Lifeline System Earthquake Damage in Yushu, Qinghai Earthquake (M_L=7.1, 14th, April, 2010)

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SUMMARY:
A destructive earthquake with the magnitude of 7.1 invaded the Yushu, Qinghai province, in the north-western China at 5:39:57(Beijing time), 14th April, 2010; the epicentre located the Latitude 33.1° N, Longitude 96.7° E. This earthquake firstly struck the densely populated town in the high altitude and bitter cold zone in China. In this earthquake, the lifeline systems were severely damaged, these site investigation results of the transportation System, power system, telecommunication and water-supply were presented in this paper. Some special seismic Hazard and geology disasters such as freezing slope failure and fissure, warm settlement, were found to be the risk to the lifeline system. Strong earthquake motion in the freezing site and the relationship among fault and the Malfunction lifeline system was also studied in this paper.

Keywords: Yushu Earthquake, Lifeline System, Permafrost Areas, Active Fault

1. INTRODUCATION

At 7:49 AM (Beijing time), On April 14, 2010, a strong earthquake with the magnitude of 7.1. Struck the Yushu County, in Qinghai Province, Western China, and the epicentre locating the Latitude 33.1 ° N, Longitude 96.7 ° E is near the town of Gyêgu, which is the capital of both Yushu Tibetan Autonomous Prefecture and Yushu County. This earthquake took place along the Gangzi-yushu active fault(Figure.1), which is stretching from NW to SE, and inclined to NE with a 40° ~70° dipping angle, this fault is thought to be the north-western part of Xianshuihe Active Fault zone, which is one of the most active faults in mainland. The earthquake source depth is 14 km. Due to this earthquake, Not only many buildings were damaged, but also many geological disaster took place, including landslide, surface rupture, collapsing, mountains cracks or fissure, sand liquefaction etc. Because Yushu is high altitude and cold region, some special meteorological disaster attached this meizoseismcal area during this earthquake, like hail, perpetual snow and ice, freezing raining and thunder and lightning, etc. In the all over the earthquake-affected area, there were about 295 landslides and rock collapsing, and 268 of them were distributed near the epicentre and along this seismic fault, and about 32 km ground rupture had been found running through the Intensity ≥ Ⅵ area . Thousands of buildings were collapsed, damaged, or destroyed, leaving more than 100,000 residents homeless or dislocated. The death toll in this earthquake stands at 2698 and 270 missing, the direct economic losses is over 800 Billions Chinese Yuan (RMB about 115 billons US Dollars) [1-4].

In this earthquake, the main lifeline systems such as transportation system, electric-power system, and water-supply and telecommunication system were damaged and degrades or partly lost their functionality or malfuncation. Their eathquake damage was attributed to wave propagation, strong shaking, and geological disasters. In this paper, the above mention four types of lifeline performance in this earthquake were introduced based on site investigation. Some special earthquake damage characteristics and recovery problems of lifeline system were also listed herein.

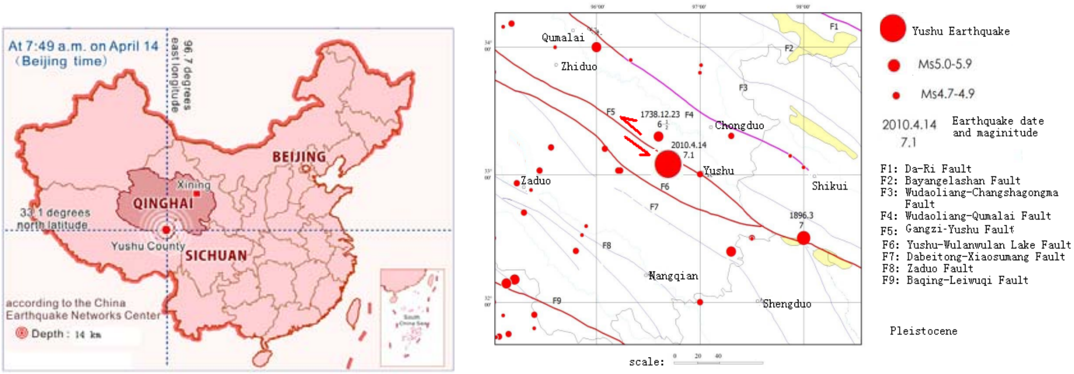

Figure.1 Yushu earthquake location and its tectonic system

2. LIFELINE EARTHQUAKE DAMAGE

During this earthquake, the typical earthquake damage related to transportation system, electric-power system, telecommunication system, and water-supply system were presented, including their physical damage, performance failure and their recovery.

2.1 Transportation System

In this meizoseismal area, there are only two main highways, named G214 and S308 respectively. During this earthquake, two highways had been damage in different damage degree, the typical earthquake damage included foundation failure, bridge and culvert damaged, etc. The highway foundation split and settlement were found in the length of 875km everywhere. About 87 landslides occurred in G214 and S308 in this earthquake (Figure.2). The ground rupture due to seismic fault was an important reason to interrupt transportation (Figure.3).

Figure 2. Interrupted road by landslide and collapsing

Figure 3. Damaged road by active fault

The bridges were damaged in different degrees were damaged in the affected area; most of bridges in Yushu were simply supported girder. Seven bridges in G214 and S318 were damaged from moderate to heavy damage. In Gyêgu town, the main seismic fault passed through one Girder Bridge, and made it diversely contra rotate and have snake motion in deck, separate between the deck and bridge approach (Figure.4). Damage seems to be due to a combination of ground surface rupture and strong ground shaking. Some typical bridge damage is shown in Figure 4(Figure 4).

a) Contra rotating and snake motion **b)** Bearing displacement and fractured seismic anchor

c) Fractured cap beam of abutment d) Baring separation

e) Beam displacement and fractured seismic anchor f) cone protection damaged

g) Bridge pier tilting h) sinistrorse displacement of guardrail

i) Deck split or crack (average displacement 40cm) j) guardrail damage

Figure 4. Bridge in Gyêgu town damaged due to wave propagation near the active fault

Because Yushu was still in late-winter, the roads were covered by snow and ice, sometimes; the temporary rescuing highway had to been stopped due to snow and ice covering the highway.

2.2 Electric-power System

In this meizoseismal area, the electric-power system was immediately damaged after earthquake. Until 16^{th}, April 2010, the electric-power partly recovered to use temporary generators. Because power supply was based on small waterpower factories, the electric-power lost their function due to the damage of waterpower factories (Figure.5)


a) The waterpower factory damage b) broken pole

c) Transformer displacement d) snapped electric line

Figure 5. Electric power damaged due to strong ground motion

2.3 Water-supply System

Around Gyêgu town, the water-supply system was damaged due to the strong ground motion, active fault and landslide or debris. Because the water-supply system in Gyêgu town consisted of concrete pipeline, ditch and canal on the ground, they are vulnerable to strong ground motion, landslides or debris (Figure 6). The emergency water-supply was set up by temporary wells and plastic pipeline until April 17th 2010.

a) Cannel buried by debris or landslide b) damaged pipeline near the active fault

c) Foundation failure of ditch due to landslide d)

Figure 6. Water-supply damaged due to landslide and active fault

2.4 Telecommunication System

In the epiceter, Gyêgu town, the telecommunication system was interrupted after earthquake due to equipment damage, building damage and shortage of electric-power system. China Telecom, China Unicom and China Mobile operate many cell sites in the earthquake disaster area. Fiber optic cable is used extensively connecting cell sites and switching centres. Normal network call volume typically increases immediately after a major disaster that creates the perception of telecommunication failure. Coupled with building and equipment failure was the long duration of power loss. The batteries in the cell sites only lasted two to three hours. Cellular service disruption in some areas within the earthquake impacted region lasted more than 30 days.

Figure 7. Damaged building and emergency telecommunication based on satellite communications

3. LIFELINE EARTHQUAKE DAMAGE CHARACTERISTICS AND PERFORMANCE

The field investigation had been proven that the damage of lifeline systems in Yushu earthquake was mainly contributed to the near-fault strong ground motion, active fault, trigged geotechnical disasters and interaction among lifeline systems.

3.1 Near-fault Strong Ground Motion

Based on the site investigation, typical damage characteristics to bridge were deck split, sliding between bearing and girder, shear key failure, damage of expansion joint, pounding of adjacent girders, and tilting and cracking of abutments. Almost all of the medium and severely damaged were near fault, where there were strong ground motion recorders. It is obvious that the nearer the bridge located to the fault, the severer the bridge was damaged. This damage phenomenon is particularly obvious within 10 m in both side of fault. There were same damaged phenomena in all of the damaged bridges near fault: 1) the girder rotated in horizon, so, the protection to anti-falling of deck was damaged. The rotation direction was anticlockwise rotation, in accordance with the fault rupture direction ((Fig.7, right-lateral strike fault). 2) The girder took place the snake-deformation in horizontal direction and waving of deck in vertical direction, which meant wave propagation effect. 3) Obvious pressure deformation in axial direction of these bridges, which meant pulse-like motion that, exposed the structure to high input energy.

3. 2 Trigged Geotechnical Disaster

A great number of Geotechnical disasters were trigged in this earthquake. According to the report of China Earthquake Administration (CEA), there were about 295 landslides and a large number of ground fissures in this earthquake affected area. The landslide was formatted partly because of frozen soil heat-thaw. The transportation system, water-electric power and water-supply were interrupted by foundation settlement, landslide, debris and collapsed rock and soil (Figure 8).

a) Highway foundation settlement and crack

b) Covered highway by landslide

Figure 8. Damaged highway due to geotechnical disasters

Equipments and apparatuses belonging to lifeline systems were buried and damaged due to these trigged geotechnical disasters too. During the procedure of rescuing and post-earthquake rehabilitation, the transportation system was interrupted by landslides, debris, and collapsing rock and soil due to the frozen soil settlement. It is these geotechnical disasters that made the emergency response difficult. Until two months after earthquake, the frequency of landslide and debris was still higher than that of earthquake invading ago. A great number of geotechnical disasters, particular landslide, debris and collapsed rock and soil were the most important factor to bring such a terrible destructive disaster. At present, details slope failure mechanism related frozen soil and risk zonation were still going on along the main fault zone.

3. 3 Interaction among Lifeline Systems

Another outstanding damage characteristic of lifeline systems in this earthquake was interactions among lifeline systems. For example, malfunction of water-supply and telecommunication system in out of Gyêgu town (XI) was mainly induced by damage and failure of power system. Most of the damaged element in water-supply system were repaired after 24 hours, but the water-supply completely lost its performance for 49 hours due to shortage of electric-supply, and telecommunication system only recovered its 50 percent of full function after 5 days although most of facilities in this system were intact, its backup system of power system worked only 5 hours every day before the power system recovery. Because of transportation interruption, through the donated rescuing materials from all over the China had been organized to be carried in Yushu airport , the equipment and apparatus, energy and rescuing team could not be distributed to the demanders in time due to the connectivity interruption of highway from airport to earthquake affected area, particular in Gyêgu town. So, one emergency temporary road had to be built up. Although carefully maintenance, but this road was usually damaged by unexpected snowing and icing.

4. CONCLUSIONS

In this earthquake, it has been proven again that the geotechnical disasters including these earthquake faults are the biggest hazard and risk to lifeline systems. So, the seismic design for lifeline systems can't focus on only improving anti-seismic abilities of their components under strong seismic wave propagation, but also reliable selection of building environments. Due to interaction among lifeline systems, network conception and its optimization should be emphasized on design of the lifeline systems.

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