ANALYSIS OF TYPICAL SEISMIC DAMAGES OF HIGHWAYS IN 2008 SICHUAN EARTHQUAKE

by Shuming FANG [**] and Hiroshi WAKABAYASHI[***]

1. Introduction

The 2008 Sichuan earthquake that measured at 8.0 Ms and 7.9 Mw occurred at 14:28 on May 12, 2008 in Sichuan province of China and occurred along the Longmenshan fault, a thrust structure along the border of the Indo-Australian Plate and Eurasian Plate. Seismic activities concentrated on its mid-fracture (known as Yingxiu-Beichuan fracture). The rupture lasted close to 120 sec, with the majority of energy released in the first 80 sec, and propagated at an average speed of 3.1 kilometers per second 49° toward north east 300km starting from Wenchuan. It is also known as the Wenchuan earthquake after the location of the earthquake's epicenter, Wenchuan County. The epicenter was 80 kilometers west-northwest of Chengdu, the capital of Sichuan, with a focal depth of 19 kilometers. Official figures state that 69,197 are confirmed dead, including 68,636 in Sichuan province, and 374,176 injured, with 18,222 listed as missing as of July 21th.

Strong aftershocks, some exceeding magnitude 6, continued to hit the area even months after the main quake, causing new casualties and damage. Between 64 and 104 major aftershocks, ranging in magnitude from 4.0 to 6.1, were recorded within 72 hours of the main quake. According to Chinese official counts, "by 12:00 CST, November 6, 2008 there had been 42,719 total aftershocks, of which 246 ranged from 4.0 MS to 4.9 MS, 34 from 5.0 MS to 5.9 MS, and 8 from 6.0 Ms to 6.4 MS; the strongest aftershock measured 6.4 MS." The latest aftershock exceeding M6 occurred on August 5, 2008.

The infrastructure of those roads leading to the quake-hit regions was destroyed seriously and most of roads were broken. So it was difficult to send relief and rescue as soon as possible. In this earthquake, the traffic facilities of 1204 small towns where belong to the fifty worst-hit areas were damaged seriously including 21 highways, 15 national roads or provincial roads and 2795 country roads, and the total of mileage of the damaged roads was about 28000km including 200km highway, 3849km national roads or provincial roads and 23800km country roads. In addition, most of the bridges and the tunnels located in the damaged roads were damaged. The total loss on traffic facilities amounted to 583 million Yuan. The detailed situation of damaged highways in the quake-hit regions was shown as table 1.

---

*Keywords: 2008 Sichuan earthquake, damaged highway, quake-hit regions

**Student Member of JSCE, Doctor, Student, Faculty of Urban Science, Meijo University
(Room 108 of Sebunsuhebun kani House, 4063banchi, Kani, Gifu, Japan, TEL080-4215-5068)

***Member of JSCE, Doctor, Professor, Faculty of Urban Science, Meijo University

Table 1: The detailed situation of damaged highways in the quake-hit regions

The name of Highway	Mileage	The detailed situation
G213 Highway from Dujiangyan to Yingxiu	39	The landslides, slungshots and fissures because of the horizontal dislocation and surface deformation caused by Earthquake existed in this road nearly 30KM. The Baihua bridge was broken.
G213 Highway from Yingxiu to Wenchuan	50	Retainingwall collapsed, and 90% of this road was buried by landslides and landslips.
G317 Highway of Yaan-Baoxing-Xiaojin-Maerkang-Wenchuan	560	20 bridges had crevices, 3 tunnels were damaged; the principal damages such as the collapsed overhanging rocks and the dropped stones primarily concentrated in the 100KM distance from Guergou town to Wenchuan.
The provincial road S303 from Yingxiu to Dawei	161	The 44KM distance from Yingxiu to Wolong was buried by landslides and mud-rock flows.
The country road from Shoujiang to Shanjiang in Wenchuan country	20	Landslides and slungshots occurred in this road, the quake lake occurred because of overhanging rocks of in Chenjiangshan
The provincial road S105 from Mianyang to Beichuang including An country	60	The damaged Anzhou bridge took a speed limit, and many landslides and slungshots appeared in the 500M away from Leigu town and 2500M away from Beichuan city in this road. The roadbed deformed seriously.
The provincial road S105 from Guangyuan to Qingchuan	71	50 roadbeds were dangerous because of landslides, landslips and crevices, 17 bridges were in danger.
The ShifangGuangqing provincial road	28	There were Landslides near the Lancaiwan, a small bridge collapsed.
The highway from Dujiangyan to Wenchuan	26	10km roadbed deformed vertically. The surface of steel reinforced concrete road was broken off vertically. The facilities of seismic prevention of bridge were damaged and the Miaoziping bridge was dropped. The Dongjiashan tunnel and Longxi tunnel didn't thread together, and the Longdongzi tunnel was dislocated and there were many rolling stones in the mouth of this tunnel, the right export of this tunnel was sealed off.

2. The forms and features of damage of the highway in 2008 Sichuan earthquake

(1) The damage forms of the highway in 2008 Sichuan earthquake

1) Landslide: A large number of cubic meters of earth and stone slipped along structural surface of layer of rock because of the powerful seismic forces and a highway was buried or dislocated such as Figure 1.

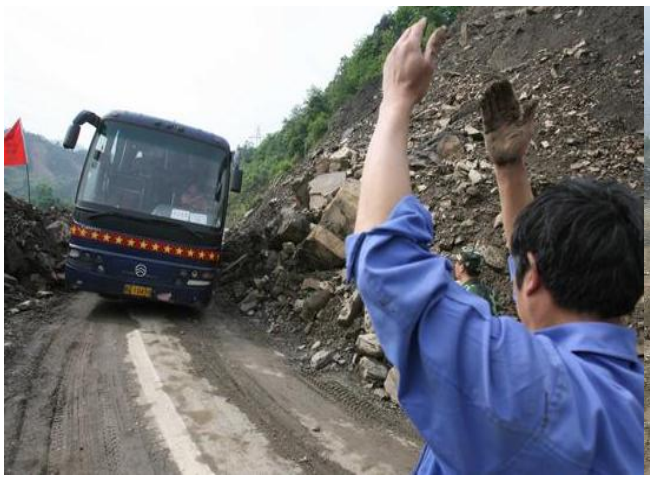

Figure 1: Landslide of the highway G213

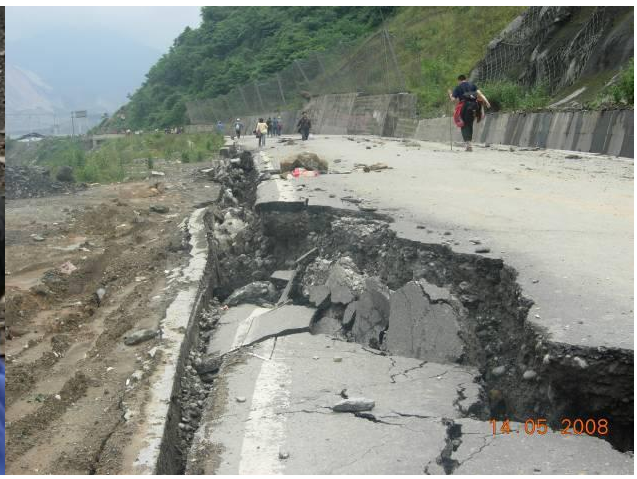

Figure 2: Collapsing of road surface of the highway G213

2) Collapsing of road surface: When the earthquake happened, the roadbeds collapsed easily after the retaining structure of roadbeds was destroyed such as Figure 2.

3) Landslip: When the earthquake happened, the rocks and soils on the steep declivities avalanched from mountain in gravity and seismic forces suddenly, then tumbled and piled up on the roadside, and smashed up and buried the highways.

4)Mud-rock flow: A mass of incompact deposit produced by this earthquake, the mud-rock flow came into being along the ditches on mountains because of the steep terrain conditions and the mixture between the rain and the deposit of rocks and soils. And the tunnels were blocked and the roads were flooded by the mud-rock flow and interrupted the traffic system in quake-hit regions such as Figure 3.

5) Barrier lake: Barrier Lake is the secondary disasters caused by earthquake. The upstream of rivers formed lakes when the rivers were blocked up by the landslide, deposit of rocks and soils and the mud-rock flow in stream valley zone. The barrier lake located in Tang jia shan canyon in 2008 Sichuan earthquake was very dangerous such as Figure 4.

Figure 3: The mud-rock flow in Wen chuan

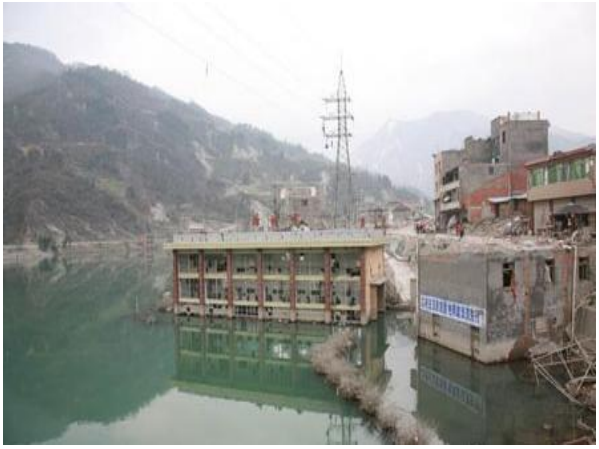

Figure 4: The barrier lake located in Tang jia shan canyon

6) Surface rupture: Surface rupture was formed by the dislocation of a mass of rock-soil because of a strong earthquake, it was relevant to the earthquake fault, and could be considered as the extension from the earthquake faults to the earth's surface in the fault displacement.

7) Bridge collapsing. There were many bridges collapsing in 2008 Sichuan Earthquake. The collapsed Baihua bridge in the G213 Highway was shown as Figure 5.

Figure 5: the collapsed Baihua Bridge in the highway G213

(2) The damage features of the highway in 2008 Sichuan earthquake

The 2008 Sichuan Earthquake damaged the traffic facilities seriously especially the highway. And the damage features of the highway was shown as fellow.

1) The range of the quake-hit area was very wide. The highways and provincial roads and country rods located in 20 cities and 150 countries of Sichuan province were damaged in various degrees. The traffic facilities of the worst-hit areas that included 39 countries such as Aba city and Mianyang country were damaged seriously. Those country roads leading to the worst-hit areas including Wenchuan country, Maoxian country, Beichuan country and Qingchuan country were interrupted completely for a time. There were 21 highways, 15 national roads or provincial roads and 2795 country roads to be damaged, and the total of mileage of the damaged roads was about 28000km including 200km highway, 3849km national roads or provincial roads and 23800km country roads. About 670 bridges with 45323 meters and 24 tunnels with 20417meters locating in those roads were damaged, and about 395 passenger stations were damaged.

2) The damage was great. Because this earthquake happened in a mountainous area, it was easy to cause the geological disasters including the landslide and the collapse and the mud-rock flow which could bring serious damage to traffic facilities such as roads, roadbeds, bridges, tunnels and retaining walls. Many roads built after many years of hard work were destroyed in a moment. The direct economic loss of transport infrastructure in Sichuan province exceeded 580 billion Yuan according to incomplete statistics.

3) Aftershocks continued for a long time. There had been 42,719 total aftershocks of which 246 ranged from 4.0 MS to 4.9 MS, 34 from 5.0 MS to 5.9 MS, and 8 from 6.0 Ms to 6.4 MS until November 6, 2008 according to

Chinese official counts.

4) It was difficult to rush to repair the broken roads. There were 3 important roads could not be used after 3 months including the Highway G213 from Yingxiu to Wenchuan, the provincial road S303 from Yingxiu to Gengda and the provincial road S302 from Mao country to Liegu town of Beichuan country.

5) It was difficult to make sure to open to traffic all the time. The traffic facilities would be damaged again by the secondary disasters such as landslide, collapse and mud-rock flow although those facilities had been built not long ago because of the aftershocks and the geological condition of the quake-hit regions .

3. The evaluation for the damage of roads in the quake-hit regions

There were two stages for the determination of traffic systems after earthquake, the first stage was to rush to repair and make sure the key roads leading to the worst-hit areas unblocked from May 12th to May 27th. The second stage was to rebuild the broken roads and damaged road of the quake-hit regions .

The grade of evaluation for the damage of roads can be divided into four grads such A, B, C and D according to the damage degree of the roads in the quake-hit regions :

A —— the ordinary vehicles can travel through these roads freely;

B —— the special vehicles that used for rushing to deal with an emergency can travel through these roads under some conditions;

C —— the special vehicles that used for rushing to deal with an emergency can only travel through these roads after strengthening or repairing these damaged roads;

D —— even the special vehicles that used for rushing to deal with an emergency can't travel through these roads because these roads couldn't be repaired for a short time.

Most of the grade of evaluation for the damage of roads in the quake-hit regions of 2008 Sichuan earthquake is C or D especially epicenter Yingxiu town.

The difference among the features of all kinds of earthquake disasters is great, so the situation of the damaged roads caused by earthquake is not similar. The degree of the damage of roads can be reflected easily and directly by using the degree of density of infection and the difficulty level of repairing the damaged roads. We would like to use the number from 1 to 10 to detect the degree of density of infection, the number 10 which stands for the greatest degree of density of infection means that the roads can't be repaired until a long time, and the number 1 means that the damaged roads can be rebuilt as soon as possible. Then density of infection of traffic systems in 2008 Sichuan earthquake relating to highways, bridges and tunnels was shown as Table 2 in all kinds of earthquake.

Table 2: The density of infection of highway caused by earthquake

Type of damage	subsidence deformation	Crevice	the earth surface upheaval and extrusion	Retaining wall damage
Density of infection	1~5	1～5	1～5	2～6
Type of damage	Landslide	Mud-rock flow	Collapse	Barrier lake
Density of infection	4～10	2～6	2～8	4～10
Type of damage	Water hazards	Bridge collapse	Tunnel block	

Density of infection	2～8	8～10	8～10	

4. Conclusion

The damage to the highway in Sichuan earthquake was serious because the seismic intensity of the epicenter in Sichuan earthquake beyond the standard of the seismic intensity for protecting the highway in China. The Chinese standard of the seismic intensity for protecting the highway should be improved especially for those roads as lifelines. And I also should study the strategy or methods for improving the disaster-relief ability in great depth.

References

1) TANG Yongjian, ZHUANG Weilin, JI Suiwang: Emergency investigation and getting through national and provincial highways in Sichuan Province after “5.12”Wenchuan 8.0 earthquake[M]. Beijing：China Communications Press, 2008.

2) Highway Planning, Survey, Design and Research Institute, Sichuan Provincial Communications Department. Conclusion of detecting and evaluating of national and provincial highways in Sichuan Province after “5.12” Wenchuan earthquake[R]. Chengdu：Sichuan Provincial Communications Department, 2008.

3) YUAN Yifan: Loss assessment of Wenchuan 8.0 earthquake[J]. Earthquake Engineering and Engineering Vibration, 2008, 30(5)：10−19.

4) XIE Heping, DENG Jianhui, TAI Jiajia: Wenchuan large earthquake and post-earthquake reconstruction-related geotechnical problems[J]. Chinese Journal of Rock Mechanics and Engineering, 2008, 27(9)：1781−1791.

5) http://www.sichuan.gov.cn/hdjl/zxftspzb/kzjz_sjtt/ftzy/200806/t20080629_293118.shtml[OL]. 2008.