Outline of Reconnaissance Report of Damage of Building During the Mid Niigata Prefecture Earthquake in 2004

by

NILIM-BRI Joint Reconnaissance Team of Damage of Buildings*

ABSTRACT

This paper presents outlines of reconnaissance report of damage of buildings, their related facilities and housing sites during the Mid Niigata Prefecture earthquake in 2004. National Institute for Land and Infrastructure Management and Building Research Institute organized a "Joint Reconnaissance Team of Damage of Buildings". The team grasped the damage situation of building and its related facilities. Reconnaissance items are earthquake ground motions, structural damages of wooden, reinforced concrete, steel buildings and housing sites and fire situations. The paper included behaviors of seismically isolated buildings during earthquake.

KEYWORDS: Building Damage, Housing Site Damage, Reconnaissance Report, The Mid Niigata Prefecture Earthquake

1. INTRODUCTION

The Mid Niigata Prefecture earthquake occurred at 5:56PM on October 23rd in 2004. The Japan Meteorological Agency (hereafter referred to as JMA) announced that the depth of hypocenter is 13 kilometer, and the magnitude was estimated 6.8 in JMA scale. A seismometer at the Kawaguchi station registered the intensity 7.

Since the epicenter of the Mid Niigata Prefecture earthquake and surrounding regions are in a mountainous district, damage features are different from those in the 1995 Hyogo-ken Nambu Earthquake. Damages of houses were caused by slopes failures or retaining wall collapses in newly prepared land.

National Institute for Land and Infrastructure Management (hereafter referred to as NILIM) and Building Research Institute (BRI) organized a "Joint Reconnaissance Team of Damage of Buildings". The team grasped the damage situation of buildings and housing sites, etc.

The paper presents outlines of reconnaissance report of damage of buildings. The reconnaissance items are earthquake ground motions, structural damages of wooden, reinforced concrete (RC), steel buildings and housing sites and fire situations. Behaviors of seismically isolated buildings during earthquake included.

2. EARTHQUAKE GROUND MOTIONS

2.1 Outline of Earthquake and Earthquake Ground Motions

The mainshock occurred at 5:56 PM on October 23rd, 2004. The seismometer of the Kawaguchi station registered the highest level 7 of the JMA intensity scale, which was first announced since the 1995 Hyogo-ken-Nambu earthquake. The peak ground accelerations of this station were 1675cm/s^2, 1141cm/s^2 and 869cm/s^2 for east-west, north-south and vertical components, respectively. In addition, extremely severe motions with intensity 6 upper (6+) were observed at three places, i.e., Takezawa district of Yamakoshi-mura, Norisaka district of Oguni

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-machi, Jounai district of Odiya-shi.

With the mainshock, an extensive area surrounding the epicenter experienced quite large ground motions. It was believed to be due to the relatively large magnitude for inland earthquake and the shallow source. The severe aftershocks occurred and were recorded in many recording stations. For the aftershock occurring at 6:34PM on October 23rd, the highest horizontal peak ground acceleration was observed at Kawaguchi station among main and aftershocks.

Prior to this earthquake, the area had not been affected even during the 1964 Niigata earthquake because the epicenter was located far north and had no experiences of earthquake disaster since 1961 Nagaoka earthquake.

2.2 Mainshock and Aftershocks

According to the JMA briefings, totally just 800 aftershocks had occurred by November 22nd. The highest JMA intensity 7 was registered at Kawaguchi station during the mainshock. The source locations of the mainshock and major aftershocks are shown in Fig.1. The figure indicates that all the earthquakes occurred beneath the affected area, i.e., Odiya-shi, Kawaguchi-machi and Horinouchi-machi.

The source mechanism was estimated as inverse fault (thrust fault) type and the western hanging wall stranded on the eastern foot wall. The source type differs from the strike-slip type for 1995 Hyogo-ken Nambu earthquake. Some of the major aftershocks had occurred in different fault plane from the mainshock. The estimation of earthquake rupture process on the fault plane using the far-field body wave records and the near-field strong motion records was conducted and it indicates that the moment magnitude of the mainshock (Mw) is 6.5. It was also estimated that the rupture duration time was 11 seconds and the maximum dislocation on the fault plane was 3.7 meter. In addition, the slip distribution on the fault plane was also estimated and shown in Fig. 2.

2.3 Characteristics of Ground Motion at Mainshock

1) Distribution of ground motions

The distribution of the JMA measured seismic Intensity is shown in Fig. 3 and the PGA distributions are also shown in the figure. The data are supplied mainly from the JMA[1], seismic intensity information network operated by the Niigata prefecture[2], and K-NET and KiK-net[3] operated by the NIED. The seismic intensity values for the data other than the JMA are reference values calculated with the same scheme for the JMA seismic intensity. The circles indicate the observation stations for JMA and seismic intensity information network for local governments. On the other hand, the rectangular symbols indicate the K-NET and KiK-net sites, and the star symbol indicates the location of the epicenter for the mainshock. The PGA values in the right-hand side figure were calculated as the magnitude of the vectorial sum of three components.

2) Feature of Ground Motion of Epicenter Region

The PGAs and PGVs for major recording sites are listed in Table 1, with epicenter distance and the measured seismic intensity.

Among many high acceleration data, K-NET Odiya and JMA Odiya stations are shown with waveforms in Fig. 4. These two recording stations are located about 700 meters apart. The K-NET station is located on the edge of the playground of a primary school and also situated next to the rice field, whereas the JMA Odiya recording station is located in the fire station site. Both records are regarded as the free filed motions that are not affected by adjacent buildings. Figure 5 shows the comparison of the acceleration response spectra for these records. It is seen that the K-NET Odiya station record has dominant period of 0.7 second. It is seen that the recorded motions are different in amplitude level in spite that their locations are so near.

Figure 6 shows the comparison of these records with those for the severe ground motion records for 1995 Hyogo-ken Nambu earthquake such as JMA Kobe, JR Takatori station and the Fukiai

Osaka Gas Supply office. The spectral amplitudes for these records are also of the highest level ever recorded in Japan.

3. DAMAGES OF WOODEN BUILDINGS

3.1 Outline of Investigation

The joint team of NILIM and BRI investigated the damages on wooden buildings in the following schedule and purposes.

a) 1st investigation: from October 24th to 29th
b) 2nd investigation: from November 7th to 10th
c) 3rd investigation: from December 12th to 13th

The main purpose of the 1st investigation was to grasp an overview of the damage on wooden buildings in the heavily damaged area and to support the Emergency Risk Assessment, which the local government implemented. The areas were Odiya-shi, Kawaguchi-machi, Nagaoka-shi, Horinouchi-machi, Tokamachi-shi and Kawanishi-machi. The information was collected from the local government and by the overview investigation from outside of the buildings.

In the 2nd and the 3rd investigation, overview grasping was continued in other heavily damaged areas such as Higashi-yoshitani in Odiya-shi, Wanazu in Kawaguchi-machi. And total 22 wooden houses with various structural systems and various damage levels were picked up in the heavy damaged area such as Shindojima in Horinouchi-machi, Budokubo in Kawaguchi-machi and Kawaguchi in Kawaguchi-machi, and detailed investigation was implemented on these houses.

3.2 Outline of Damages on Wooden Buildings

It seemed that the collapse often occurred for the slight buildings such as the barn and the workshop in which the consideration of seismic performance is scarce (Photo 1), or the buildings which were built in traditional construction method. On the other hand, the 2nd story collapse, which is so far supposed to be little in the earthquake damage of wooden houses, was observed at Wanazu in Kawaguchi-machi and Higashi-yoshitani in Odiya-shi (Photo 2).

1) Houses of traditional construction method

For the houses of the traditional construction method, the main seismic resisting elements are considered to be shear resistance of clay walls and bending resistance of posts with suspended wall. However, much damage of the bending rupture of posts was observed in the houses of traditional construction during the earthquake (Photos 3 and 4). The thickness of the post was usually about 120 mm and it seems insufficient as a bending element.

Diagonal braces are often used in case of clay wall of traditional construction method. The joints at the end of braces are often nailed ones only, and they were easily parted by tensile force (Photo 5).

Following cases also showed the severe damages. In case when roof tiles are often used, the seismic force is larger than houses with other right weight roofing materials such as steel plates. Additionally, a lot of farmhouses have large rooms with few walls around them.

2) Houses of recent construction method

Damage of houses with recent construction method is rather slight. But, in case when damages of ground occurred, the damages of the foundation and sometimes damages of the frame structures occurred. In the mountainous areas, the houses were suffered from damage of prepared housing sites such as the landslide (Photo 6).

3) Wooden houses with RC foundation with large height

As the damaged area is a heavy snowfall area, wooden houses often have a foundation with large height (high foundation) for the convenience in snow season. As a whole, the damage of the wooden houses with RC high foundation is slight. It is reasonable to think it is because most of them were rather recently constructed and they have sufficient shear walls in the upper wooden story. When the seismic element is not sufficient in the wooden story, such houses with high foundation also were damaged heavily (Photo 7).

One example in Higashi-yoshitani was observed that upper wooden story on the RC high foundation completely collapsed, but the structural details are obscure (Photo 8). On the other hand, there are some cases that the RC high foundation was damaged due to site ground failure (Photo 9).

4) Dwellings with shop

There are many damaged buildings for dwellings with shop. They usually have a large opening facing to the road, and it tends to cause insufficient amount of shear walls and eccentricity, regardless of whether construction method is traditional or recent (Photo 10).

5) Three-storied house with first story of steel structure

The second story in a three-storied house with the 1st story of steel structure was heavily damaged (Photo 11). This house was originally two-storied wooden house and later jacked up on the new first story of steel structure. The upper part is made by traditional construction method with less seismic resisting elements.

4. DAMAGES OF REINFORCED CONCRETE BUILDINGS

4.1 Outline of Damages of RC Buildings

To investigate behaviors of RC buildings, following points are focused;

a) To grasp damage patterns based on characteristics of RC buildings

b) To obtain basic data for the investigation of the relationships between strong motion record and building damage

c) To investigate the damages of mid- and high-rise buildings which have been interested after the 1995 Hyogo-ken Nambu earthquake

d) To investigate effect of seismic retrofit on behaviors RC buildings

In the highly seismic intensity areas, many RC buildings are used for public establishments, such as, schools and city halls, etc. Most of them are low-rise buildings with four stories or less. A few mid- and high-rise buildings are used for hospital. Eight RC buildings suffered from severe and medium damages. The number of damaged RC buildings is relatively small, compared with that of wooden houses. Although the extremely strong ground motions were recorded in Odiya-shi, etc., most of the RC buildings in these areas were not severely damaged.

The shear failure of short columns with hanging and standing walls were observed. The shear failure of columns by eccentricity and the flexural failure with buckling of longitudinal reinforcements were also observed. Most of these buildings were designed under the previous seismic code before 1981. The seismic code was revised to a current one in 1981. During recent other earthquakes, the old buildings were severely damaged and had been highlighted its brittleness. The collapse of middle or soft-first story of mid- and high-rise buildings, which was focused on after the 1995 Hyogo-ken Nambu earthquake, was not observed in the Mid Niigata Prefecture earthquake.

There are some seismic retrofit school buildings in the areas. Their performance was well acceptable to avoid severe damages. For those buildings, the method of retrofitting by increase of strength was applied.

4.2 Damages of RC Buildings

1) Building A

The damages ranging from “slight damage” to “serious damage” occurred in three building in a school. The buildings are one for classrooms built in 1961 (3 story RC building with a penthouse), one for administrative rooms, classrooms and special classrooms in 1962 (the same as before) and one for special classrooms in 1962 (the same as before). The building for classrooms and the building for administrative rooms, etc. have the same structure in plane and elevation.

The shear failure of short columns with hanging and standing walls (Photo 12) and shear cracks were observed. On the first floor of the building for special classrooms, the shear failure was observed in not only short columns but columns with relatively large aspect ratio (Photo 13).

2) Building B

The building B has undergone several expansions. There are a three-story building (1968), a seven-story building (1969), a seven-story building (1980), a three-story building (1982), a three-story building (1988) and a four-story building (1991). Each building is structurally separated through expansion joints. Among above buildings, the building in 1968 had most serious damages (Photo 14). Shear failure were observed in short columns on the first floor (Photo 15). Shear failure of short span beam in the building in 1969 (Photo 16) and flexural cracks at the beam ends were also observed. In the same building, the large shear failure was observed on the wall of corridor. Nonstructural walls of the building in 1980 suffered from serious damages (Photo 17). Other buildings designed by current seismic code had very little damage.

5. DAMAGES OF STEEL BUILDINGS

5.1 Outline of Structural Damages in Steel Gymnasiums

The survey team investigated the damages on steel gymnasiums that suffered from the Mid Niigata Prefecture earthquake. Objectives of the damage investigation of steel gymnasiums are as follows;

a) Characteristics of structural damage and nonstructural damage

b) Relationship between design year and damage level

c) Relationship between structural damage and nonstructural damage

d) Presumption of intensity of input earthquake ground motion into the surveyed gymnasiums.

The team investigated totally the number of 63 steel gymnasiums which are located in the highly seismic intensity areas as shown in Fig. 7.

Structural damages of the steel gymnasium were observed in longitudinal direction of the structures and little damage was observed in span direction. Fracture and buckling of braces as shown in Photos 18 and 19 were observed. Fractures of bolts and welding parts at the brace connection as shown in Photos 20 and 21 were also observed. As the other structural damages, fracture and buckling of roof horizontal brace, fracture of bolts at column base (Photo 22), fracture of stud base (Photo 23) and floor settlement were observed.

Damages of the surveyed gymnasiums were classified in damage level and design year. Figures 8 and 9 present the number of damages of braces and bolt connection of braces. From these figures, the ratio of the number of severe damage (such as buckling, fracture), which were designed and constructed according to the current seismic code (after 1982), is smaller than that of the previous one (before 1981). On the other hands, in terms of the damage of roof horizontal brace and floor settlement (Figs. 10 and 11), the tendency of damage ratio of the gymnasiums designed by the current seismic code is similar to that by the previous one.

5.2 Damage of Nonstructural Elements in Steel Gymnasiums

Damages of window sashes and glasses were observed in some gymnasiums as shown in Photos 24 and 25. Damages of falling down of transverse interior wall were observed (Photo 26). Damages of falling down of some ceiling boards were also observed (Photo 27). Damages of falling down of roof board were not observed (Photo 28). Damages of falling down of ceiling board were not observed in the seismic retrofitting gymnasiums (Photo 29).

6. DAMAGES OF FOUNDATION AND HOUSING SITE

6.1 Outline of Damages

The site investigation to understand the outline of damages of the foundations, housing sites and grounds were conducted four times.

In the Mid Niigata Prefecture earthquake, a lot of landslides and failure of retaining walls on slope ground occurred. Damages that grounds were separated and foundations were broken by the collapse of the slope were observed, as shown in Photo 30. The severe earthquake motion and the influence of the rainfall to the ground are considered to be the causes of damages.

The quick inspection of the housing site was done. Table 2 shows the outline of the quick inspection result of housing site. The number of housing sites for the quick inspection is 3,329 (until 20th of November, 2004). The number of housing sites judged to be unsafe is 519(16%), and that to be limited safe is 361(11%). There are a lot of regions with comparatively large-scale landslide occurred.

A lot of damages due to liquefaction were observed. The liquefied sites were recognized in the Nagaoka-shi (Nagaoka New Town, etc.), the Kashiwazaki-shi, Mitsuke-shi, and Kariwa village. Minamihonmachi in Mitsuke-shi had the damage of flood on July 2004. The liquefaction damage occurred in not only natural grounds with the saturated sedimentation sand but also the areas with loose sand in the backfill parts for pipe installation. The uplifting of manholes was observed everywhere.

Additionally, a lot of settlements of houses had been generated in housing sites and small-scale reclaimed areas in Nagaoka-shi. The cause of settlements is the failure of the housing sites or the retaining walls.

6.2 Damage from Slope Failure

A Youkyu-chou aera in Nagaoka-shi is the newly developed residential district around the Youkyu-mountainous areas. The comparatively large-scale landslide in the filling part occurred. A lot of failures and cracks of foundations, the inclination of superstructure, etc. was observed. Moreover, it is judged that the stability of the slope was not enough, because the region was swamp ground and the valley in old times.

Photo 31 shows the damage situation of the house in the upper part of the slope. The horizontal and vertical displacements were about 1.5m and 0.5m due to slope failure, and the house has settled. The concrete retaining walls in the backyard on the slope were split with 0.5m or more, and the ground was pushed out downward.

Figure 12 and Photo 32 are the damage situations of the house under the slope. The house on the lower part was pushed along the landslide, and the continuous footing in the house was distorted with 0.5m or more, and several places in the house were broken.

6.3 Damage from Liquefaction

Photos 33 and 34 show the damage situations in Kariwa-village and Nagaoka-shi. The concrete slab was destroyed by a partial upheaval of the ground due to liquefaction. The house was inclined greatly. There was a steel building with three stories whose differential settlement was about 30cm.

7. BEHAVIORS OF SEISMICALLY ISOLATED BUILDING

7.1 Outline of Observation of Seismically Isolated Building

Nine seismically isolated buildings (hereafter referred to as isolated building) were constructed in Niigata prefecture until October in 2004. Six buildings shown in Table 3 were surveyed. The isolated buildings are RC structures with 3 to 8 stories and a steel house is included. Types of isolators are lead rubber, high damping rubber and natural rubber bearings, and sliding bearings. Earthquake motions during the main shock were recorded in two buildings and a scratched displacement record was observed in one building.

To investigate behaviors of isolated buildings during earthquake and situations of isolators and surroundings of isolated layers, following items are considered;

a) Hearing and questionnaire from inhabitants in the isolated buildings
b) Findings of operation evidences of isolators and isolated layers
c) Situation of fallen snow around isolated buildings
e) Collection of earthquake observation records of isolated buildings

7.2 Behaviors of Isolated Building with Sliding Bearing

The arrangement of isolators in the building A is shown in Fig. 13. The isolated layer is consisted of 21 sliding bearings and 18 natural rubber bearings. After the earthquake, it was observed that the sliding trace was left on sliding plates and the residual deformation of the rubber bearings was kept. It is estimated that the isolated layer had at least 20 cm displacement as shown in Photo 35. The residual deformation of rubber bearings was 3 cm as shown in Photo 36.

Photo 37 presents indoor situation of isolated and non-isolated buildings. The damages of structure, non-structure, equipment and indoor scattering are almost nothing in the building A. Functions as evacuation place were kept just after the main shock.

7.3 Observed Earthquake Motion of Isolated Building

Observed acceleration waveforms of the main shock and their maximum values are shown in Fig. 14 and Table 4, respectively[4]. Ratios of the maximum acceleration at 1st floor to that at foundation in horizontal (north-south and east-west) and vertical components are 0.27, 0.25 and 1.54, respectively. The isolated effect, that is., a reduction of acceleration, is recognized in the horizontal vibration, while the vertical acceleration was a little amplified.

The time history of relative displacement trace at isolated layer is illustrated in Fig. 15. The displacement histories are obtained by integration of acceleration records. The maximum displacement of about 20cm occurred in the northwest to southeast direction.

7.4 Snow Fall around Isolated Building

The mid of Niigata Prefecture is a region with much snow falling. Figure 16 shows the plan of the building A and Photo 38 presents the situation of snow around the building taken at positions in Fig. 15. Pipes for melting snow are installed in building sides along roads and the water of pipes plays a role of melting snow. On the other hand, in backsides of the building, there is much snow along the building and it is necessary to check whether the snow will resist against smooth movement of isolated building.

8. BUILDING FIRES AFTER EARTHQUAKE

8.1 Building Damage by Fire

Only nine building fires occurred after the earthquake according to the official reports of Nagaoka-shi, Ojiya-shi and Tohkamachi-shi fire departments. All building fires are listed in Table 5. And the locations are shown in Fig. 17. Fires occurred in high seismic intensity areas.

Almost all fires occurred immediately after the mainshock or repeated aftershocks. At the 1995 Hyogo-ken Nambu earthquake, more than 200 fires occurred not only just after the mainshock, but also occurred several hours or several days later. Although the aftershocks repeated for long time in the Mid Niigata Prefecture earthquake, most fires occurred within one hour after the mainshock.

As five of nine building fires were put off in a short time by the residents nearby, damages by the fires are partly or very limited. On the other hand, four fires spread to or had a risk to spread to the surrounding building. The most damaged case was six buildings burn in conjunction with the landslide at Nigorisawa-machi in Nagaoka-shi, as shown in Photo 39. In the rural and mountainous area housing sites are limited, many building are built along the roadside and closely each other. Then, the fire spread easily to the next building.

8.2 Causes of Building Fire Damage

The fires after the earthquake ware caused by heater, gas explosion, electricity, incense stick, and etc. The dwellings with using heater were not so many in urban areas, but some dwellings used heaters already in mountain area. There are two fires caused by wood-burning stove, as shown in Photo 40. In the urban area kerosene heater of FF type are popular today. Because almost heater have the anti-seismically automatic put-off device, there are no fire reported caused by this kind of kerosene heater.

The two gas explosions happed by leaking at gas pipes in the buildings, not gas ovens or gas fittings, as shown in Photo 41. The mainshock was occurred just time for cooking dinners by using gas ranges. Many people got scald, but no fires occurred by the gas fittings. It is assumed that gas leak and fires were prevented, because microcomputer-controlled gas meters for assurance of safety by automatic shut-off were installed nearly 100% in dwellings of the service area.

At the 1995 Hyogo-ken Nambu earthquake, it was concerned that recovery of electric power caused fires. This time there was no electricity related fire. The recovery service to severely damaged building was suspended, and when evacuating building circuit breakers were requested to be off by public information. The lessons learned from the 1995 Hyogo-ken Nambu earthquake saved the loss due to fires.

9. CONCLUSIONS

The joint reconnaissance team of damage of buildings was organized in collaboration between NILIM and BRI to grasp the damage situation of buildings and housing sites, etc. in the Mid Niigata Prefecture earthquake. The team was consisted of sub group of earthquake ground motions, structural damages of wooden, RC, steel buildings and housing sites, seismically isolated buildings and fire situations.

Outlines of the damages of buildings are summarized as follows;

1) Earthquake Ground Motion

The wide area registered high acceleration amplitude larger than 500 cm/s^2. More than 1000 cm/s^2 acceleration amplitudes were also recorded in the epicenter area.

2) Damages of Wooden Buildings

a) Severely damages on the bending rupture of posts were observed in the houses under traditional construction because of insufficient bending elements.

b) Diagonal braces whose end joints are nailed are easily parted by tensile force.

c) Damages of houses under recent construction method are rather slight

d) The damages of the wooden houses with RC high foundation are slight. It was observed that in the case when the seismic elements of wooden story were not sufficient wooden houses were damaged heavily.

e) Many damaged buildings for dwellings with shop were observed. It is the reason why the amount of shear walls is not sufficient.

3) Damages of RC Buildings

a) Eight RC buildings were suffered from severe and medium damages. The number of damaged RC buildings is relatively small. The shear failure of short columns with hanging and standing walls were observed. Most of these failures occurred in the buildings which were designed under the previous seismic code before 1981. b) The damage on middle or soft-first story of mid- and high-rise buildings, which was focused on after the 1995 Kobe Earthquake, was not observed.

c) Seismic retrofit school buildings were not suffered from severe damages because of effect of strengthening.

4) Damages of Steel Gymnasiums

a) Structural damages of the steel gymnasiums: fractures and buckling of brace and fractures of bolts and welding parts at brace connections were observed in longitudinal direction.

b) Damage situations of the gymnasiums were compared under design year. The number of severely damaged gymnasiums designed under the current seismic code (after 1982) is less than that designed under the previous one (before 1981). On the other hands, the damage situations of roof horizontal braces and floor settlements are almost same under the current seismic code and previous code.

c) Damages of window sashes and glasses, and damages of falling down of transverse interior wall were observed. Damage of falling down of some ceiling boards was also observed. Damage of falling down of ceiling board was not observed in the seismic retrofitting gymnasiums.

5) Damages of Foundations and Housing Sites

a) In the newly developed residential district, the comparatively large-scale landslide in the fill

part occurred. A lot of failures and cracks of foundations, the inclination of superstructure, etc. was observed. The horizontal and vertical displacements were about 1.5m and 0.5m due to slope failure.
b) The liquefaction damage occurred in not only natural grounds with the saturated sedimentation sand but also the point where loose sand exists in the backfill for pipe installation.
c) Additionally, a lot of settlements of houses had been generated in housing sites and small-scale reclaimed areas. The cause of settlements is the failure of the housing sites or the retaining walls.

6) Behaviors of Seismically Isolated Buildings
a) The damages of structure, non-structure, equipment and indoor scattering are almost nothing in the seismically isolated buildings.
b) From observed acceleration waveforms during the main shock, the isolated effect, that is., the reduction of acceleration, was recognized in the horizontal vibration, while the vertical acceleration was a little amplified.
c) The water of pipes plays a role of melting snow. On the other hand, in backsides of the building, there is much snow along the building.

7) Building Damage by Fire
a) Only nine building fires occurred in areas with high seismic intensity after the earthquake. Almost all fires occurred immediately after the mainshock or aftershocks. At the 1995 Hyogo-ken Nambu earthquake, more than 200 fires occurred not only just after the mainshock, but also after several hours or several days.
b) The most damaged case was that six buildings burnt in conjunction with the landslide.
c) The fires after the earthquake were caused by heater, gas explosion, electricity, incense stick, and etc.
d) The mainshock occurred just time for cooking dinners by using gas ranges. Many people got scald, but no fires occurred by the gas fittings. It is assumed that gas leak and fires were prevented, because microcomputer-controlled gas meters for assurance of safety by automatic shut-off were installed nearly 100% in dwellings.

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4. Earthquake Observation Data were provided by Mr. Masatoshi Tamari of Mitsubishi Jisho Sekkei Inc.

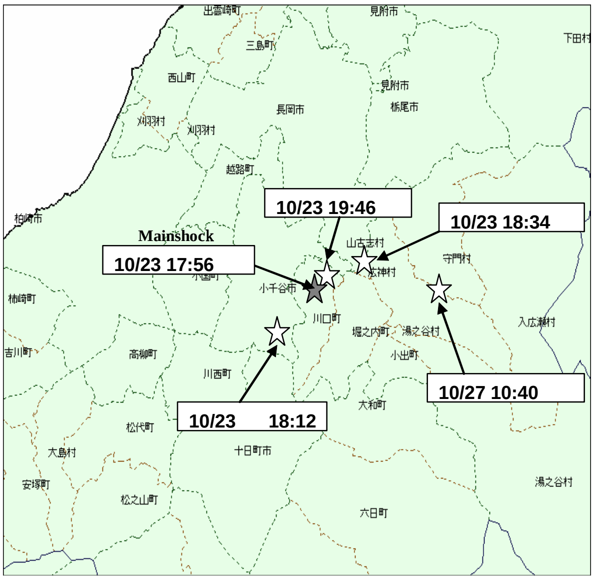


Fig. 1 Locations of Epicenter for Main and After Shocks

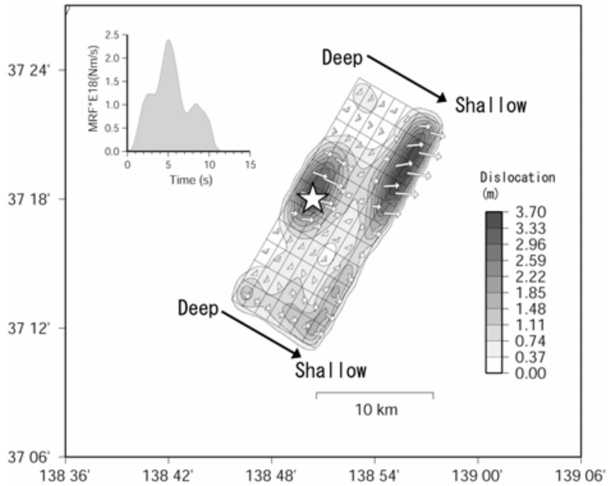
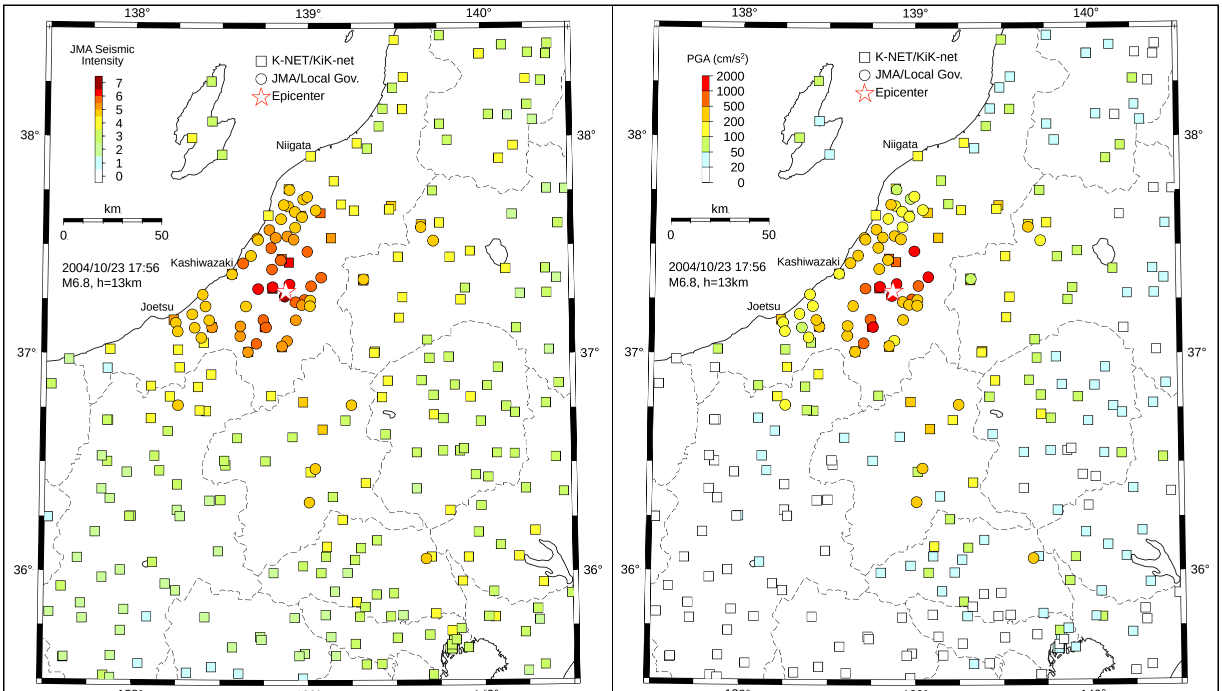


Fig.2 Slip Distribution on Fault Plane and Source Time Function



(a) Seismic Intensity Distribution for Mainshock

(b) PGA Distribution for Mainshock

Fig. 3 Distribution of Earthquake Ground Motions

Table 1 PGAs and PGVs for Major Strong Motion Records from JMA, K-NET, KiK-net and Seismic Intensity Information Network for Local Governments

Type	Symbol	Site Name	Distance (km)	Inten-sity	Max. Acceleration (cm/s^2)			Max. Velocity (cm/s)		
					NS	EW	UD	NS	EW	UD
Niigata	65042	Kawaguchi	2.5	6.5	1141.9	1675.8	869.6	44.57	134.57	62.26
Niigata	65041	Yamakoshi	4.3	6.3	583.4	721.8	1059.1	100.99	90.20	68.79
K	NIG019	Odiya	7.0	6.7	1144.3	1313.5	820.0	96.14	132.13	31.16
JMA	JMA532	Odiya	7.0	6.3	779.2	897.6	730.8	60.79	92.63	23.25
K	NIG021	Tokamachi	21.1	6.2	1715.7	849.2	564.4	58.87	44.82	13.62
K	NIG028	Nagaoka	15.1	6.1	870.5	706.1	435.6	61.85	60.55	26.05
K	NIG020	Koide	10.6	5.5	521.8	407.6	312.2	31.72	25.52	14.56
JMA	JMA530	Nagaoka	16.2	5.5	395.8	430.3	324.5	31.30	23.55	16.85
K	NIG017	Nagaoka	16.9	5.5	468.5	369.0	331.0	40.05	23.55	15.05
JMA	JMA90F	Muikamachi	25.3	5.2	136.0	111.3	186.5	25.44	18.57	9.16
K	NIG022	Shiozawa	28.4	5.1	342.1	341.6	126.5	17.98	21.14	3.63
JMA	JMACB7	Hirokami	13.8	4.7	333.9	286.4	310.8	15.55	13.68	5.39

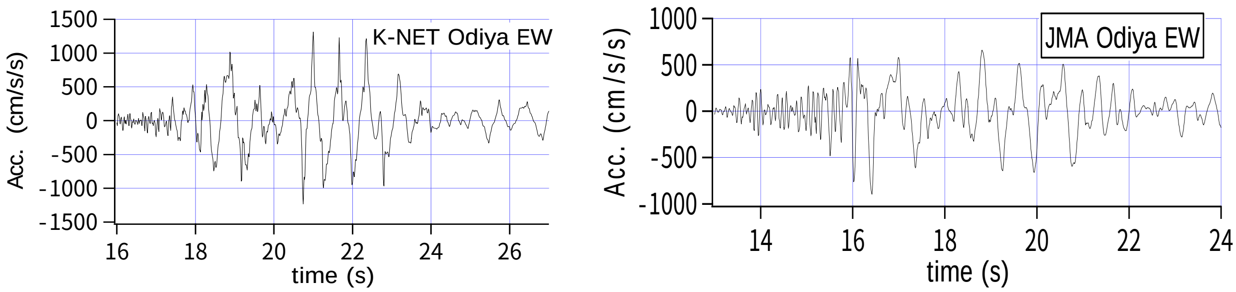


Fig. 4 Comparison of Waveforms for K-NET Odiya and JMA Odiya Stations

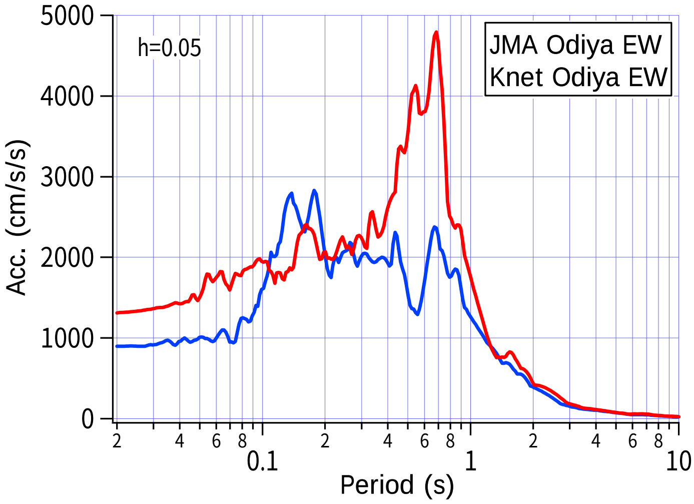


Fig. 5 Comparison of Acceleration Response Spectra

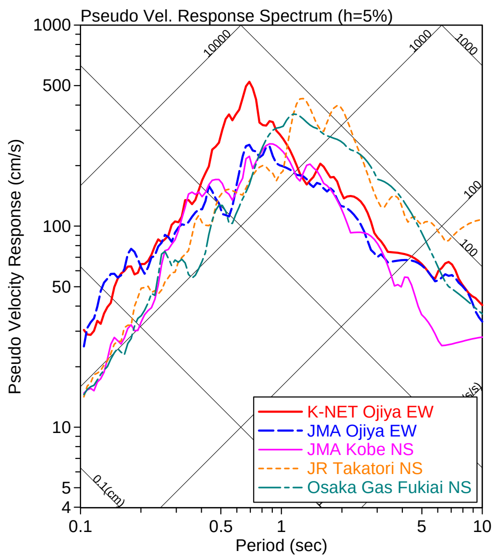


Fig. 6 Comparison of Pseudo Velocity Spectra for Odiya Records with 1995 Hyogo-ken Nambu Earthquake Records


Photo 1 Collapse of Workshop


Photo 2 Collapse of 2nd Story in House


Photo 3 Damage of Traditional House


Photo 4 Bending Rapture of Posts


Photo 5 Joint Failure at Brace End


Photo 6 Collapse due to Landslide

Photo 7 Damage of House with RC High Foundation

Photo 8 Collapse of House with RC High Foundation

Photo 9 Damage of RC High Foundation due to Damage of ground Site

Photo 10 Damage of Dwelling with Shop

Photo 11 Damage of Three-storied House with 1st Story of Steel Structure

Photo 12 Shear failure of short columns (Inside)

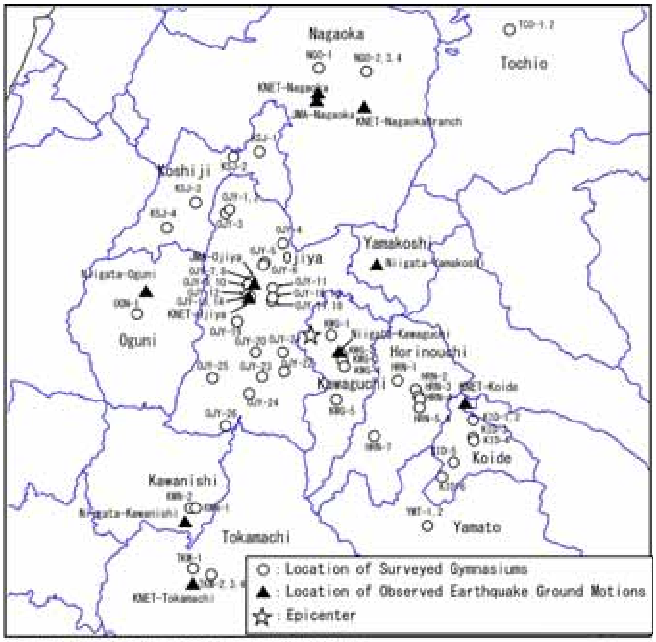
Photo 13 Shear failure of short columns (outside)

Photo 14 Building constructed in 1968

Photo 15 Shear Failure of Short Column

Photo 16 Shear Failure of Short Span Beam

Photo 17 Damage of Nonstructural Wall



※地図は国土地理院数値地図25000(行政界・海岸線)を利用

Fig.7 Location of Surveyed Gymnasiums

Photo 18 Fracture of Brace at Bolt Connection

Photo 19 Buckling of Brace

Photo 20 Fracture of Bolts at Brace Connection

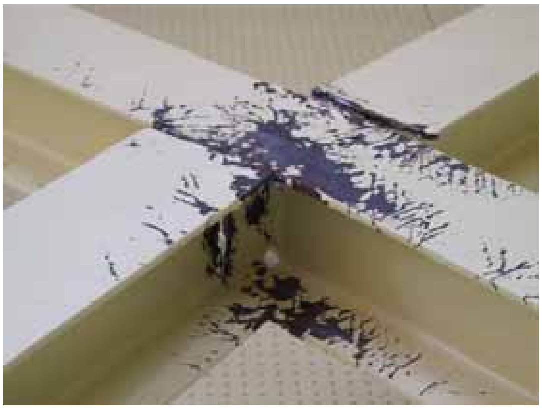


Photo21 Fracture of Welding Connection

Photo 22 Fracture of Bolts at Column Base

Photo 23 Fracture of Stud Base

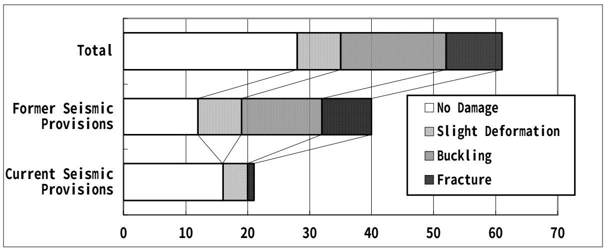


Fig. 8 Number of Damage on Braces

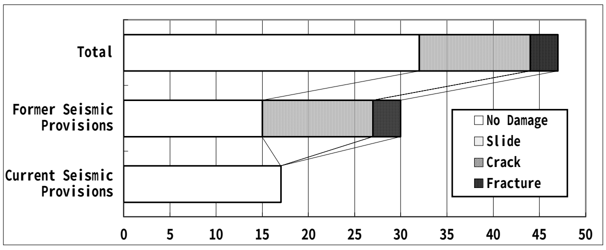


Fig. 9 Number of Damage to Bolt Connections on Brace

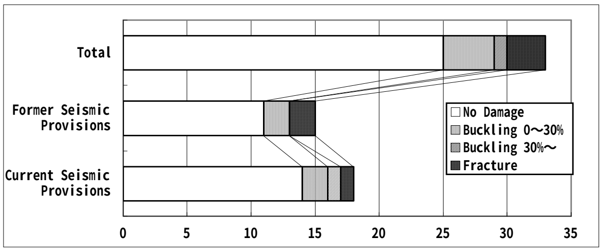


Fig. 10 Number of Damage on Roof Horizontal Braces

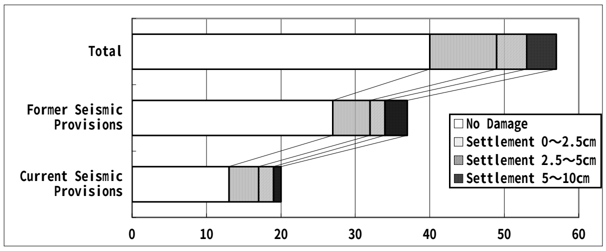


Fig.11 Number of Damage on Floor Settlement

Photo 24 Damage of Window Sash

Photo 25 Damage of Window Sash

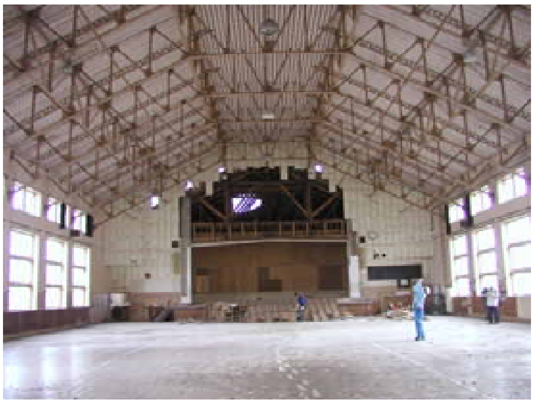


Photo 26 Dropped Interior Wall


Photo 27 Dropped Ceiling Board


Photo 28 Non Dropped Roof Board


Photo 29 Non Dropped Ceiling Board
(Seismic Retrofit Gym.)

Photo 30 Damage Examples (Landslide, Ground Crack)

Table 2 Quick Inspection Result of Housing Site (Up to 20 November 2004)

No.		Total	Red(unsafe)		Yellow(limited safe)		Bulue(inspected)	
1	Nagaoka city	1599	96	6%	81	5%	1422	89%
2	Ojiya city	226	135	60%	48	21%	43	19%
3	Tokamachi city	405	21	5%	15	4%	369	91%
4	Mitsuke city	152	25	16%	9	6%	118	78%
5	Mishima town	22	17	77%	1	5%	4	18%
6	Kawaguchi town	392	103	26%	95	24%	194	49%
7	Horinouchi town	63	22	35%	12	19%	29	46%
8	Koide town	73	11	15%	19	26%	43	59%
9	Kariwa village	56	6	11%	18	32%	32	57%
10	Nishiyama town	25	3	12%	3	12%	19	76%
11	Sumon village	164	26	16%	23	14%	115	70%
12	Koshiji town	126	45	36%	25	20%	56	44%
13	Irihirose village	10	4	40%	4	40%	2	20%
14	Oguni town	16	5	31%	8	50%	3	19%
	Total	3329	519	16%	361	11%	2449	74%

Photo 31 Damage Situation
(Upper Part of Slope, Youkyutyou in Nagaoka-shi)

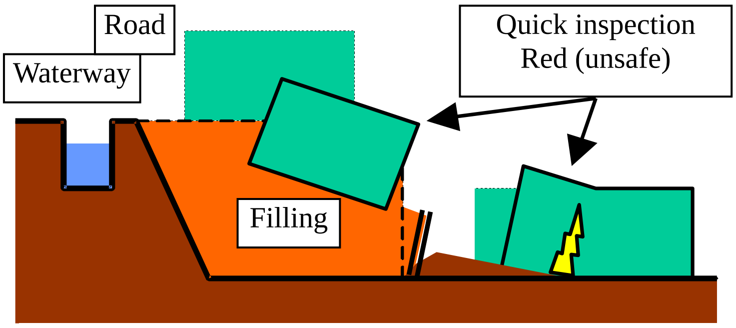


Fig. 12 Damage Situation
(Youkyutyou in Nagaoka-shi)

Photo 32 Damage situation
(Under part of slope, Youkyu-cho, Nagaoka-shi)

Photo 33 Damage Situation
(Liquefaction, Kariwa-village)

Photo 34 Damage Situation
(Liquefaction, Nagaoka-shi)

Table 3　Outline of Surveyed Seismically Isolated Buildings

Name	Super-structure	No. of Story	Use	City	Kinds of Isolators	Earthquake Motion Observation
A	RC	5	Welfare	Odiya-city	Sliding Bearing and Natural Rubber Bearing	O
B	RC	8	Collage	Nagaoka-city	High Damping Rubber Bearing	O
C	RC	4	Office	Nagaoka-city	Lead Rubber Bearing	O*1
D	RC	3	Clinic	Sanjyo-city	Lead Rubber Bearing and Natural Rubber Bearing	
E	S	3	House	Niigata-city	Sliding Bearing and laminated rubber	
F	RC	4	Hospital	Yuzawa-Machi	Lead Rubber Bearing, Natural Rubber Bearing and Ball bearing	

*1 : A scratched displacement apparatus was installed

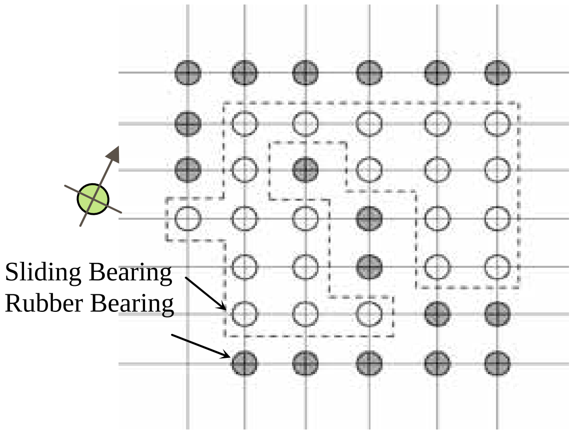


Fig. 13　Arrangement of Isolators

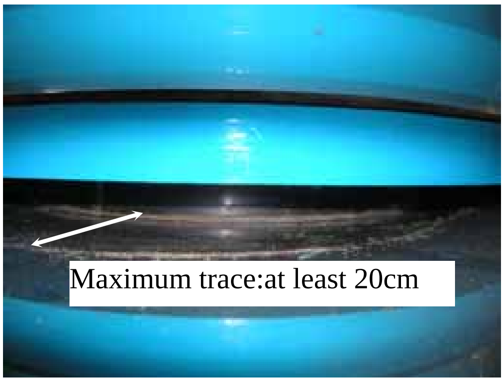


Photo 35　Sliding Trace of Sliding Plate

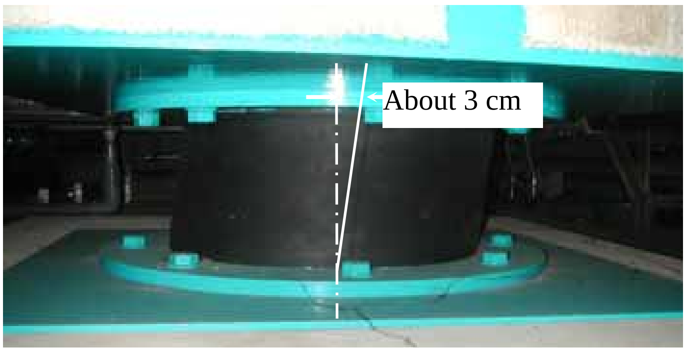
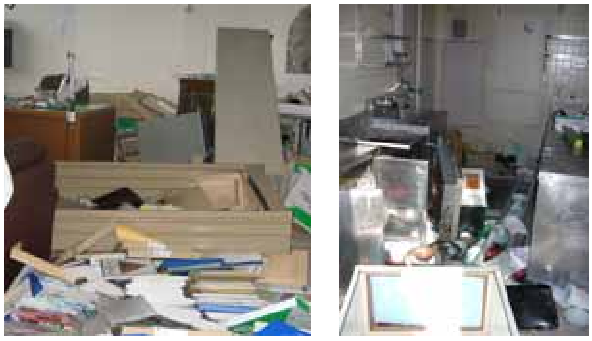


Photo 36　Residual Deformation of Rubber Bearing

(a) Inside Isolated Building



(b) Inside Non-isolated Building

Photo 37 Indoor Situation of isolated and Non-isolated Buildings
(Photos are provided from Mr. Masatoshi Tamari of Mitsubishi Jisho Sekkei Inc.)

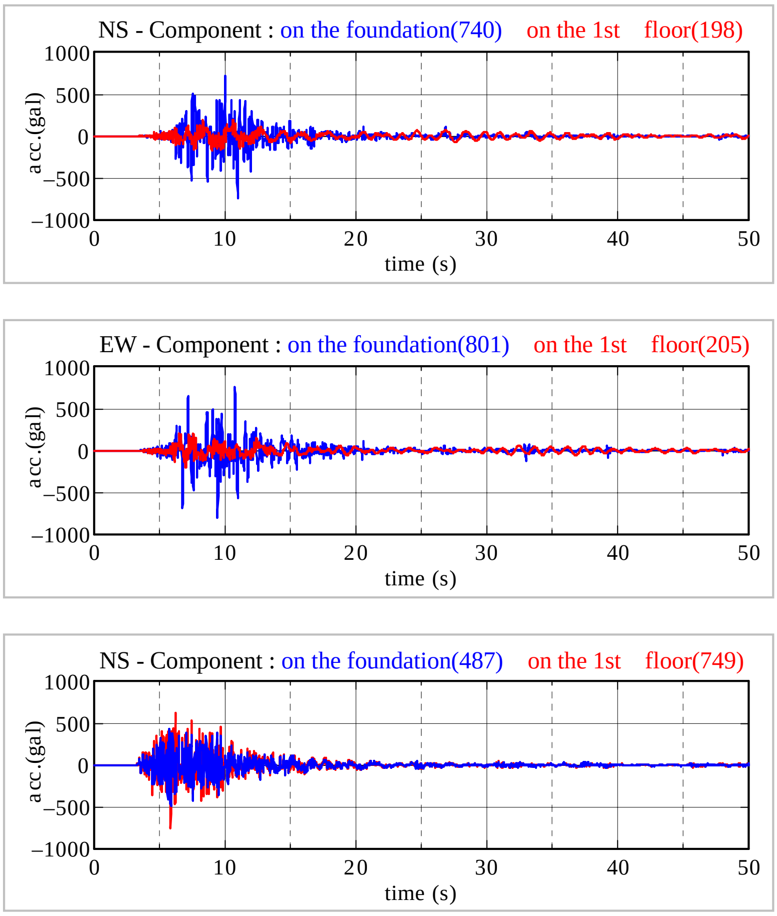


Fig. 14 Observed Acceleration Waveforms during Main Shock in Building A

Table 4 Maximum Acceleration in Building A

Direction	Foundation (Below isolator)	1st floor (Above isolator)	Ratio of1st floor to foundation
NS	740.4	198.0	0.27
EW	807.7	205.2	0.25
UD	487.2	749.4	1.54

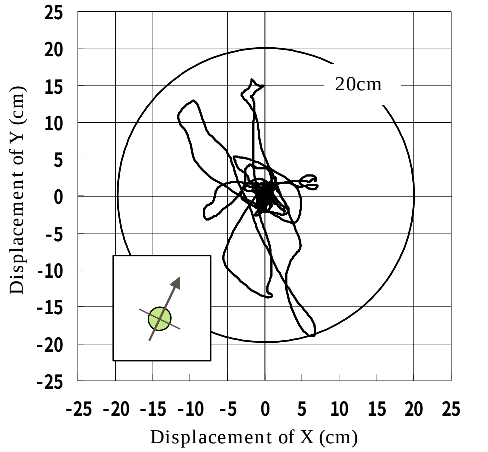


Fig. 15 Displacement Trace of Isolated Layer in Building A

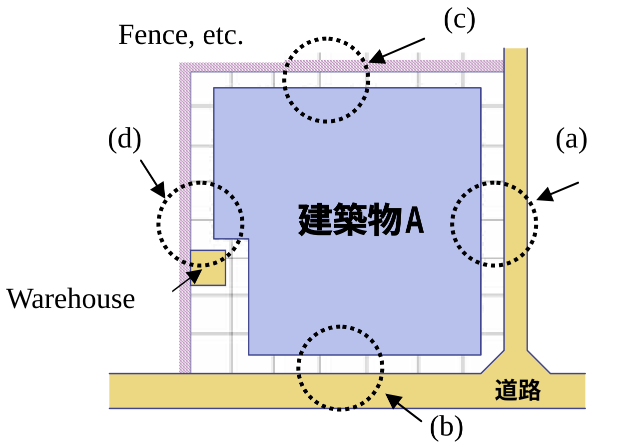
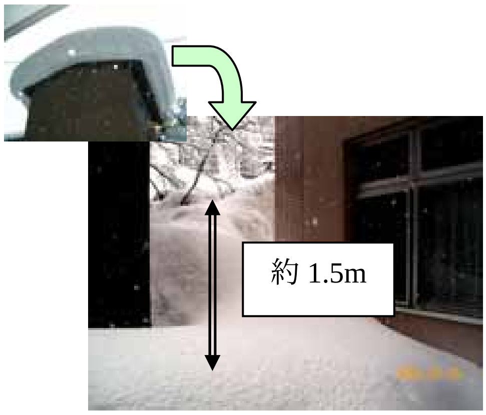


Fig. 16 Position for Observation of Snow
(a to d are corresponding to those in Photo 38)

(a) Water for Melting Snow

(b) No Snow belong Road

(c) Drift of Snow

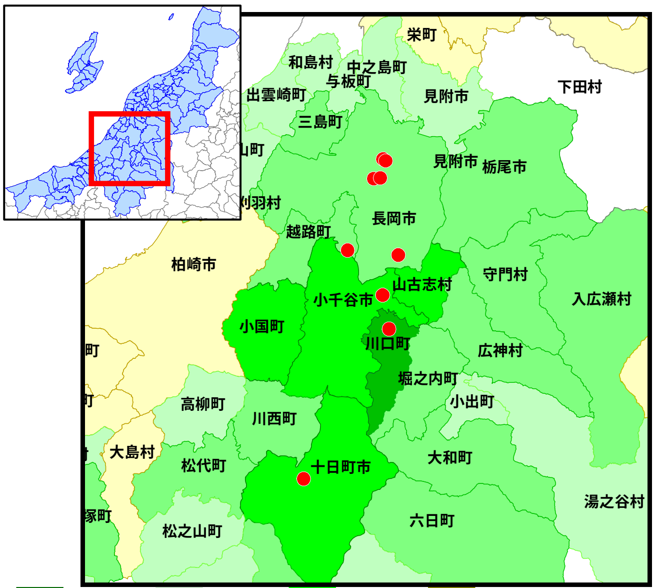


(d) Fall of Snow from Next Door

Photo 38 Situation of Snow around Building

Table 5 Building Fires after Earthquake

	Building Usage	Structure, N. of floors	Site	Damage	Cause of fires	Time
1	factory	S, 2F	urban	limited	electricity	immediately
2	factory	S, 2F	urban	limited	liquid metal	immediately
3	hotel	RC, 9F	urban	partly	gas explosion	immediately
4	house	unknown	rural	6 buildings	unknown (landslide)	immediately
5	apartment	S, 3F	urban	whole building	gas explosion	immediately
6	house	W, 2F	rural	limited	incense stick	immediately
7	warehouse	W, 2F	rural	whole building	heater	immediately
8	house	W, 3F	rural	2 buildings	heater	immediately
9	house with office	S, 3F	urban	limited	heater	unknown



SI7 SI6+ SI6- SI5+ SI5- SI: JMA Seismic Intensity

Fig. 17 Location of Building Fires

Photo 39 Site of Nigorisawa Fire and Landslide (Six Buildings Burnt Down)

Photo 40　Site of　Iwamagi Dwelling Fire (Two Building Burnt Down)

Photo 41　Site of　Sen-ju Three Story Apartment House Fire