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THE EARTHQUAKE DAMAGE CHARACTERISTICS OF LIFELINE SYSTEM IN JIASHI EARTHQUAKE (21 FEBRUARY, 2003)

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SUMMY

At 10:03 in the morning of 21 February, 2003, an earthquake (M_L = 6.8) took place in Jiashi, Xinjiang Uygur Autonomous Region, which locates in north-western china. As a rough estimation, the earthquake led to 268 deaths, 4000 injured, 70,000 building collapse and 77677 building in danger, out of them 103 schools, 900 class rooms collapsed, 16 township health clinics destroyed. The direct loss is 1.3 billion RMB. The lifeline systems in urban and suburban area were severely damaged. The paper presents the earthquake damage characteristic of electric network, water-supply, telecom, traffic network. After the strong shock and 3000 aftershocks, most of water-supply systems were damaged, including pipeline rupture, 8 Dams craze, and power-supply malfunction, etc. the electric supply is interrupted because there were 59 transformers, most of high-voltage and 220 voltage electric-lines near the epicenter, some of poles, and most of substations in suburban to be damaged. With regards to traffic systems, the damage was also serve, the two main highway, No.312 and No.46 national, 411 km village road and 9 bridges and culverts were damage, including landslide block and foundation failure. The telecom was damage because the electric was broken off; some key establishment and equipment were damaged. According to the survey, some damage characteristics of these lifeline systems are analyzed, some significative conclusion is obtained.

Key word: Lifeline Systems, Earthquake Damage Characteristic, Jiashi Earthquake

INTRODUCTION

A strong earthquake (M_L = 6.8) took place in Jiashi, Xinjiang Uygur Autonomous Region at 10:03 in the morning of 21 February, 2003,, which locates in north-western china. The earthquake source locates latitude 39°30´ north and longitude 77°12´ east. Its depth is 25.2 km in the earth; the intensity in the epicenter is , and its area is about 540 km^2. Six counties, where there is an area of 21498 km^2, have suffered severe earthquake damage, 510,000 people affected, out of whom 100,000 were seriously affected., the toll is 268, a total of 4000 people were injured, 2058 seriously. 38259 livestock are killed; seven villages were razed to the ground. The total direct loss is over 1.3 billion RMB.

The Jiashi locates the southern edge of the Tianshan Range and the north-eastern edge of the Tarim Basin. The hypsography in north-west is higher that in the east-south, with a natural gradient of 1/1000. The seismic zone of Jiashi lies to the inter-join zone of the Tianshan folds, Bomier structural arcs and Tarim Basin. The zone is also the joint of

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India plate and Euro-Asian continental plate, The Indian Plate continuously moves northward at a rate of 4.5 cm per year relative to the Eurasian Plate generating massive mountain ranges including the Himalaya and causing the uplift of the Tibetan Plateau. These stresses are transmitted to the north, through the rigid and undeforming Tarim Basin, where they generate the Tianshan Range and numerous earthquakes like this recent event. Several nearby mapped faults have orientations similar to the thrust fault that the earthquake occurred on. There are many earthquakes in this area every year. In 1902, an earthquake with the magnitude of 8.25 occured in Atushi, and another earthquake with the magnitude of 6.9 took place in the same site. According to the result of earthquake explore, the thickness of the earth's crust have a great change, from the 50km to 70km, in a limited distance, there is a low-velocity zone in the Jiashi earthquake zone. There are 3 big faults, the regional E-W-trending active marginal faults surrounding the Tarim Basin control the distribution of marginal seismic zones. The strong earthquakes are most likely to occur where the regional E-W trending faults meet the minor NS-NNW, NW and NE-trending faults as exampled by the Jiashi swarm. Although there is little possibility for large earthquake to take place between epicentral areas of the Jiashi earthquake swarm in the near future, occurrences of earthquakes with magnitude between 6 and 7 can not be precluded in the east and south adjoining regions in recent years. The geological environment (historic epicenter and regional seismic fault) is shown in the Fig.1.

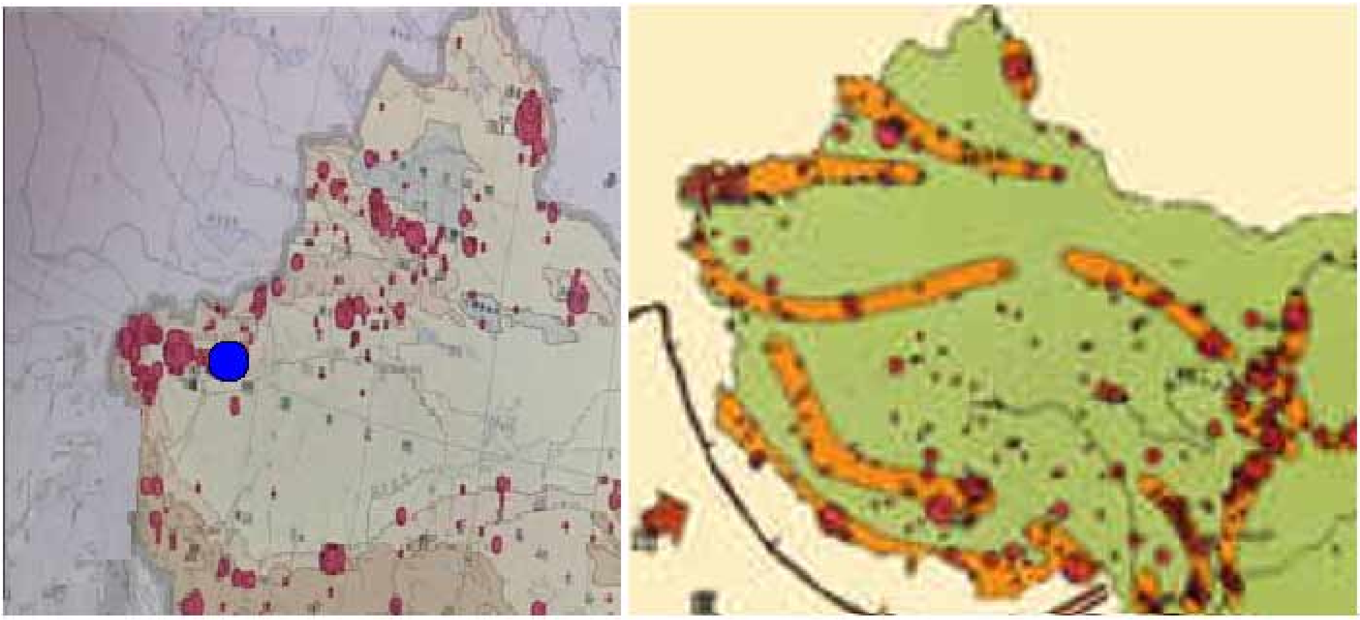


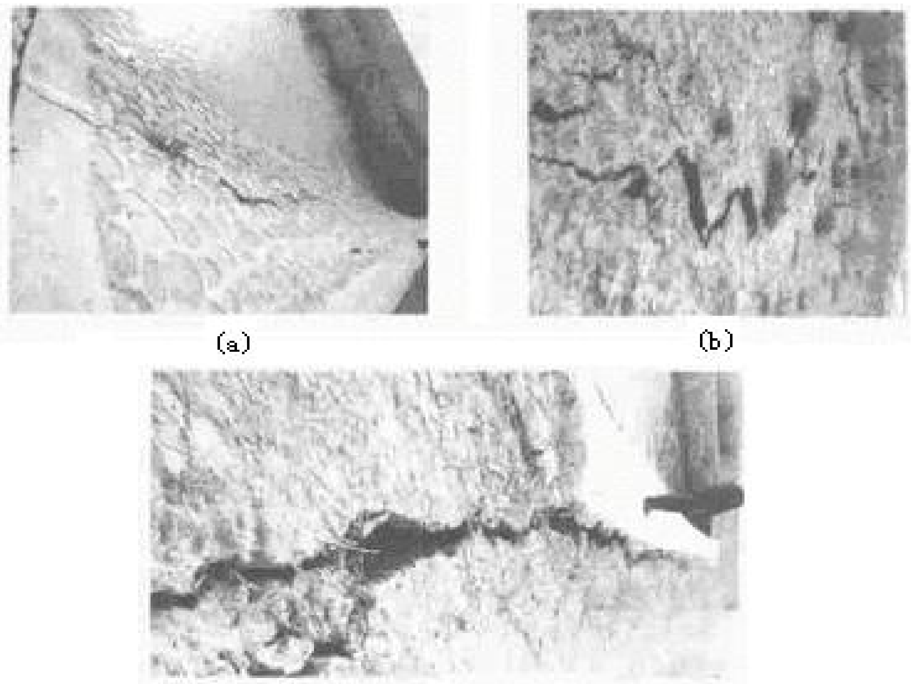
Fig.1 the distribution historic epicenter (Left) and regional seismic fault (right), the blue circle is the location of this epicenter.

THE EARTHQUAKE DAMAGE OF LIFELINE SYSTEM

2.1 Water-supply system

In the seismic zone, the reservoirs suffer the most severe earthquake damage in the water-supply network system. Almost all of reservoirs have been damaged; the typical damages are the split of dams, slope failure, strobe deformation and split, tube well damage, and pump room collapse and facilities damage. Particularly, there is severe seepage of the soil dam in Rongan reservoirs which was built in 1959, a longitudinal crack with the maximum width of 10mm stretches over several hundreds meters. Another soil dam in Molong reservoirs in Bacun County also suffer a severe damage, in this dam, the maximum splitting width is 10cm, a longitudinal crack with the length of 300 meter occurred, and a landslide is induced, with the length of 140 meter (Fig. 2). 1/4 of the Xiaohaizi Dam with the total length of 2000 m ruptured and seepage in 400 places took place. In the evening at 3rd, March, a 30 m length of dam occurred landslide and collapse.

The other water-supply elements suffer damage in different degree. Two water towers collapsed (Fig. 3), and five tower crack, out of them 3 severe. Most of wells and some of pipelines are severely damaged in the zone of and . The fault ratio of pipeline is 2.92 place/ km in and , the total length is 258 km, several villages were drowning because of the crack of these pipelines. The crack of these pipelines was induced by the surface fracture and un-even soil substance because of liquefaction. The water from these pipelines exacerbated the potentials of the sand liquefaction in return. The well and other facilities were mainly damage by the building collapse and strong surface motion. Some intact facilities can't function due to the interruption of the power-supply and other related equipment of the entire water-transmit network. The length of malfunction of power line which supplies the power for water-transmit system is 4km in Ⅸ and Ⅷ, it led to the halt of the water-supply in these area for one day.



(a) (b)

(c)

Fig.2 the typical crack of the soil dam [3]

（a: crack of the channels of water output; b: crack of dam body; c: split of the channels of water output）

Fig.3 the collapsed tower

2.2 traffic network system

The traffic systems had suffered a severe damage in and . In Bachu County, the earthquake damage in the X602 provincial highway was severe, the splitting road surface covered over 10,000 m^2 (Fig.4) ,and the total length was 2km. a 1500m^2 road foundation slope failure took place at the X602-K6. The fault water transmit pipeline at the point of X602-K6+700 inundated the road surface for 1200m. In Jiashi Country, one 10-meter-high and one 8-meter-high arch bridge damaged, and one 10-meter-high slab bridge damaged. One 2-meter-high culvert collapsed. The split and sink of the road surface is seen everywhere. There are many kinds of highway facilities to be damaged.

Fig.4 the split and sink of the highway surface

Fig.5 the split of bridge [3]

2.3 power-supply network system

The damage of power-supply system mainly focused on the tilt and fault of the wire pole, burn of transformer (Fig.5), damage of capacitor, ammeter and switch, and the collapsed building. In the earthquake area, over 3,000 wire pole tilted and ruptured, the ratio of damage is 20 %. 48 transformers with different voltage patterns were burned. 1057 ammeters 16% building related to the power-supply system were damaged in a different degree.

Fig.6 the tilt of the wire pole and the fault of the powerline (liquefaction)

2.4 telecommunication network system

The telecommunication is not advanced here, so, it's' damage was limited. Most of damages took place in the urban area, the earthquake damage put up the tilt of the telecom pole, and the fault of cable which were induced by the collapsed building.

The other lifeline systems, such as sewage and disposal system, gas-supply system, had hardly been damaged. There are three factors to contribute to this, (1) the earthquake affected area is countryside where their number is limited and had been built in a little area; (2) most of these systems were recently built.

ASSESSMENT OF SEISMIC LOSSES OF THE LIFELINE SYSTEM

Economic losses usually comprise direct economic losses and indirect losses. Due to the extreme complexity of estimating indirect economic losses, only direct losses are taken into consideration herein.

The direct economic losses include the repairing cost for damaged buildings and facilities and cost of the indoor properties damaged during earthquake. Following formula is applied in this system,

$$L(I)=\sum_{j}\sum_{s}b_s(j)B_s(j)+\sum_{j}\sum_{s}Q_s(j)W_s(j)+\alpha NF(t) \quad (1)$$

where *L(I)* denotes the total economic losses for an area affected by an earthquake with intensity *I*; $b_S(j)$ is the losses ratio of the buildings of category *s* (as well as equipment and facilities) damaged at *j*-th level; $B_S(j)$ is defined as the total cost for the buildings of *s* category damaged at *j*-th level; $Q_S(j)$ as ratio of the losses of the equipment, facilities and other indoor properties damaged at *j*-th level in buildings of category *s* to their total cost $W_S(j)$; *N* is defined as the cost for normal daily production; α ,the production reducing factor and *F(t)*, production recovering function, which could be approximately estimated. For example, in case it takes T days to recover the production to full run, the losses from production can be approximately estimated as $\frac{1}{2}aNT$.

According to this formulation, the losses of lifeline system in the whole earthquake area were calculated, the result is shown in table one (Table 1).

Table 1. The direct economic losses of the lifeline system (unit: ten thousand RMB)

Pattern / Add.	Water-supply	Power-supply	Traffic system	telecomm	total
Bachu County	5328.36	503	39	10.60	5880.96
Jiashi County	410	15.80	10		435.80
Maigaiti County	50		10		60
Yuepu lake County	250	20.00	10		280
Atushi County	30				30
Nongshan	1000	20.00	18		1038
total	7068.36	558.80	87	10.60	7724.76

THE DAMAGE MECHANISM OF LIFELINE SYSTEMS

Most of infrastructures and buildings in Jiashi Country are not designed and built in accordance with the China Aseismic Code. According to the site survey, although these infrastructures and buildings are designed and built

Fig. 7 the surface fracture and liquefaction without the application of Asiemic Code is one of the important factors, the damages of lifeline systems can mostly be due to two factors, one is the liquefaction of the sand; the other is the surface fracture.

In Bachu County, the sand liquefaction could be seen everywhere in the Ⅸ and Ⅷ, the maximum diameter of the hole of the sand eruption is 3 meter. The surface fracture can also be seen in the seriously damage area (Fig.7), the maximum crack width is over one and half meter in Bachu. The pipelines of water-supply were damage by the surface fracture and un-even soil-layer subsiding induced by the sand liquefaction.

CONCLUSIONS

The earthquake damage characteristics of lifeline system have ulteriorly proved that it is necessary that the application of the aseismic code is the important to improve the aseismic abilities of the infrastructures and buildings. Some new techniques should be studied to resist the sand liquefaction and surface fracture. Some practical aseismic design methods should be supplied to the poor area. The sand liquefaction where there is a large distribution of dry and loosed sands should be attached importance to. The interactions among lifeline systems could be seen during this earthquake. Fox example, one highway foundation subsided and the pavement splited because of the sand liquefaction where the pipeline of water-supply were broken and the water inundated in the dry sand layers; the telecommunication interrupted because of the power-supply failure. The power systems were also affected by the inundation induced by the break of the water-supply pipeline (Fig.6).

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