DAMAGE TO LIFELINE SYSTEMS AND OTHER URBAN VITAL FACILITIES FROM THE TANGSHAN, CHINA EARTHQUAKE OF JULY 28, 1976

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SUMMARY

This paper is intended to describe the seismic damage to water supply, sewerage and city gas systems and other urban vital facilities, such as airport, harbors, medical, electric power and telecommunication in Tangshan and Tianjin city as well as structural damage to highway and railway bridges, and the lessons from this earthquake.

INTRODUCTION

The Tangshan earthquake of July 28, 1976 with 7.8 of magnitude brought great disasters to Tangshan city with a population of about six hundred thousand and many disasters to Tianjin and Beijing. It took the lives of 242,000 people, caused 164,000 injuries. The epicenter was in Tangshan down town area. The focal depth was 12-16 km, and the peak intensity was grade XI by the New China Intensity Scale. Isoseismals of the main shock were shown in Fig. 1, together with those of a large aftershock with 7.1 of magnitude and several areas of intensity anomaly.

The peak acceleration recorded on the ground level and on buildings is shown in Table 1, which shows a rather strong vertical component, with max. vertical acceleration more than 50% of that of the horizontal even at epicenter distance about 400 km. Historically, the Tangshan region haven't been attacked by the earthquake of large magnitude, so the VI grade is determined for Basic Intensity and the buildings were not required to be designed to resist earthquake.

WATER SUPPLY SYSTEM

The underground water are used for domestic and industrial purposes in Tangshan urban area and Hangu, Tanggu districts of Tianjin, however, in Tianjin urban area, the water are supplied from the river. The most of the water pipes were made of cast iron. Periodical water supply-cut caused by damages of pipelines, wells and collapse of buildings was found after main shock. In Tangshan city, the potable water supply was resummed to whole city on August 10, and basically recovered in late September. While in Tianjin city, it was restored at the end of August.

The summaries of damages to water supply distribution cast iron pipes with diameters equal to or greater than 75 mm in Tangshan, Tianjin urban area and Tanggu district are shown in Table 2. Fig. 2 shows the relation between the damage ratio of the distribution pipes and their diameters in Tianjin urban area. The damage ratio is defined as the number of failures per unit length (km) of water pipes. The characteristic of the damages may be summarized as follows:

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The damage ratio of pipes is decreased with the increase in diameters. There are three kinds of failure for pipeline, i.e. the damage of joints, the break of pipe and the failure of its fittings, such as bends, T and cross sleeves and valves. For the pipes with diameter of 75-300 mm, there is minor difference between the damage ratio of each kinds of failure. While for the pipes with larger diameter, the joint has the highest damage ratio, but the breaks of pipes are few.

The damage ratio is closely related to the surrounding soil condition. The pipes that suffered from serious failure are situated, without exception, on loose sandy grounds, on river-sides, on trench-sides, on pit-sides, and on other loose soft or on severely non-uniform grounds. For example, a cast iron pipeline with length of 200 m and diameter of 400 mm near Douhe in Tangshan had 10 breaks.

The damage ratio of fittings for pipes reached as high as 0.82. The joints with rubber ring for a few of pipeline had no damages. However, the rigid joints were rather severely damaged.

The gas steel pipes with diameter of 600 mm and length of 60 km had no damages. However, the damage ratio of rusted steel pipes attained as much as 20. The seismic performance of plastic pipes is comparatively poor. For example, a total of 8 breaks have been reported to have occurred in the PVC pipes with diameter of 50-200 mm and length of 3.8 km in Yungcun village, Wuqian County of Tiangjin, where the intensity is of grade VII. Its damage ratio reached 2.1.

Fig. 3 shows the relation between damage ratio and intensity of the well locations. These indicated that: The damages of well tube mainly depend on its surrounding soil condition, and the damages of well buildings mainly depend on the intensity and the type of structures.

HIGHWAY AND RAILWAY BRIDGES

The severe damages were found in highway and railway bridges, which led to the periodical traffic interruption. It has been restored on August 10. The damage percentages in total length of bridges attained to 62 in Tangshan and 21 in Tianjin respectively. A total of 30 highway bridges were séverely damaged or collapsed. 40% of railway bridges were damaged. A list of bridges severely damaged in Tangshan and Tianjin is shown in the Table 3. The locations of each bridge are shown in Fig. 1.

The main damage phenomena of bridges can be summarized as follows: Subsidence of embankment and movements of the abutments toward the river channel due to the landslip of both shores, which led to shortening of bridge spans and tilting and cracking of piers as well as fall of girders in longitudinal direction. Settlement of, tilting and cracks at the piers due to liguefaction of soil. Movement, impact of girders and shear failure of its supporting bolts due to the action of inertia forces.

The damage to bridges depends both on intensities and ground conditions. However, the latter was effected greatly. During the 1975

Haicheng earthquake, it was also found that the most damaged bridges were located on the soft soil. The accumulative damages caused by the main shock and aftershocks can not be ignored. For example, the Luanxian County and Zhaocun highway bridges and the No. 105 railway bridge still could operate after the main shock, however, they were severely damaged or collapsed after the aftershock with 7.1 of magnitude.

OTHER LIFELINE SYSTEMS AND URBAN VITAL FACILITIES

Sewerage. The sewerage main pipes with 1,161 km of length in Tangshan and Tianjin cities suffered slight damage and brought neither paralysis of whole system nor severe pollution in the cities. However, the way under the flyover crossing bridge was inundated with water due to the collapse of pump house, and it led to periodical traffic interruption.

Gas supply. Both the natural gas and the contained liquefied gas were slight damaged. Gas supply was resumed at some places on July 31. It was in late August that gas supply was resumed basically. The fall of containers gave no fire accident. After the earthquake, the contained liquefied gas not only satisfied the previous customers needs but also provided the gas for hundred additional medical units.

Airport. Tangshan Airport suffered damages of only some buildings, normal operation was soon resumed.

Wharfts. The wharfts along the river in Tianjin city were intact, but a lot of wharfts damaged in Tanggu district due to the worse ground conditions. Its damage is of 50% in harbors, 74% of docks in river shores.

Medical facilities. Medical activities in Tangshan after the eathquake were completely impeded due to the collapse of buildings at hospitals and relied upon the additional medical teams for help.

Power supply. Power supply in Tangshan city after the earthquake were completely interrupted because of the damage to buildings, equipment and fittings at electrical plants. Power supply was temporarily restored by means of truck power on July 28. The power was supplied to Tangshan through the network on July 29. The function of Tangshan electric power plant was completely recovered by the end of 1976.

Communication. The communication in Tangshan city after the earthquake was entirely cut off because of the collapse of buildings and damage to lines and poles. The 42% of short-distance transmission lines were damaged in Tianjin. The emergency communication to Beijing adopted by underground cables which were intact in the morning of July 28. It was entirely restored on Sep. 1.

LESSONS FROM THE EARTHQUAKE

The Tangshan earthquake clearly indicated that the more civilized citizen's life is, the more important the lifeline earthquake engineering and other urban vital facilities would be. For example, a great deal of ground water flew into passageways of Kailuan Coal Mine, which brought great difficulty to restore the production.

The underground pipelines, wells and bridges located in the region with soft, non-uniform or potential liquefaction soil are considered to be the most vulnerable against earthquake ground motions. It is necessary to pay more attention to site selection.

Connecting joint having some flexibility, such as flexible joint, remained in safe, but solid joints were easily damaged. Special attention should be paid to prevent the ruptures of pipes with small diameters and failure of pipe fittings. Steel pipe itself had no break, but the corrosion became a weak point in piping system. Pipes and joints made from cast iron had damages owing to its brittleness. PVC pipes, in spite of its flexibility, were greatly broken for its weakness against shearing force. Contained liquefied gas has a good performance against earthquake.

The collapse of the buildings and structures and the functional damage of the electric power facilities are the main causes of lifeline interruption. It is a good way to use underground or semiunderground structures and electric networks for the security of lifeline system.

Fall of girders is one of the most severe damage phenomena of bridges. It should adopt effective measures to avoid it.

For mitigation of future earthquake disasters, the evaluation and strengthening existing lifeline systems must be carried out in seismic region. These are being done in 36 cities in China now.

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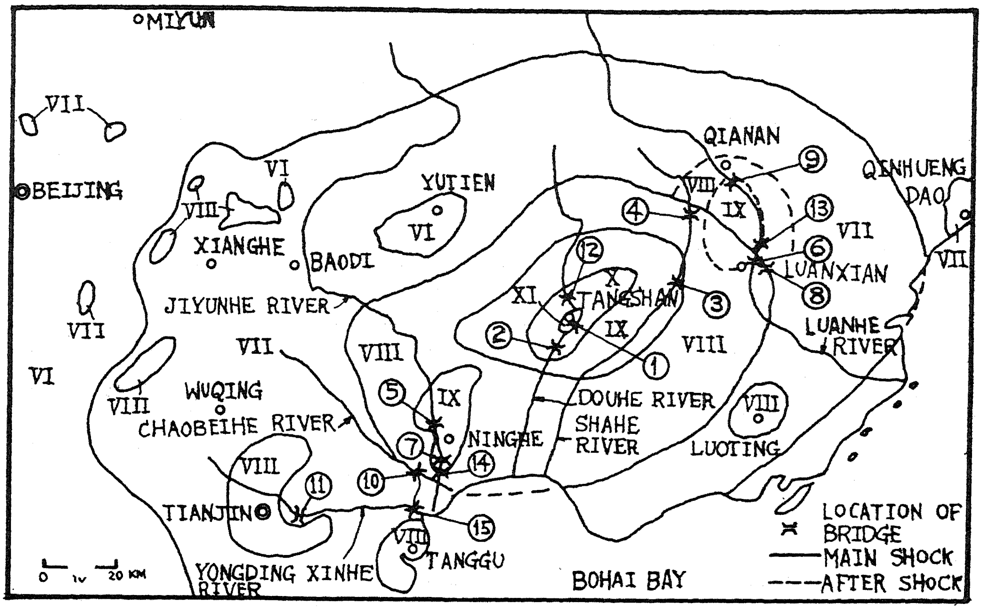

Fig.1 Isoseismals of Tangshan Earthquake and Locations of Bridge

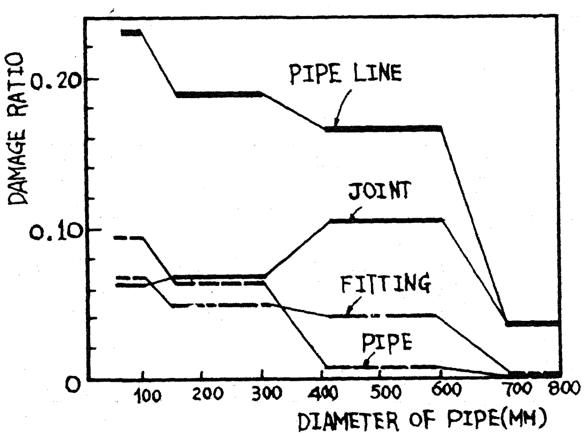

Fig.2 Relation between Damage Ratio and Diameter of Cast Iron Water Supply Pipes in Tianjin Urban Area

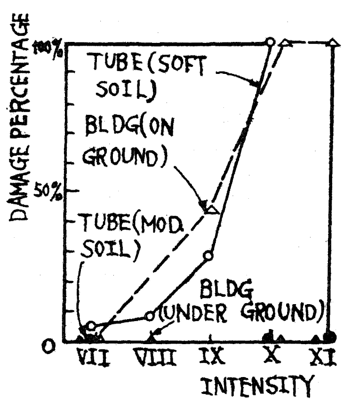

Fig.3 Relation between Damage Percentage & Intensity of Water Well Location in Tangshan and Tianjin

Table 1. Acceleration at Various Places during the Main Shock

Structure	Epi. Dis. (km)	Intensity	Subsoil	Location	Max. Accel. (gal)		
					N-S	E-W	Ver.
Miyun Dam	153	VI	Sand with Gravel	Free Ground Bottom Top	56.6 51.8 148.9	95.3 33.0 153.0	48.7 46.4 48.9
Hujialou Bldg	153	VI	Sand Clay	1st Floor 5th Floor	-- 214.1	53.3 109.6	-- 64.5
Beijing Hotel	157	VI	Sand Clay	Basement 1st Floor 17th Floor	48.9 71.8 160.6	57.9 64.8 195.2	31.6 -- 70.9
Hongshan	391	IV^+	Rock	Ground Level	7.1	--	4.7
Fengcun Railway Bridge	405	IV^+	Clay Sand	Bottom of Pier Top of Pier North Abutment North Shore	22.2 14.2 15.2 16.7	15.0 -- 15.5 13.8	6.7 -- 7.9 10.2

Table 2 Damage to Water Supply Distribution of Cast Iron Pipes with Diameters Equal to or Greater than 75 mm in Tangshan and Tianjin

Location	Diameter of Pipe (mm)	Length (km)	Damage Ratio			
			Joint	Pipe	Fitting	Total
Tangshan Urban Area	75-100 150-200 250-400 600 Sum	36.25 30.04 35.24 4.77 106.30	1.77 3.60 4.03 1.89 3.04	0.99 1.17 0.45 0 0.82	-- -- -- -- --	2.76 4.77 4.48 1.89 3.86
Tianjin Urban Area	75-100 150-300 400-600 700-800 Sum	302.7 379.9 146.3 27.0 855.9	0.063 0.068 0.116 0.037 0.074	0.086 0.063 0.007 0 0.060	0.066 0.053 0.041 0 0.054	0.215 0.184 0.162 0.037 0.188
Tanggu District of Tianjin	75-100 150-200 250-400 600 Sum	35.51 27.36 12.28 1.85 77.00	1.58 1.54 1.87 1.62 1.61	2.56 1.06 1.22 0 1.75	0.42 1.64 0 0 0.78	4.56 4.24 3.09 1.62 4.14