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Analysis of Damages Caused by Earthquakes to Traffic Facilities in Mountainous of West China

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Abstract: The paper lists the types of direct and indirect damages to roads, bridges, tunnels caused by the earthquake in mountainous areas in the west of China, and the reasons for damages are analysed. Due to the steep mountain terrain, poor geological conditions, the limit of the local economic development level, the lack of design for anti-seismic or an inadequate consideration of seismic level along with the relative low level of the construction technology, the damages from the earthquake are particularly severe in mountain areas.

Keywords: earthquake damage; traffic facilities; mountainous areas in west china; countermeasure

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Introduction

The May 12, 2008 Ms8.0 Wenchuan, Sichuan, China earthquake (hereinafter referred to as Wenchuan Earthquake) occurred within the Longmen Shan active fault zone[1]. According to statistics, roads were destroyed at the length of more than 22000 *km*. More than 2900 bridges were collapsed and 27 tunnels were damaged. Earthquake damage was so serious partly because the earthquake occurred in the mountainous areas and partly because of the limited anti-seismic ability of the traffic facilities.

1 The damage caused by the earthquake

This article mainly takes Wenchuan Earthquake (2008), Ludian Earthquake (2014) for example, listing the types of the earthquake damages to traffic facilities, many of which unique to the mountains.

1.1 The damage directly caused by the seismic

1.1.1 Roadbed and pavement damage

The main damage forms of road bed and pavement to road are overall fracture, dislocation and slip[2]. Road bed damage forms are road bed rupture and slip, the main damage forms of pavement are pavement cracking, cement concrete pavement surface buckling, etc. Serious damage of subgrade and pavement in Wenchuan Earthquake is shown in Fig. 1.

1.1.2 Bridge seismic damage

The Baihua Bridge is severely damaged in Wenchuan Earthquake, which mainly included the collapse of the global structure of the fifth continuous girder unit, damage to the substructure and superstructure of the Bridge. The Baihua Bridge collapsed in Wenchuan Earthquake is shown in Fig. 2.

1.1.3 Tunnel seismic damage

Tunnel seismic damage mainly happens when the tun-

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Fig. 1 Highway roadbed of severe earthquake damage

Fig. 2 The collapsed Baihua Bridge in Wenchuan Earthquake

nel portal are buried by land slip, collapse, tunnel portal crack, structure damage even collapse[3].

The earthquake caused great damages to the tunnel portals and lining, for example, the portal walls of the Tao Ping tunnel broke up which is on the road from Dujiangyan to Wen chuan.

Fig. 3 Breaking up of the portal walls of the Tao Ping tunnel

1.2 The damage of traffic facilities caused by the secondary disaster of earthquake

According to incomplete statistics, the earthquake directly caused nearly thousands of large - scale collapse. Land slips threatened the safety of the disaster areas people's lives and property[4]. Land slides are blocking roads, smashing up vehicles, and having serious damages to traffic facilities.

Wenchuan Earthquake triggered land slip, collapse, mud - rock flow amounted to more than 15000[5].

1.2.1 The damage caused by collapse

In Wenchuan Earthquake, the road from Dujiangyan to Wenchuan is indeed the "lifeline" of the rescue. Because the roads were so badly damaged that relief troops, personnel and medical supplies were postponed to enter the disaster - hit areas.

And then, the ongoing collapse after the earthquake caused damage of Bridges. On July 25, 2009, the bridge on national road 213 was smashed up completely by crumble, causing about 100 - meter bridge to collapse, which is shown in Fig. 4.

Fig. 4 The Chediguan Bridge smashed up by boulder

In Lushan Earthquake, roads also were cut off due to collapse.

1.2.2 The damage caused by land slip

The roads were badly damaged by land slips, relief troops, personnel and medical supplies were postponed to enter.

Road in the epicentreal area were buried by land slip after Ludian Earthquake, which is shown in Fig. 5.

1.2.3 The damage caused by mud avalanche

Two years after Wenchuan Earthquake, there were outbreak of stony mud avalanches in Dujiangyan (on Aug, 13th), and Yingxiu (on Aug, 14th), resulting in large - scale disasters[2]. The roads having been damaged by the debris flow is shown in Fig. 6.

Several years or even decades after Wenchuan Earth-

Fig. 5　Land slip plug road

Fig. 6　Road is hit by the debris flow after Wenchuan Earthquake

quake, stony mud avalanches are bringing great difficulties to the post – disaster reconstruction.

2　The cause analysis

The particularly severe damages from the earthquake are mainly results of such situations as the poor terrain and geological conditions in mountainous area, the limit of the local economic and social development level and the relative lack of design and construction technology level.

2.1　The damage caused by the earthquake directly

2.1.1　Roadbed and pavement seismic damage

Overall settlement of roadbed and pavement is one of the common damages in earthquake epicenters, and the main causes of this damage are as following:

(1) The seismic waves cause the liquefaction of the roadbed base, and form a large roadbed subsidence area. Typical sections are mainly located in the roadbed which is filled with sand or gravel in high water table area[6].

(2) Due to the uneven of the filling body or soil mechanical properties of the roadbed, the seismic waves cause uneven settlement of roadbed soil and result in overall subsidence of pavement and roadbed in some areas. The typical sections are mainly at abutment, culvert back, wall back fill embank*m*ent, vertical and horizontal cut and filled transition sections[6].

(3) The uplift and extrusion of roadbed and pavement are mainly taken place at the roads in the earthquake epicenter. The main reason is the deformation effect of the seismic waves to the pavement and roadbed. The roadbed and pavement raise overall, so the road forms wavy, alice arch shape and dislocation cracking by the deformation from extrusion and uplifting among themselves[6].

(4) Potholes and fragmentation of the pavement occur mostly on the mountain roads in the epicenter area, and main reason is the broken of the huge rocks′ falling from the upper slopes. The rocks fall by the seismic waves and punch potholes upon the road, and then result in a broken pavement. For example, a typical damage occurred in the provincial highway303, between Yingxiu to Dengsheng, large stones dropped down to the road and destroyed the pavement.

The conditions of overall collapse of roadbed sliding and whole fracture, dislocation and slip of roadbed pavement are the same, just to a greater extent. This disaster mainly appears in the side of roadbed, such as mountainous side line, riverside roadbed, etc, especially after the destruction of the roadbed retaining structure, roadbed collapse is easily to occur[6].

2.1.2　Bridge seismic damage

There are generally two reasons for beam falling: one is due to the abutment pier slip to the channel direction, when slide momentum is too large, the broken bridge pier leads to the fall to the ground; another is the destruction of the bearing beam, leading to the fall to the ground of beam[7].

Though construction of simply supported beam bridge is easy, but the earthquake resistant ability is poor, which is mentioned above as the Baihua Bridge.

Bridge pier is very high in the mountainous areas, so often it is easy to cause aggregate crushing, shear failure and damage due to a lack of stirrup reinforcement ratio or the piers using pebble as spine material[2].

Basically, the bridges that have been built did not consider the anti – seismic design, and there is no other anti – seismic measure except for the setting of shock stopper.

Construction defects, because of the age limit in the 1990s, there are no perfect building programs and professional team of design, construction and supervision. Some bridges have undue defects for the lack of quality control and mismanagement during the construction.

2.1.3 The tunnel seismic damage

In addition to seismic force, portal and fault movement caused by earthquake is external cause of the damage of tunnels. Generally speaking, the tunnel portal back slope destruction has greater influence on traffic facilities[2].

In Wenchuan Earthquake, tunnel body structures are also damaged, so the main reason is that there are many tunnels through the fault along with the change of the geological conditions[8].

In the Wenchuan earthquake, the intensity at epicenter is much larger than the fortification intensity of the original design for the tunnel lining structure. The slopes' collapse at the entrance of the tunnels is mainly because that the entrance slope is too steep and extremely high.

There are two main reasons for the lining cracking and broking: one reason is that there are no deformation and expansion joins at the connection areas of the lining constructions, and the adjacent silicon plates are basically rigid connected; and the other reason is that The lining and early supports as well as the early supports and rock are basically tight contacted, and there is no anti - shock processing technology.

Due to the quality problems of the construction, the lining and the behind of the surrounding rocks are empty and it is not dense, which causes the earthquake damage.

2.2 The damage caused by the secondary disaster

The following specific analysis is over the reasons under various secondary disasters of earthquakes.

2.2.1 The damage caused by collapse

The mountains in the western areas are high and steep, whose slope gradient is mostly greater than 55°, forming ideal terrain for collapsing[2]. Earthquake can lower the geotechnical strength, the structure and integrity of the slope. All kinds of structure surface of slope rocks mass strength are reduced, the stability of rock mass is greatly reduced too. The earthquake which is over the 7 - degree intensity in the mountainous areas will induce a large number of collapses.

Since the earthquake took place in the deep cut Longmenshan mountain and canyon area, especially in Beichuan - Yingxiu fault which is modern topography boundary fault dividing the high and low Longmenshan Mountain, the terrain elevation difference is extremely large. Under the joint action of strong ground shaking and surface rupture dislocation due to the high magnitude earthquake, large - area and large - scale collapse were taken place in Longmenshan Mountain area especially at the high seismic intensity zones.

2.2.2 The damage caused by land slip

Because of the local economic and social development level, a large number of mountainous areas roads are in high slope and at greater slope rate, so without a lot of slope protection engineering, it easily causes land slip[2].

Flat land, which is suitable for urban construction in mountains are scarce resources. Lots of slope of the mountain are cut and towns and roads are built over steep slope.

When the stability of natural slope is destroyed, it increases the probability of land slip[2].

The earthquake aftershocks have caused loose rock further appearing large - scale secondary disasters such as land slips. The damage of Wenchuan Earthquake is so large, shaking loose dirt and shattering rocks are "unprecedented", so is scale of the landslide in Mianyang consequently.

During the seismic wave propagation in the slope of the body, complex dynamic response process generates when encounters discontinuous interfaces, and forms "tensile stress effect" at the interface resulting in the pulling slope crack.

2.2.3 The damage caused by stony mud avalanche

Debris flow is often due to the loose deposits caused by the landslides and collapsed after the earthquake.

Mountainous terrain conditions are suitable for the formation of mud - rock flow. In earthquake, collapses and land slides produced a lot of loose solid materials.

Once encountered with storm rains, stony mud avalanche is bound to occur. Mountainous areas stony mud avalanche often starts from the first rainy season after the earthquake, and continues for more than 20 years.

After earthquake, collapse and land slip, especially large - scale collapse and land slip at intensive place, the more the solid source is, the greater the likelihood of a large - scale outbreak of mud avalanche there is.

3 Conclusion

The study of the reasons for damage of the traffic facilities will be conducive to taking targeted counter measures, promoting disaster prevention and mitigation career development[2].

Through listing the types of direct and indirect damage caused to the transportation infrastructure of earthquake, the analysis of its causes is made, and expounds the engineering countermeasures to reduce direct and indirect damages.

Due to the steep mountain terrain, poor geological conditions, the limit of the local economic development level, the lack of design for anti – seismic or an inadequate consideration of seismic level along with the relative low level of the construction technology, the damages from the earthquake are particularly severe in mountain areas.

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中国西部山区交通设施震害分析

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摘　要: 文章列举了中国西部山区地震对道路、桥梁和隧道造成直接破坏和地震次生灾害造成间接破坏的类型,分析了破坏的原因。山区地形陡峭,地质条件较差,地方经济水平有限,设计未考虑抗震或者抗震等级不足,施工技术水平相对欠缺是造成山区交通设施震害格外严重的原因。

关键词: 地震损坏;交通设施;中国西部的山区;对策