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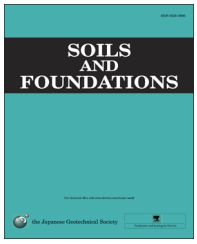

Damage to sewage systems caused by the Great East Japan Earthquake, and governmental policy

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Abstract

The Great East Japan Earthquake and its accompanying liquefaction and tsunami severely damaged many sewage systems including sewage pipes, manholes, pumping stations and sewage treatment plants over a wide area from Tohoku to the Kanto region. We conducted a questionnaire survey, interview survey and on-site confirmation in order to summarize and categorize the damage factors that shut down facilities such as drainage systems and treatment systems. We also studied the effectiveness of countermeasures to prevent liquefaction of the sewage system. The results showed that 90% of sewage pipes and 70% of manholes were damaged by liquefaction and that 54% of wastewater treatment plants and 75% of pumping stations were damaged by tsunami. Nevertheless, no severe damage was found along sewage pipe sections where liquefaction countermeasures had been executed, suggesting that the countermeasures are effective.

Keywords: Great East Japan Earthquake; Sewage system; Liquefaction; Tsunami; Disaster control

1. Introduction

On March 11, 2011, the largest earthquake ever recorded in Japan, the Great East Japan Earthquake, occurred off the Sanriku Coast with a magnitude of 9.0 on the Richter scale. This earthquake and its accompanying liquefaction and tsunami severely damaged many sewage systems including sewage pipes, pumping stations, and wastewater treatment plants over a wide area from Tohoku to the Kanto region. Sewage drainage and treatment facilities were paralyzed temporarily in many areas (Yasuda et al., 2012; Matsuhashi et al., 2012a). Immediately after the earthquake, information was inconsistent and fragmented, and many local governments were unable to determine the extent of the damage. On March 15, four days after the earthquake, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) set up the Sewage Response Headquarters in Miyagi and Tokyo, with the main roles of managing disaster support and handling information related to assistance. As a result, more than 6000 staff from various local governments assisted those local governments affected by the damage (Matsuhashi et al., 2012b).

There have been many large earthquakes in Japan such as the Niigata Earthquake (1964), Kushiro Offshore Earthquake (1993), Hanshin Earthquake (1995), Niigata Chuetsu Earthquake (2004), Noto Peninsula Earthquake (2007), Niigata Chuetsu-Oki Earthquake (2007), and Iwate-Miyagi Earthquake (2008). Each time, sewage systems, and especially sewage pipes, have been damaged, and the MLIT has surveyed the damage and proposed policies in response to the earthquakes (Japan Sewage Works Association, 2006a). The MLIT has also repeatedly examined the effectiveness of earthquake

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countermeasures (Japan Sewage Works Association, 1997, 2005, 2008), and has clarified some mechanisms such as the lifting of manholes by liquefaction (Koseki et al., 1997, 1998) and damage to sewage systems by lateral flow (Hamada and Wakamatsu, 1997). After the most recent earthquake, once again the MLIT set up a committee to study earthquake and tsunami countermeasures in sewage systems. This committee, which included academic experts and staff from local governments, the MLIT, and affiliated organizations, assessed the extent of the damage, produced a plan for rapid restoration, and proposed a new policy for all sewage systems to counteract large earthquakes and tsunami.

This report focuses on the damage to sewage systems including sewage pipes, manholes, wastewater treatment plants, and pumping stations due to liquefaction and tsunami caused by the Great East Japan Earthquake. As members of the committee, we conducted a questionnaire survey, interview survey and on-site confirmation in order to categorize the damage factors that shut down facilities such as drainage systems and treatment systems, to summarize the damage situation, and to assess the effectiveness of countermeasures against liquefaction. The findings will be useful for not only those local governments where damage occurred, but also all local governments when drawing up plans for early restoration and making sewage systems more resistant to earthquakes including accompanying tsunami and liquefaction.

2. Damage factors and damage situations

A questionnaire survey was conducted to determine the extent of the damage to sewage systems at 135 local groups from August to October 2012. The questionnaire covered basic information, extent of damage, and damage factors in sewage systems including sewage pipes, manholes, wastewater treatment plants, and pumping stations. The response rate to the questionnaire was 71% (96/135) for sewage pipe systems, 72% (86/120) for wastewater treatment plants, and 67% (86/120) for pumping stations. Non-responders included those in areas where this survey was impossible due to the tremendous damage caused by the tsunami.

2.1. Sewage pipes

Based on the questionnaire results, the damage to sewage pipes caused by the earthquake is listed in Table 1. Of 65,001 km of sewage pipes in 139 cities, 642 km were damaged. This is a much larger figure than in past large earthquakes such as the Hanshin Earthquake (1995), Noto Peninsula Earthquake (2007), and Niigata Chuetsu-Oki Earthquake (2007). The Great East Japan Earthquake caused widespread damage not only in the Tohoku region including Miyagi, Fukushima, and Ibaraki prefectures which are located near the epicenter, but also the Kanto region including Chiba, Kanagawa, and Tokyo, which is approximately 400 km from the epicenter (Yasuda et al., 2012). However, the damaged proportion, which is obtained by dividing the damaged pipe length by the total sewage pipe length, was lower than in past large earthquakes. This is primarily because large cities such as Tokyo and those in Kanagawa have already reinforced the main sewage pipes to make them earthquake resistant.

2.2. Damage to sewage pipe system by liquefaction

Our survey revealed that the type of damage to sewage pipe systems including manholes varied from region to region. In the Tohoku region near the epicenter, pipe sag, manhole uplift, and road surface subsidence occurred by partial liquefaction. These phenomena have often been observed in previous large earthquakes (Fukushima et al., 2006). In the

Table 1
Damage to sewage pipes, wastewater treatment plants and pump stations by the Great East Japan Earthquake and past large earthquakes.

Earthquake	Prefecture	Number of devastated cities	Proportion of damaged sewage pipes (%) (damaged length (km)/total length (km))		Damage to wastewater treatment plant	Damage to pump station
Great East Japan (2011)	Aomori	1	0.1	(0.1/113)	3	2
	Iwate	13	0.4	(13/3712)	10	10
	Miyagi	40	3.3	(317/9739)	38	64
	Yamagata	0	0	(0/0)	2	0
	Fukushima	23	2.5	(129/5186)	16	10
	Ibaraki	36	1.6	(148/9509)	25	17
	Tochigi	3	0.4	(1/287)	5	0
	Saitama	1	0.0	(0.006/214)	2	8
	Chiba	13	0.6	(54/8510)	3	0
	Kanagawa	1	0.0	(0.6/11,625)	10	1
	Tokyo	1	0.1	(12/15,793)	4	0
	Niigata	2	0.2	(1/426)	1	0
	Nagano	0	0	(0/0)	1	0
Total		134	1.0	(676/65,114)	120	112
Hanshin (1995)		11	1.0	(162/13,919)	8	6
Noto Peninsula (2007)		6	2.3	(15/652)	8	2
Niigata Chuetsu-oki (2007)		5	1.6	(50/3072)	6	3