Lessons Learned from Damage to Drinking Water Supply System in the 2016 Kumamoto Earthquake in Japan

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ABSTRACT

This study is focusing on damage to drinking water supply system in the 2016 Kumamoto Earthquake and the lessons learned are given. Mw 6.2 earthquake struck in and around Kumamoto City in Japan at a depth about 11 km at 21:26 JST on April 14, 2016. Around twenty eight hours later, at 01:25 JST on April 16, an Mw 7.0 stronger earthquake occurred in the same area at a depth of about 12 km. More than 8,000 houses were totally collapsed. Total fatality after the main shock was 49 dead with 1 missing. The main shock triggered many geo-hazards such as landslides, surface faulting and liquefaction. Drinking water supply system were heavily damaged by not only strong ground motion but also large ground deformation induced by the geo-hazards.

Damage analysis was conducted and the following findings are clarified.

1. The damage rate of pipelines of Kumamoto City is 0.08 cases/km. This value is similar to that of Sendai City in the 2011 Tohoku Earthquake, that is, 0.07 cases/km. The damage rate of Kobe City in the 1995 Kobe Earthquake was 0.32 cases/km and 0.30 cases/km in Nagaoka City in the 2004 Niigata-ken Chu-etsu Earthquake. These earthquakes recorded JMA seismic intensity 7. This difference seems to depend on percentage of installation length of seismic resistant pipe.
2. Pipe length of liquefied area is about 0.8% of the total length in Kumamoto City. The damage rate of pipelines in liquefied area was however about ten times of that in non-liquefied area.
3. The pipelines crossed a surface faulting suffered severe damage. The countermeasure for pipeline crossed a fault is necessary in the future.
4. Damage to air valve also affected suspension of water supply. The damage was caused by not only strong ground motion but also abrupt increase of water pressure in a pipe. The cause of abrupt increase of water pressure in a pipe just after an earthquake should be clarified.

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INTRODUCTION

Two strong earthquakes affected Kumamoto City and the nearby towns and villages. The first earthquake which was identified as the fore shock occurred on April 14, 2016, 9:26 PM in local time with a moment magnitude Mw=6.2. The epicenter was located at 32.849° N, 130.635° E at a depth of 11km. The second event identified as the main shock occurred on April 16, 2016, 1:25 AM in local time with a moment magnitude Mw=7.0. The epicenter of this earthquake was located at 32.791° N, 130.754° E, with a focal depth of 12km. A JMA (Japan Meteorological Agency) seismic intensity of 7, that is, the maximum grade of JMA scale was recorded at Mashiki Town in Kumamoto Prefecture in the fore shock and at Mashiki Town and Nishihara Village in Kumamoto Prefecture in the main shock.

Total fatality after the main shock was 49 dead with 1 missing. Number of totally collapsed houses was 8,369, partially collapsed houses 32,478 and slightly collapsed houses 146,382, respectively. The main shock triggered many geo-hazards such as landslides, surface faulting and liquefaction. Drinking water supply system were heavily damaged by not only strong ground motion but also large ground deformation induced by the geo-hazards. This paper introduced an outline of the damage to drinking water supply system by this earthquake and the damage analysis done to the pipelines buried in liquefied areas. Finally the lessons learned from this earthquake are given.

OUTLINE OF EARTHQUAKE AND DAMAGE TO WATER SUPPLY FACILITIES

Tables I and II list observation sites where large peak ground acceleration (PGA) and large peak ground velocity (PGV) were recorded, respectively. PGA and PGV listed in these tables are vector summation of horizontal two components. 9.25 m/s/s of PGA that is close to gravity acceleration was recorded at KiK-net Mashiki in the fore shock. Maximum PGV of 1.38 m/s was recorded at Mashiki-machi Miyazono, not same place as PGA, that is, at Kik-net Mashiki. In the main shock, accelerations greater than gravity were recorded at Ozu-chou Ozu, Minamiaso-mura, kawayo and Kik-net Mashiki. PGV more than 1 m/s was recorded at total six observation sites. The maximum PGV was 2.56 m/s recorded at Nishihara-mura Komori. These values were very large in comparison with those in the past earthquakes. It seems to be one of characteristics of near fault earthquake motions.

The piping length of drinking water supply in Kumamoto City is 3,238 km. The total number of pipe damages was 233, therefore, the damage rate was 0.07 per kilometer. As Figure 1 shows, the number of damage by pipe material was 0.63/km for SV (other joint), 0.39/km for CIP, 0.16/km for VP, 0.12/km for SP (welded joint), and 0.04/km for DIP (other joint).

TABLE I. LARGE PEAK GROUND ACCELERATION IN THE 2016 KUMAMOTO CITY

	Site Name	PGA(m/s/s)	Site Name	PGV(m/s)
1	KiK-net Mashiki	9.25	Mashiki-machi, Miyazono	1.38
2	Mashiki-machi, Miyazono	8.15	KiK-net Mashiki	0.92
3	Kumamoto nishi ku, Kasuga	7.36	K-net Kumamoto	0.72

TABLE II. LARGE PEAK GROUND VELOCITY IN THE 2016 KUMAMOTO CITY

	Site Name	PGA(m/s)	Site Name	PGV(m/s)
1	Ozumachi, Ozu	17.54	Nishihara-mura, Komori	2.56
2	KiK-net Mashiki	13.14	Mashiki-machi, Miyazono	1.82
3	Minamiaso-mura, Kawayou	12.92	Minamiaso-mura, Kawayou	1.39

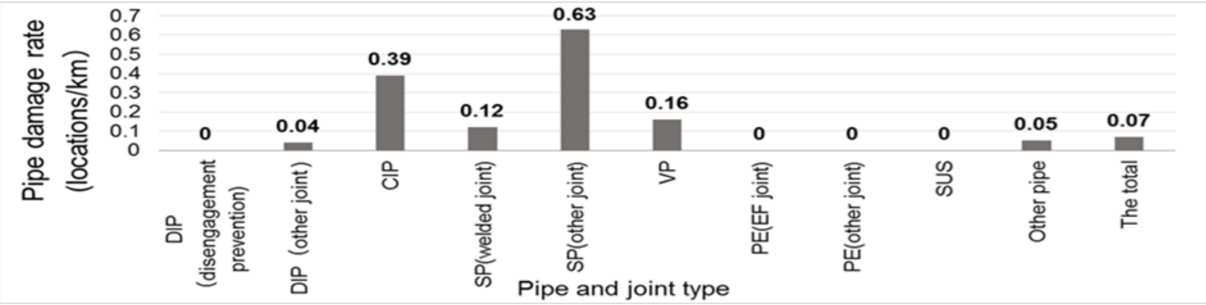

Figure 1. Pipe damage tare by pipe material in Kumamoto City

DAMAGE TO PIPELINE BURIED IN LIQUEFACTION AREA

Liquefaction occurred in and around Kumamoto City. The damage rate of drinking water pipeline in the areas where sand volcano densely appeared was evaluated in Kumamoto City. The pipe length in the liquefied areas was 26.7km. This length is about 0.8% of the total length in Kumamoto City. It indicates that the liquefaction occurred in Kumamoto City was not extensive. The damage rate of pipelines in liquefied area was 0.64/km because that the number of pipe damage was 17. The damage rate in liquefied area was about ten times of that in non-liquefied area.

DAMAGE TO AIR VALVE

Table III shows the number of locations of damage and damage rates of pipes and valves in Kumamoto City. This table indicates that damage to valves such as air valves was not small compared with damage to pipes in the 2016 Kumamoto earthquake. The number of damage to air valves in each prefecture in the 2016 Kumamoto earthquake is shown in Figure 2. This figure explains that the damage was concentrated in Kumamoto Prefecture and Oita Prefecture where the epicenter was located and near. On the other hand, air valve damage has also occurred in areas relatively far from the epicenter such as Saga City in Saga Prefecture and Nobeoka City in Miyazaki Prefecture. It seems that the damage was caused by not only strong ground motion but also abrupt increase of water pressure in a pipe. The cause of abrupt increase of water pressure in a pipe just after an earthquake should be clarified.

TABLE III. DAMAGE TO PIPELINE AND VALVES [1]

	Number of damage	Damage rate (locations/km)
Pipes	233	0.07
Valves	144	0.04

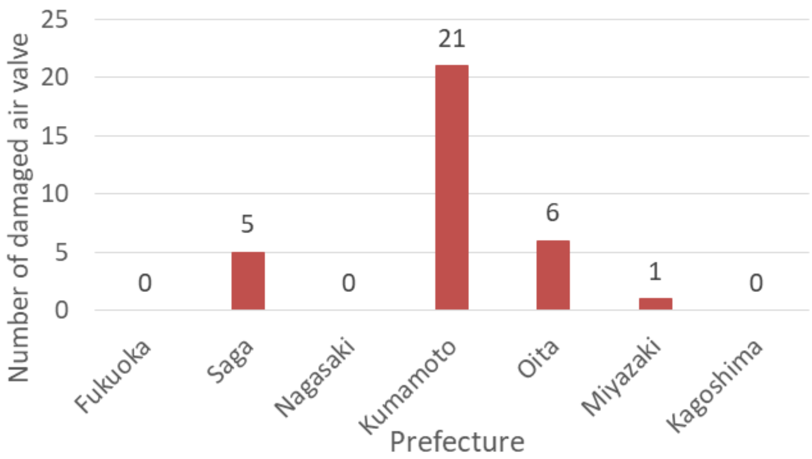

Figure 2. Number of damage to air valve in each prefecture

CONCLUDING REMARKS

Damage analysis was conducted and the following findings are clarified.

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ACKNOWLEDGMENTS

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REFERENCE

[1] Kumamoto City Water and Sewerage Waterworks Bureau, 2017. “Status of pipeline damage” (in Japanese)