Zone and which are the accumulation areas of some old slumped masses. Along the groove pass F1 and F'1 which are faults with indication of activation during the earthquake. During the Diexi earthquake in 1933, the water-containing overburden layer was affected by both faulting and shaking, which led to sharp increase in the pore water pressure and caused slope instability.
- Diexi Falling Subzoneduring the earthquake, the rock and soil on the back edge slope fell rapidly, and due to the high altitude of the source area and the steep slope in the flowing area (50°~70°), the colluvial deposits slid down the slope at high speed and were transformed into debris avalanche, and some additional debris falls resulting in damage to the ancient city (Wang Lansheng et al., 1999).

3.2 Characteristics of disasters caused by earthquake landslide and falling in Songping Valley Zone (Zone B)

The types of slope failure disasters induced by the strong earthquake occurred in 1933 on the slopes of both sides of Songping Valley mainly include: falling of superficial material, medium/small-scale landslide, and debris flow. These disasters were mainly limited to the left bank slope of Songping Valley and the associated tributaries, while the right bank slope has only small-scale landsliding in the intensity X area (Fig.3). Falling is the most widely distributed ground failure effect produced by the earthquake in the Songping Valley and also the most serious mountain hazard, there are altogether 13 rock and debris falls around the Gongpeng Lake. The numbers of earthquake-induced landslides is relatively small but are generally larger than elsewhere. Altogether 5 landslides were observed. These falls, landslides and debris flows blocked the Songping Valley to varying extents and formed a series of barrier lakes which created useful water supply resources, such as Gongpeng Lake, Lower Bailazhai Lake, Lianghekou Lake, etc.

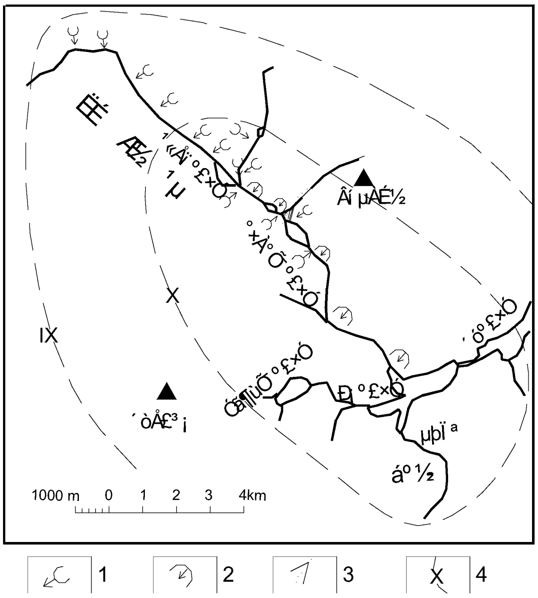

Figure 3. Distribution of the mountain hazard in Songping-River
1. Falling; 2. Landslide; 3. Debris flow; 4. Coseismic line and intensity

The landslides in this zone shows distinct zoning characteristics, i.e., the slope failure is mainly concentrated on the dip slope on the left bank and the subsequent slope on the right bank of Songping Valley. Small-scale falling occurred only in the strongly decomposed and decompressed zone of the upper superficial layer of the steep rock in the X intensity area. The destructiveness wore off with the reduction in the earthquake intensity, and relatively larger-scale landslide, falling and debris flow were distributed mostly in the X intensity area. The IX intensity area was mainly the falling of the decomposed and decompressed rock in the upper and steeper sites, while the VIII intensity area was mainly the exfoliation of the superficial overburden layer or the strongly decomposed layer.

3.3 Geological structure and deformation-failure of bank slopes in Longchi Zone (Zone C)

Through ground survey as well as several surveys of the lateral tunnel, diversion tunnel, underground workshops and so on that are under construction, and in combination with the comprehensive analysis of the radon gas and VLF site test results, we conclude that: the earthquake that occurred in 1933 does not pose any impact on the overall stability of the bank slope. The exception to this was were some limited falls of saturated surficial material in the shattered fault zone were noted. No large-scale failure similar to the landslides in Jiaochang and Ganhaizi were noted, and most of the ground failure was caused by the impact of sliding material from the opposite bank (Jiaochang Landslide), therefore this zone is weakly affected by the deformation-failure, and the geological configuration formed a sharp contrast against that in Zone A on the opposite bank. This may be genetically related to the slope and rock mass structure, the earthquake mechanism and the stress field in this zone. The 1933 earthquake caused the disappearance of the perennial catchment in the Longchi depression, which is the result of Guancaigou – Longchi Fault movement during the earthquake.

3.4 Characteristics of slope deformation-failure in Tuanjie Village – Yuerzhai Valley Zone (Zone D)

In the Tuanjie Village – Yuerzhai Valley Zone (Zone D), the earthquake occurred in 1933 mainly induced falling in the Yuerzhai Valley and landslide in Tuanjie Village at the entrance of the valley. The scale of the falling and landslide is only second to the scale in the Diexi Jiaochang Zone (Zone A). The degree of slope deformation-failure in the entire zone is also only second to that in Zone A.

The landslide of Tuanjie Village is located in the juncture of Songping Valley and Yuerzhai Valley and there are several quebradas and tensile cracks developed in the clay band. Due to its unusual landform like an isolated island suspended on its three sides, the slippage control surface formed by the interface between the clay layer in the upper part and the boulder-pebble-gravel-sand layer in the lower part of the terrace, and the trailing edge cutting plane of landslide formed by the interface between the terrace substances and back slope bedrocks, and under the strong earthquake action in 1933, a creeping-style landslide occurred along the interface between the clay layer and the boulder-pebble-gravel-sand layer.

3.5 Summarization of slope instability types in the Diexi Seismic Area

From the above analysis and studies on the different deformation and failure characteristics of different zones, we can conclude 4 types of slope instability in the Diexi Seismic Area:

3.5.1 Consequent rock slope instability

Earthquake-triggered rock slope instability is caused by the sudden loss of skid-proof capacity of the slope body under the action of earthquake and shall have the following prerequisites: (1) toppling or fall conditions; (2) The bedding surface of rock mass shall have certain gradient; (3) The angle of internal friction is controlled by a plane of weakness; (4) The sliding block control border is formed by pursuing the quebradas or seismic fault. This type of instability often occurred in the subsequent rock slopes on the left bank of Minjiang River and the left bank of Songping Valley, and the rock formation leans to the river valley at a dip angle of 20-40°. For instance, in the front edge landslide in Jiaochang (Wang Lansheng, et al, 1999), during the earthquake when the landslide was activated, it slid rapidly down to the valley and stopped on the opposite bank, and this process is described as activating-rapid sliding-rapid stopping. Upon stopping, the sliding mass will surely rupture and decompose due to inertia and form secondary sliding masses successively in two stages and three groups, and sliding blocks were formed along the quebradas.

3.5.2 Falling of decomposed and decompressed rock zone

The strong earthquake activity loosened the rock mass structure of the decomposed and decompressed rock zone of the slope, formed a fracture plane and caused dislocation of the weaker plane. The repeated action has finally caused slope instability. Falling of such decomposed and decompressed rock zone during the earthquake occurred more on the right bank in Xiaohaizi in the upper reaches of Minjiang River and the left bank slope of Songping Valley. For instance, the Gongpeng Lake fall is located on the left bank of Songping Valley, due to the strongly-weakly decomposed phyllite steep slope, the vertical joint fissure to (or obliquely crossing) the rock formation was developed and the structure was ruptured, then the fall occurred during the earthquake. In addition to this, there is also a relatively large scale Yinping cliff fall, which occurred along the decomposed and decompressed zone whose thickness was 10~50 meters.

3.5.3 Debris flow from high, steep rock slopes

The rock mass in the strongly decomposed and decompressed zone dominated by high, steep rock slopes failed during the earthquake. The sliding mass accelerated and developed into a rock avalanche (Sturtzstrom) before it collided with the opposite slope. The mechanism for the formation of debris flow consisted of two processes, i.e., the debris formation and fluidization of the moving mass. Similar failures, such as the Bailazhai debris avalanche overtopped topographic features such as the branch gully to the left side of Songping Valley.

3.5.4 Sharp increase of pore water pressure in the deep overburden layer

The occurrence of landslide may be genetically related to the sharp increase of excess pore pressure in the disturbed soil mass when the porous and water-rich overburden layer was under the action of earthquake and activated faults, and such sharp increase reduced the shear strength of the soil mass that resulted in slope instability, such as the landslide from the deep overburden layer in the Jiaochang Valley – Ganhaizi Valley.

4. DISCUSSIONS ON THE MECHANISM FOR FORMATION OF SLOPE DEFORMATION AND FAILURE DISTRIBUTION CHARACTERISTICS IN THE DIEXI SEISMIC AREA

This section of the paper describes the mechanism for the formation of slope failure distribution characteristics from two aspects, namely, the mechansim of earthquake and the stress field.

4.1 Genetic relationship between the distribution characteristics and the mechanism of earthquake

Regarding the focal mechanism of the Diexi earthquake occurred in 1933, a representative viewpoint is that it is a quake caused by the negative torsion and slippage of the buried fracture in NW direction in Songping Valley and that in EW direction in Shuajin Temple (Fig. 4). From the development of the falling, landslide and ground fissure occurred during the Diexi earthquake, we can see that the strong rupture site of the causative fault should be somewhere around Jiaochang. The earthquake was caused by the movement on several seismic faults, such as the faults in Mount Canling, Jiaochang Valley, Ganhaizi Lake, Guancai Valley and so on, among which, the seismic fault on Mount Canling is the tail extension of that in Songping Valley and forms a boundary of pulled fault trough together with F1 (Jiaochang) fault in SN direction and the Guancai Valley arc-shaped fault close to EW direction on the south side, i.e., the Diexi - Jiaochang Tensile Fault Area. The deformation and failure of rock mass in the tensile fault area were rather severe, which caused a great number of ground fissures and produced vertical tensile subsidence, such as the taphrogenic groove with a depth of 10~15 meters and a width of about 50 meters in the Jiaochang Fault Area.

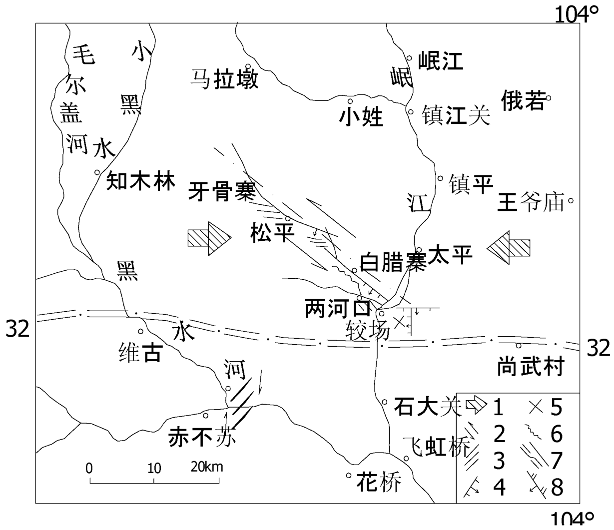

Figure 4. Pattern of tectonic stress in Diexi
1. EW direction main compressed stress; 2. main compressed stress induced shearing and twisting process; 3. the tensile fault area induced by earthquake;4. seismic faults;5.X-ground fissures; 6. track ground fissures; 7. The gravity aerial survey calculates faults; 8. press and twisting faults from actually measure

These seismic faults and ground fissures formed the control border of slope instability together with the unfavorable structural plane of the rock mass of the slope, which played a very important role in controlling the distribution characteristics of the deformation and failure in the Diexi Seismic Area. For instance, in Diexi Jiaochang Zone (Zone A), the earthquake-induced seismic faults and ground fissures formed the fault network on the ground and caused tension fractures and rifts. The faults and ground fissures became the control border of slope instability, and with the unfavorable structural plane of the consequent slope itself, the slope could easily become destabilized, therefore in this zone the most occurred were falling and landslide of consequent rock, and the deformation and failure were rather intense. In the Songping Valley Zone (Zone B) and the Tuanjie Village – Yuerzhai Valley Zone (Zone D), the seismic faults and ground fissures occurred during the earthquake are less severe than those in Zone A, so are the degree and scale of the deformation and failure. In the Longchi Zone (Zone C), as there was only one extended fault active in the area nearby the depression when the earthquake happened in 1933, the ground fissure was underdeveloped, and as it is an obsequent slope, no large-scale instability and failure occurred in the bedrocks of the bank slope, instead there were only some local and small-scale fallings occurred from the superficial part of the overburden layer, with little slope deformation and failure, posing a sharp contrast with Zone A.

To sum up, the mechanism of the earthquake controlled the spatial development and distribution of seismic faults and ground fissures, which in turn controlled the distribution characteristics of slope deformation and failure.

4.2 Genetic relationship between the distribution characteristics and the stress field

The Diexi Seismic Area is located in the juncture of a buried structure in EW direction and the Songping Valley fault in NW direction. Such a special tectonic position is a favorable site for stress buildup and development. Under the action of the stress field of the structure in near EW direction, the stress in the Songping Valley fault in NW direction built up gradually, and when it exceeded the shear strength of the fault zone, it caused negative torsion and slippage and then earthquake occurred. On its both sides formed the local stress tensile zone and compressed zone, thus playing a role in controlling the distribution characteristics of the deformation and failure in the Diexi Seismic Area.

At the ends of the shear fracture of the seismic fault in Songping Valley are two zones concentrately distributed with different deformation fields and stress fields. The Diexi-Jiaochang Zone is right located in the tensile area within the levorotatory activites of Songping Valley fault, while the Tuanjie Village – Yuerzhai Valley Zone and the Longchi Zone are in the compressed area. As in the shearing and twisting process, the tensile resistance of the rock and soil masses is weaker than their compression resistance, deformation and fracture are prone to occur, therefore the deformation and failure of the Diexi Jiaochang Zone (Zone A) were much more intense than those in the Tuanjie Village – Yuerzhai Valley Zone (Zone D) and the Longchi Zone (Zone C), which triggered large-scale rock falling and landslide.

In addition, the Longchi Zone located in the compressed area almost had no large-scale deformation and failure due to the difference in the slope structure and type (obsequent and falling home), the stress release during seismic facture and the action of energy dissipation and isolation of F8 fault, instead there were only local falls and slides from the top of the slope on deep overbruden layer. This formed a sharp contrast with Zone A where large-scale landslide and falling from the bedrocks along the inclined slope structure occurred in the Diexi Jiaochang Zone.

Though the Songping Valley Zone (Zone B) was under the control of the slope structure, the deformation and failure mainly occurred from the slope body on the left bank, but some of the large-scale falling and landslide were also mainly concentrated in the local stress tensile area nearby Jiaochang.

Therefore, there is obvious genetic relationship between the distribution characteristics of the slope deformation and failure and those of the local stress field caused by the Diexi earthquake occurred in 1933.

5. COUNTERMEASURES FOR PREVENTION AND CONTROL OF SLOPE DEFORMATION AND FAILURE IN DIFFERENT ZONES OF DIEXI SEISMIC AREA

The slope deformation and failure in the Diexi Seismic Area have typical distribution characteristics. The mechanism of deformation and failure varies between zones, and even within the same zone. Therefore, different zone or different mechanism of deformation shall take different prevention and control measures.

- Zone A mainly has large-scale rock falling and landslide, and its destabilization and failure are often related to cracks, active faults and stress fields. For instance, the near SN and EW directional earthquake rift, ground fissure and arc-shaped active rift have formed a rift network on the ground, and caused tension fracture and subsidence, rifts and ground fissures become the main control border of slope instability. Therefore, for disaster prevention in the X intensity area of Jiaochang zone, full considerations should be given to the distribution of quebradas and the extension characteristics of the unfavorable structural plane. Ground fissures shall be backfilled, tamped, leveled and drained timely, and real-time monitoring shall be conducted to prevent them from triggering large-scale rock landslide again. Meanwhile, appropriate engineering and regulating measures may be taken against slopes that may become destabilized, depending on their importance. Measures to be taken include support, anchoring, shotcreting, slope cutting, drainage and so on, so as to increase the frictional strength of the weaker plane and the sliding resistance of the slope.
- For Zone B, besides falls from the decomposed and decompressed zones and superficial consequent landslide, there is also such type of mechanism that the destabilization of the high and steep decomposed and decompressed zone can be transformed into debris flow. Therefore, for the falling, crag and dangerous rock produced in the decomposed and decompressed zone on top of the high and steep rock slope, considerations shall be given to their relation with man and buildings, and prevention and control measures shall be taken, or protective measures such as slope cutting, slope protection, clearing-up of crags, retaining at basal slope, etc.
- Zone C has little deformation and failure, and the overall stability is good, only small-scale fallings may occur from local and superficial areas. Both the water-containing deep overburden and shattered fault zone are not destabilized.
- The deformation and failure in Zone D are mostly dominated as falls and shear failures. The Diexi earthquake triggered rifts and ground fissures (probably liquefaction in addition to landslide movement), therefore for disaster prevention in this zone, consideration shall be given to the distribution of quebradas, and as in Zone A, the ground fissures shall be treated appropriately and subject to real-time monitoring. Appropriate engineering and regulating measures shall be taken against important slopes that may become destabilized. Measures shall include support, anchoring, shotcreting, drainage and so on, so as to increase the frictional strength of the weaker plane and the sliding resistance of the slope.

In conclusion, the slope instability and failure in high earthquake intensity areas are often related to the fissures, active faults and stress fields caused by the earthquake. Therefore, for disaster prevention, full consideration shall be given to the role of rift and fissure in controlling slope deformation and failure, in other words, to the role of endogenic geological process in controlling the superficial geological disasters. 'Diagnosis and treatment based on overall analysis of the potential disasters and finding out appropriate measures for such disasters', so as to prevent the disasters from occurring and to reduce the losses of life and property.

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