

The Abnormal Behavior of Water Supply Systems just after Earthquakes in Case of Saitama City

Akihisa Ishida*, Mitsuyasu Tamase*, Masayuki Nagashima**, Masakatsu Miyajima***

Earthquakes cause rapid increase of water flow and rapid decrease of water pressure at water distribution system. Because that it causes the stop of water supply, we cannot send water to the areas that need water. However, we have never found out a cause of this abnormal behavior, therefore, we cannot take specific countermeasures against them on the present situation. The purpose of this study is to find out the cause of the abnormal behavior. We investigated the water flow and water pressure when the earthquakes occurred and seismic characteristics of earthquakes that occurred in Saitama city in 2011. We found out that the seismic motion of horizontal direction and the specific period gives a strong influence to water supplies.

1. INTRODUCTION

The 2011 Great East Japan Earthquake whose seismic focus was located at Oshika Peninsula offing has occurred on March 11th. The earthquake caused one of the biggest tsunami and tsunami inundation areas spread from the shoreline to 6km at most and it brought about sever damage. We focused on the damage of water supply among those damages. The earthquake caused rapid increase of water

flow and rapid decrease of water pressure at water distribution stations even water pipes didn't get any damage such as a burst and leakage. Figure 1 shows the transition of water flow and water pressure at Seibu water distribution station at the 2011 Great East

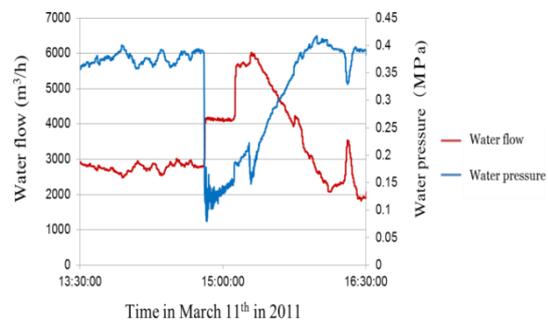


Figure 1 The transition of water flow and water pressure at Seibu water distribution station at the 2011 Great East Japan Earthquake

* Graduate School of Natural Science and Engineering, Kanazawa University, Kakuma-machi Kanazawa, Ishikawa, Japan (E-mail: akihisa-2507-in-maine@hotmail.co.jp)

** Saitama City Waterworks Bureau, Tokiwa, Urawaku, Saitama, Japan (E-mail: heu12-u1w1@city.saitama.lg.jp)

*** Department of Environmental Design, Kanazawa University, Kakuma-machi Kanazawa, Ishikawa, Japan (E-mail: miyajima@se.kanazawa-u.ac.jp)

Japan Earthquake. It caused the suspension of water supply and a malfunction of water supply systems. This abnormal behavior is similar to the behavior when a large scale of water leakage occurs on pipes and it would be difficult to confirm whether this behavior is caused by the damage of pipes or not. And also, a number of the damage of air valves has been reported and it is thought that the damage was caused by decrease of water pressure. This kind of damage is less influence when the scale of earthquakes are small but there is fear of extending secondary damage such as disrupting fire extinguishing in case of the seismic motions that bring out a lot of fires. Therefore, we need to take countermeasures to build water supply system which are strong enough against any earthquakes. The purpose of the study is to find out what kind of seismic motion effects the abnormal behavior. We analyzed the water flow and water pressure when the earthquakes occur and seismic characteristics of earthquakes that occurred in Saitama city in 2011.

2. RELATION BETWEEN ABNORMAL BEHAVIOR AND SEISMIC MOTION

Target Area

We selected Saitama city as a target area. Saitama city is located in the middle of Kanto Region, and 200km² in land area and has a population of 1,200,000. It is consisted of tableland and lowland, and doesn't have mountains and hills. Saitama city has 20 water distribution stations and filtration plants, and they send 538,000m³ of water to the residents each day. Even among those stations, we focused on Seibu water distribution station. Seibu water distribution station utilizes force feed pump and sends 78,000m³ of water each day. This station is supplying water the most and has the highest water supply function in Saitama city. We calculated the amount of increase of water flow and the amount of decrease of water pressure at each earthquake. We defined the amount of increase and decrease as the comparison of the mean of the value for 5 minutes till the earthquake occurs and that after earthquake.

Earthquakes in Saitama City in 2011

We compared water flow and water pressure when earthquakes occurred, and the data of seismic characteristics. We got the data of seismic waves from Strong-motion Seismograph Networks (K-NET) which National Research Institute for Earth Science and Disaster Prevention provides. The data of 87 earthquakes recorded at the Kawaguchi seismic observatory station which is 12km away from Seibu water

distribution in 2011 are used in this study. There is the closest to Seibu water distribution station. The range of magnitude of the earthquakes used here is from 3.8 to 9.0 and instrumental seismic intensity is from 0.8 to 5. According to the investigation, we found out that there were 63 earthquakes which got the abnormal behavior of water flow and water pressure out of 87 earthquakes. It means that the water supplies in Saitama city were affected by the abnormal behavior in about 70% of earthquakes. In addition, the water flow increased from $3000\text{m}^3/\text{h}$ to $6000\text{m}^3/\text{h}$ and the water pressure decreased from 0.35MPa to 0.1MPa at the 2011 Great East Japan Earthquake. It took more than 1 hour to recover from the abnormal behavior completely. We consider that the abnormal behavior is severe problem for Saitama city from these things. We compared the data of water flow and water pressure, and seismic characteristics, and estimated what kind of seismic characteristics influence the abnormal behavior of water distribution systems.

Instrumental Seismic Intensity

We investigated the relations between the amount of increase of water flow or the amount of decrease of water pressure, and the instrumental seismic intensity of earthquakes. Figure 2 shows the relation between the amount of increase of water flow and the instrumental seismic intensity, and Figure 3 shows the relation between the amount of decrease of water pressure and the instrumental seismic intensity. The black lines show the approximate lines. According to these figures, it seems that if the magnitude of seismic intensity gets bigger, the amount of behavior increases as well. However, we can't say that instrumental seismic intensity of earthquakes strongly influences the behavior of water flow and water pressure because that it seems that the values are dotted sparsely, and the correlation coefficients of two figures are 0.54 and 0.59 each.

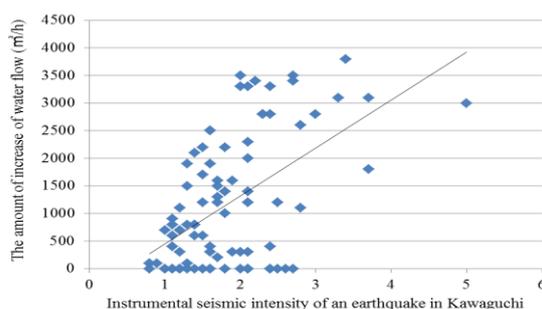


Figure 2: The relation between the amount of increase of water flow and the instrumental seismic intensity

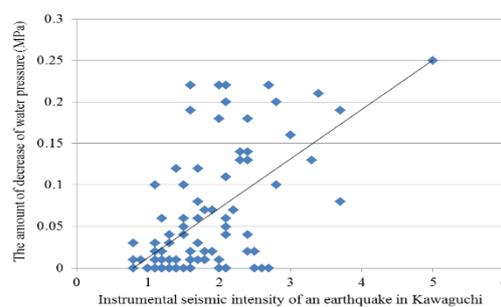


Figure 3: The relation between the amount of decrease of water pressure and the instrumental seismic intensity

Velocity Response Spectrum

We consider that there is another factor influences the abnormal behavior and we paid attention to the maximum velocity response spectrum of horizontal and vertical directions. We investigated the relation between these factors and the abnormal behavior of water flow and water pressure. Figures 4 and 5 show the relation between the increase of water flow and maximum velocity response spectrum of horizontal and vertical directions respectively. Figures 6 and 7 show the relation between the decrease of water pressure and maximum velocity response spectrum of horizontal and vertical directions respectively. It seems that the earthquakes with strong velocity response spectrum of horizontal direction tend to get the abnormal behavior according to Figures 4 and 6. By contrast, the values of maximum velocity spectrum of vertical direction are almost less than 5cm/s and it doesn't have a lot of difference from earthquakes. In addition, it seems that the values are plotted lengthwise and the abnormal behavior occurred even with small velocity response spectrum according to Figures 5 and 7. As results, we consider that water supplies tend to get the influence from the seismic motion of horizontal direction, and the vertical motion doesn't give a big influence to water supplies.

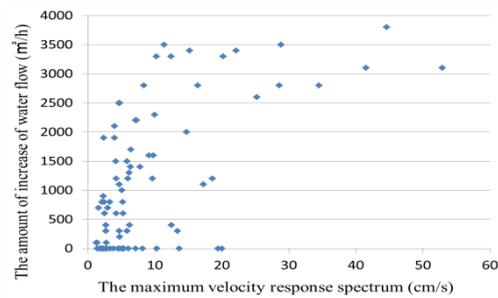


Figure 4: The relation between increase of water flow and the maximum velocity response spectrum of horizontal direction

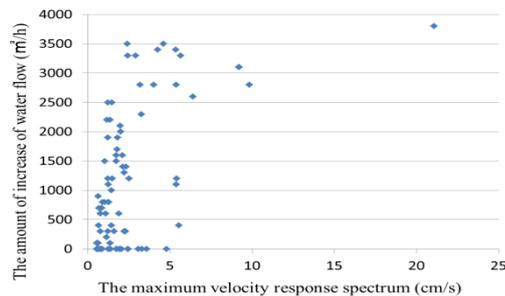


Figure 5: The relation between increase of water flow and the maximum velocity response spectrum of vertical direction

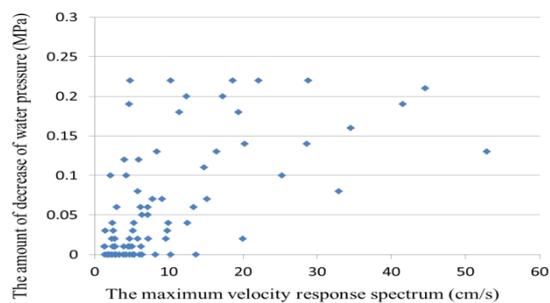


Figure 6: The relation between decrease of water pressure and the maximum velocity response spectrum of horizontal direction

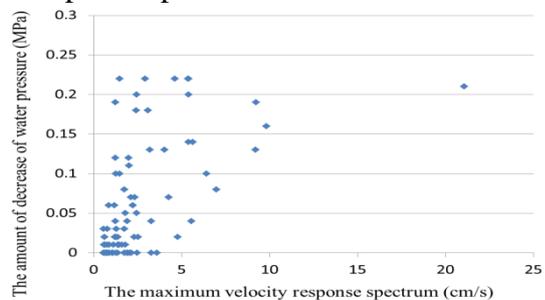


Figure 7: The relation between decrease of water pressure and the maximum velocity response spectrum of vertical direction

The Period

We focused on the period at the maximum value of velocity response spectrum and investigated the relation between the abnormal behavior and the period. Figure 8 shows the relation between the increase of water flow and the period of horizontal direction and Figure 9 shows the relation between the decrease of water pressure and the period of horizontal direction. According to the figures, the earthquakes with longer period which is around 1 second tend to get the abnormal behavior. The earthquakes with shorter period which is less than 0.5 seconds got less influence of earthquakes compared with the earthquakes with longer period.

The Velocity Response Spectrum and the Period

We analyzed each factor individually so we put two factors together and made the figures to see more details. We defined “behavior occurred” as the amount of increase of water flow exceeds $1000\text{m}^3/\text{h}$, and the amount of decrease of water pressure exceeds 0.1MPa on this study. Figure 10 shows the relation between occurrence of abnormal behavior of water flow and seismic characteristics of horizontal direction. Figure 11 shows the relation between occurrence of abnormal behavior of water pressure and seismic characteristics of horizontal direction. These figures show that the earthquakes

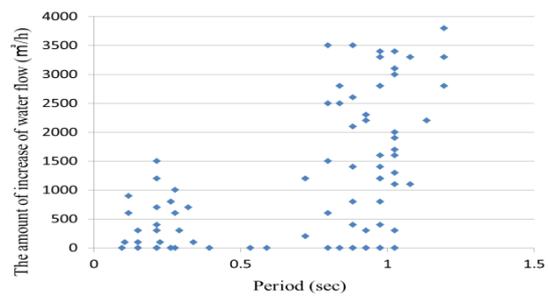


Figure 8: The relation between increase of water flow and the period of horizontal direction

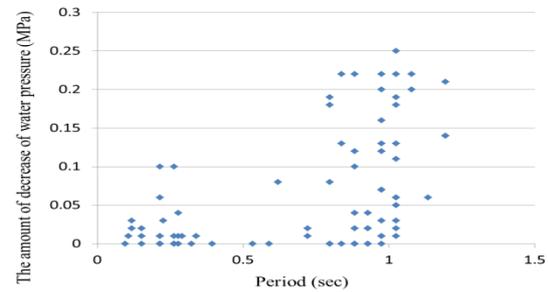


Figure 9: The relation between increase of water flow and the period of horizontal direction

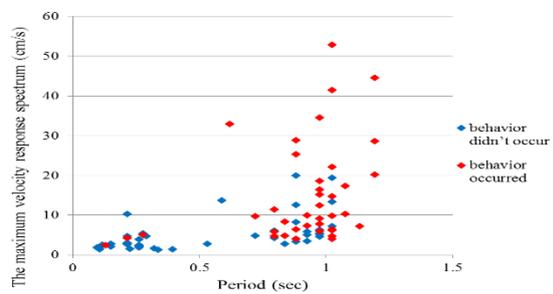


Figure 10: The relation between occurrence of abnormal behavior of water flow and seismic characteristics of horizontal direction

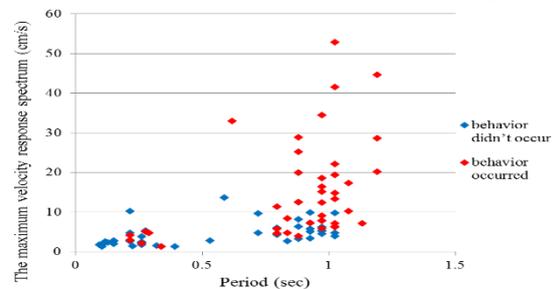


Figure 11: The relation between occurrence of abnormal behavior of water pressure and seismic characteristics of horizontal direction

with stronger velocity response spectrum and longer period give a lot of influence to water supplies. We found out that the tendency that the abnormal behavior didn't occur if the velocity response spectrum is low even if it is long period ground motion. Therefore, it is clarified that it is easy to influence the abnormal behavior if the earthquake is longer period motion and has larger velocity response spectrum.

3. CONCLUSION

First of all, we thought that the magnitude of seismic intensity in earthquakes influences the behavior of water flow and water pressure so we investigated the relation between them. We got the tendency that the stronger earthquake occurs, the stronger the behavior shows but the data is dispersing, and the mutual correlation is vague and we couldn't find a crucial proof with magnitude of the instrumental seismic intensity in earthquakes. Secondly, we focused on the velocity response spectrum and the period. We found out that the water supplies tend to get the abnormal behavior by seismic motion in horizontal direction and there is a tendency that if the velocity response spectrum increased, the behavior goes high as well. By contrast, the influence of that in vertical direction is not strong for water supplies. In terms of the period, we could see the tendency that the earthquakes with long period motion gets more influence compared with short period motion. Lastly, we investigated two factors together and made the figures to see the relation between the abnormal behavior and seismic characteristics. We could see the tendency that the earthquakes with longer period of horizontal direction and strong velocity response spectrum are easy to affect water supplies. According to these results, we consider that the water supplies get influence of sloshing in water tanks by resonance due to long period earthquake motion.

REFERENCES

Kouichi Murata and Masakatsu Miyajima(2007), The influence of the abnormal behavior of water flow and water pressure which the sloshing in water tanks just after the earthquake gives, Journal of Japan Association for Earthquake Engineering, 7, 1, 27-42, 2007