Investigation of Damage of Masonry Garden Wall by The Niigata-ken Chuetsu-oki Earthquake in 2007

Y. Nakamura[1], M. Urai[2] and K. Sato[2]

[1] *Assistant Professor, Dept. of Architecture, Niigata University, Japan*
[2] *Graduate student, Graduate school of Niigata University, Japan*
Email: nakamura@eng.niigata-u.ac.jp

ABSTRACT :

In this study, damage of masonry garden walls was investigated. Masonry garden walls such as stone masonry wall and concrete block masonry wall, are frequently used the boundary between each house lot in Japan. The collapse of masonry wall which face street also causes street blockage. Therefore, the damage of masonry wall collapse disturbs evacuation behavior and rescue work. The design standard for masonry garden wall is set in Japan, however existing masonry walls which are not followed the standard are observed by actual condition survey in Niigata city. A fourth of garden walls is not set reinforced steel bar and a half is not set counterfort, respectively. The damage to masonry garden walls by the Niigataken Chuetsu-oki Earthquake in 2007 was surveyed. The collapse of concrete block masonry wall was caused by the insufficiency of reinforced bar or counterfort, corrosion of steel bar and not anchored steel bar. Especially, the rusty reinforced steel bar is severe. The damage ratio of stone masonry wall is eighty percents. Most of collapsed stone masonry walls were not reinforced.

KEYWORDS: Masonry Garden Wall, The Niigata-ken Chuetsu-oki Earthquake in 2007, Street blockage

1. INTRODUCTION

The Niigataken Chuetsu-oki, Japan Earthquake in 2007 which occurred on July sixteenth caused severe damage. Eleventh people were killed and more than a thousand buildings were heavy damaged. High Japanese Metheorological Agency(JMA) seismic intensity scale(I_{JMA}) were recorded. I_{JMA} 6 plus was recorded at Kashiwazaki(Shindokei, K-NET), Kriwa(Shindokei), Nishiyama-Kashiwazaki(Shindokei), Oguni-Nagaoka (Shindokei) and Iizuna, Nagano(Shindokei). In these areas, high seismic intensity also recorded by the 2004 Niigata-Chuetsu, Japan, Earthquake. I_{JMA} 6 plus was recorded at Oguni and I_{JMA} 6 minus was recorded at Kariwa.

2. RECORDED STRONG MOTIONS

Damage investigation was made around fifteenth strong-motion recording stations. I_{JMA}s of these sites range from 5 minus to 6 plus. Two stations are operated by National Research Institute for Earth Science and Disaster Prevention (K-NET), two stations are by Japanese Meteorological Agency(JMA), the others are by each local government(Shindokei). Figure 1 shows the locations of the strong-motion recording stations where the damage to masonry garden walls was surveyed. The recording station names and the seismic destructive power indices, such as I_{JMA}, PGA, PGV, SI and $V_{1\text{-}2}$(Sakai

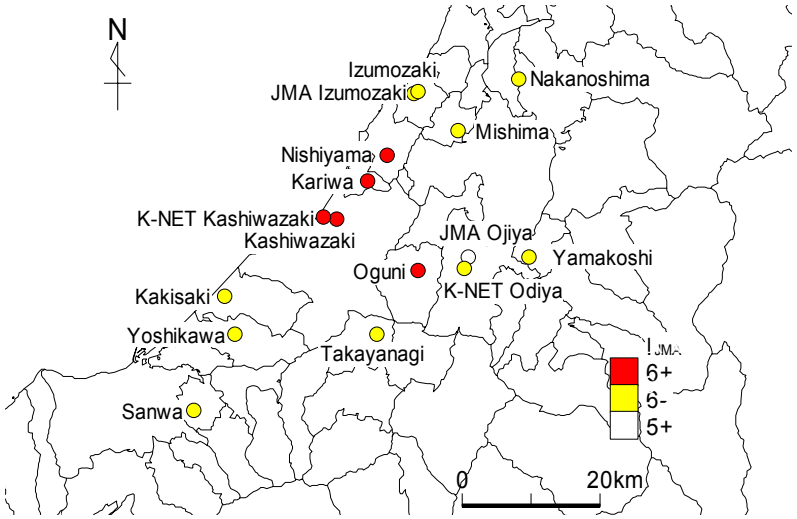

Figure 1 Locations of strong-motion recording sites of the Niigataken Chuetsu-oki, Japan Earthquake in 2007

(2004,2006)) are shown in Table 1. These indices are calculated using vector sum of two horizontal components except I_{JMA}. PGVs of 3 stations exceeded 100(cm/s). Response acceleration spectra and response velocity spectra with a damping factor of 0.05 from recorded strong ground motions are shown in Figure 2. High response velocity can be seen in the period rage of from two seconds to four seconds for strong ground motions at Kashiwazaki and Kariwa. The response at other sites is high in the shorter period region.

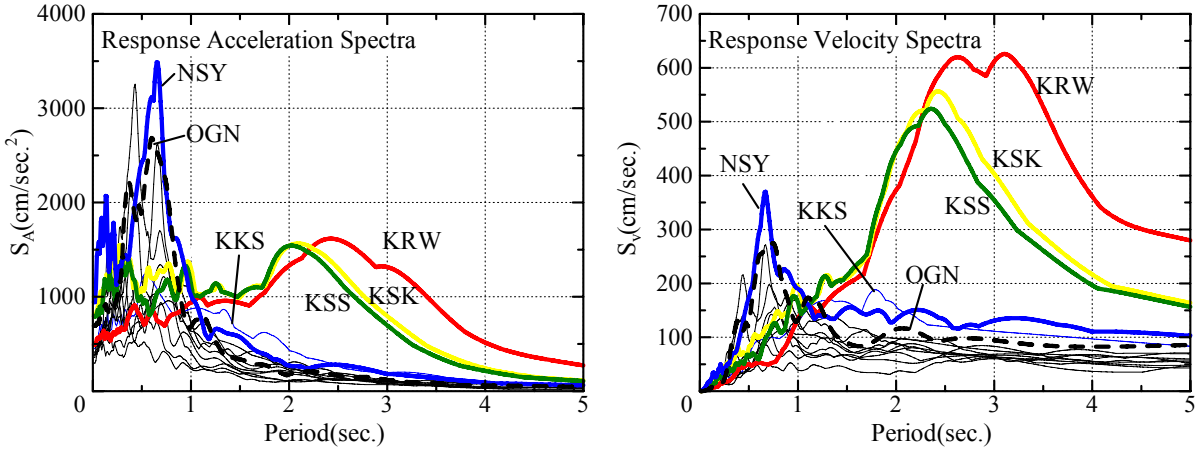

Figure 2 Response spectra from recorded strong ground motions
(Damping factor of Teranishi Y 0.05)

Table 1 Strong-motion recording stations and seismic indices and damage ratio of garden walls

Station name	ID	PGA	PGV	SI	I_{JMA}	V_{1-2}	dmw
Kashiwazaki(K-NET)	KSK	812.0	148.8	316.7	6.3	246.3	19/87
Kashiwazaki(Shindokei)	KSS	793.5	136.2	298.8	6.3	248.8	
Oguni, Nagaoka (Shindokei)	OGN	692.6	81.8	216.4	6.1	115.4	0.00
Nishiyama, Kashizawaki (Shindokei)	NSY	944.1	86.4	235.2	6.2	147.1	3/10
Kariwa(Shindokei)	KRW	490.3	150.6	274.6	6.0	218.8	1/8
Kakizaki, Joetsu (Shindokei)	KKS	449.9	82.0	196.9	5.8	164.3	0.00
Yoshikawa, Joetsu i(Shindokei)	YSK	471.7	57.8	160.1	5.8	123.1	0.00
Sanwa, Joetsu (Shindokei)	SNW	305.5	46.1	121.3	5.5	96.3	0.00
Nakanoshima, Nagaoka (Shindokei)	NKN	356.8	36.5	119.4	5.5	88.3	0.00
Mishima, Nagaoka (Shindokei)	MSM	389.6	41.4	127.8	5.6	98.5	0.00
Yamakoshi, Nagaoka (Shindokei)	YMK	414.0	42.5	124.0	5.7	66.9	0.00
Izumozaki(Shindokei)	IZS	382.5	38.5	112.6	5.5	71.9	0.00
Izumozaki(JMA)	IZM	698.0	55.3	158.5	5.9	88.0	0.00
Ojiya(K-NET)	OJK	524.8	51.8	124.8	5.5	63.0	0.00
Ojiya(JMA)	OJJ	393.9	31.5	67.2	5.1	39.7	0.00

PGA: Peak ground acceleration (cm/s2)
PGV: Peak ground velocity (cm/s)
SI: Spectrum Intensity (cm)
I_{JMA}: Japanese Metheorological Agency seismic intensity scale
V_{1-2}: Average elastic velocity response in a period range of 1 to 2 seconds with a damping factor of 0.05 (cm/s)
dmw: Damage ratio of masonry garden walls

3. DAMAGE AROUND THE STRONG-MOTION RECORDING SITES

3.1. K-NET Kashiwazaki, Kashiwazaki(Shindokei)

These two observation points are located on the Kashiwazaki local municipal office. Collapsed houses were observed around these points. Houses for combined residential and commercial use with opening front of a street were obviously damaged. Eighty percents stone masonry garden walls were falling down in this area. A concrete garden wall which was set reinforced steel bar and counterfort, was fallen by weak foundation. Damage of asphalt road surface was occurred. RC buildings in Kashiwazaki dai-ichi Junior high school which is about 0.5 kilometers from this point were moved individually. 17cm gap at expansion joint which connected two buildings was occurred. (Photograph 1-12)

3.2. Kariwa(Shindokei)

This observation point is located on the Kariwa public office. There is rice field around this point. There is not collapsed house. A two-story warehouse, a stone masonry wall and a lantern were collapsed.
(Photograph 13-16)

3.3. Nishiyama, Kashiwazaki(Shindokei)

This observation point is located on the Nishiyama public office. Cracks in the ground and concrete block masonry wall leaning were occurred around this point.
Ceiling panels of gymnasium in Nishiyama Junior high school which is about 0.5kilometers from this point, were fallen down. Cracks and Gap in the ground were occurred. There was inundation by water supply pipe damage. (Photograph 17-23)

3.4. Oguni, Nagaoka(Shindokei)

This observation point is located on the Oguni, Nagaoka public office. There was not remarkable damage around this point.
In Shimo-Oguni elementary school which about 2 kilometers from this point, a three-story RC building which was build in in1963 was damaged. This building was also damaged by the 2004 Niigata-Chuetsu earthquake and judged light damage by damage level classification. It became more severe damage by the Niigataken Chuetsu-oki Earthquake in 2007. There are shear failure columns and walls with opening. Six columns were damage class three and a column was damage class five. Walls with opening which were damage class four or five were observed.(Kato(2007)) (Photograph 24-28)

3.5. Kakizaki, Joetsu(Shindokei)

This observation point is located on the Kakizaki, Joetsu public office. This office is built on the hill. There is not remarkable office building damage but crack on the ground near office building was observed. Cracks of concrete block masonry wall and on the ground were occurred. (Photograph 29-32)

3.6. Yoshikawa, Joetsu(Shindokei)

This observation point is located on the public welfare office near Yoshikawa, Joetsu public office. Server building damage was not around this point. Inter rocking blocks front of Yoshikawa, Joetsu public office were damged. (Photograph 33)

3.7. Yamakoshi, Nagaoka(Shindokei)

This observation point is located on the Yamakoshi, Nagaoka public office. There is not remarkable office building damage. Entrance stairs has cracked

3.8. Other observation points

Heavy damaged buildings and masonry wall damage were not observed around other points.

Photograph 1 Kashiwazaki local municipal office

Photograph 2 K-NET Kashiwazaki observation point.

Photograph 3 Kashiwazaki-chuocho seismic intensity. (Shindokei) observation point.

Photograph 4 Collapsed house (Kashiwazaki)

Photograph 5 Heavy dameged house (Kashiwazaki)

Photograph 6 Collapsed stone masonry walls. The street completely blocked by with both side walls. (Kashiwazaki)

Photograph 7 Collapsed house and stone masonry wall(Kashiwazaki)

Photograph 8 Heavy damaged warehouse with mud wall. (Kashiwazaki)

Photograph 8 Concrete block masonry wall with reinforced steel bar and counterfort falling (Kashiwazaki)

Photograph 9 Cracked block masonry wall and street surface. (Kashiwazaki)

Photograph 10 Damage of asphalt road surface(Kashiwazaki)

Photograph 12 A gap in expansion joint of Kashiwazaki daiichi Jr high school buildings.(Kashiwazaki)

Photograph 13 Kariwa public office building

Photograph 14 The seismic intensity meter(Kariwa)

Photograph 15 Collapsed stone masonry wall(Kariwa)

Photograph 16 Collapsed two story warehouse(Kariwa)

Photograph 17 Kashiwazaki Nishiyama public office building

Photograph 18 The seismic intensity meter(Nishiyama)

Photograph 19 Cracked gable surface of house(Nishiyama)

Photograph 20 Concrete block wall falling and road surface gap (Nishiyama)

Photograph 21 Nishiyama junior high school buildings(Nishiyama)

Photograph 22 Damage of ceiling panel of gymnasium in Nishiyama Junior high school(Nishiyama)

Photograph 23 Gap of asphalt surface front of Nishiyama Junior high school. (Nishiyama)

Photograph 24 Oguni, Nagaoka public office building

Photograph 25 A view from Oguni public office

Photograph 26 Shimo-Oguni elementary school building(2.2km from Oguni)

Photograph 27 Shear crack of wall of Shimo-Oguni elementary school (Oguni)

Photograph 28 Shear crack of column of Shimo-Oguni elementary school (Oguni)

Photograph 29 Kakizaki, Joetsu public office building

Photograph 30 Back side view of public office building

Photograph 31 Blue sheet was covered on the road by surface cracked(Kakizaki, Joestu)

Photograph 32 Crack of concrete block wall (Kakizaki, Joestu)

Photograph 33 Damage of Inter Rocking Block(Yoshikawa, Joestu)

4. DAMAGE INVESTIGATION OF MASONRY GARDEN WALLS

4.1. Investigation of Damage to Masonry Garden Walls

The investigation was carried out on garden walls which face a street. There is not authorized damage grade of garden wall, therefore the fifth level damage grade as shown in Table 2 was set with reference to past investigation report(Sato(2007), Teranishi(2006)).
Damage ratios are shown in Table 1. Collapse or heavy damaged walls were around K-NET Kashiwazaki, Nishiyama, Kariwa. In the other area, severe damage was not observed. Total number of surveyed wall was under ten at Nishiyama and Kariwa. Statics of investigation result at Kashiwazaki is described in the next section.

Table 2 Damage Grade of Masonry Garden Wall

Damage Grade	Description of Damage
Collapse(D5)	Collapse and falling
Heavy (D4)	more than half of the units falling, Drift of about more than 20 degree, Remarkable cracks(crack width is about over 10mm)
Moderate(D3)	more than one-third of the units falling, Drift of about 10 to 20 degree, , Local cracks(crack width is about 5mm to 10mm)
Light(D2)	Top units falling, Drift of about 5 to 10 degree, Local crack (crack width is about less than 5mm)
Slight(D1)	Top rail falling.
None(D0)	No damage

4.2. Damage of Masonry Garden Walls around Kashiwazaki

Total number of surveyed walls was eighty-seven. The ratio of garden wall type is shown in Figure 3. Fifty-five percent are concrete block walls and eighteen percent are stone masonry walls. A remarkable feature of this area is high ratio of stone masonry. Damage ratios of each garden wall type are shown in Figure 4. Falling stone masonry walls break into pieces and these were removed soon after the earthquake, therefore, the removed stone masonry wall was equal to damage grade D5. The damage ratio of stone masonry wall is eighty percents. The stone masonry wall under 110cm height is required to be reinforced with steel dowel connection or steel cramp by AIJ standard. Eleven out of twenty collapsed stone masonry walls were not reinforced. The concrete block masonry wall is required to be reinforced with steel bar (AIJ(1997)). More than half of the heavy damaged concrete block masonry walls were not reinforced by steel bars. On the other hand, three-fourth falling concrete block walls had steel bars. In these walls, there were not enough the diameter of steel bars or a steel bar didn't pass through basement in these walls. It was caused which a diameter as not enough or vertical steel bars which were not passed through the basement.

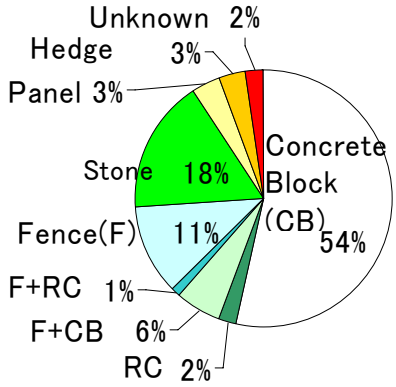

Figure 3 Type of Garden wall

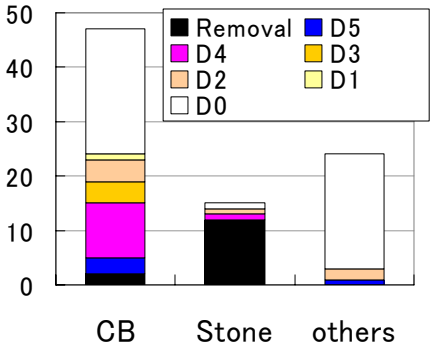

Figure 4 Damage Ratio

5.CONCLUSIONS

The damage to masonry garden wall by The Niigataken Chuetsu-oki Earthquake in 2007 around the strong-motion recording stations was surveyed.
(1) The ratio of concrete block wall has the highest percentage and stone masonry has the second most high. A remarkable feature of this region is high ratio of stone masonry wall.
(2) The ratio of damage grade D5 and removed of stone masonry wall was about eighty percents and concrete block wall was about eleven percents.
(3) Eleven out of twenty collapsed stone masonry walls were not reinforced by steel dowel connection or steel cramp.
(4) Small diameter of steel bar or vertical steel bars which were not passed through the basement caused falling, although three-fourth falling concrete block walls had steel bars.

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