ICUS NEWSLETTER

International Center for Urban Safety Engineering

Institute of Industrial Science
The University of Tokyo

SPECIAL ISSUE
January 2005

Central Part of Niigata Prefecture, Japan was Striken by M 6.8 Earthquake on October 23, 2004

By

Kimiro MEGURO

A magnitude 6.8 earthquake, with a focal depth of 13 km, stroke the central part of Niigata Prefecture, Japan, at 17:56 on October 23, 2004. Due to this earthquake, strong ground motions up to 1.7 g were recorded. Forty people were killed and 2,800 houses collapsed or were heavily damaged. Many landslides and liquefied sites were observed. Civil infrastructure such as highway facilities, bullet train system, and many other lifeline systems were also damaged. ICUS dispatched reconnaissance teams to the affected sites several times to investigate various damage due to the earthquake. This is a quick report summarizing these site surveys.

On October 23, 2004, at 17:56, a magnitude 6.8 earthquake, with a focal depth of 13 km, stroke the central part of Niigata Prefecture. The Japanese Meteorological Agency (JMA) named this event the 2004 Mid-Niigata Prefecture Earthquake. Due to this earthquake, strong ground motions with JMA seismic intensity, I_{JMA}, 7, which corresponds to the highest intensity in this scale, were observed. This is the first time since the JMA changed its intensity definition, from a human perception based definition to an instrumental observation based one, that this intensity was observed.

Peak ground accelerations up to 1.7g and peak ground velocities up to 133 kines were observed. These are much higher than those of the ground motion recorded during the 1995 Kobe Earthquake. I_{JMA} 7 was observed at Kawaguchi town and Ojiya city. Yamakoshi village and Oguni town experienced I_{JMA} 6+ while I_{JMA} 6- was observed at Nagaoka city, Tookamachi city, Tochio city, Koshiji town, Mishima town, and Horinouchi town.

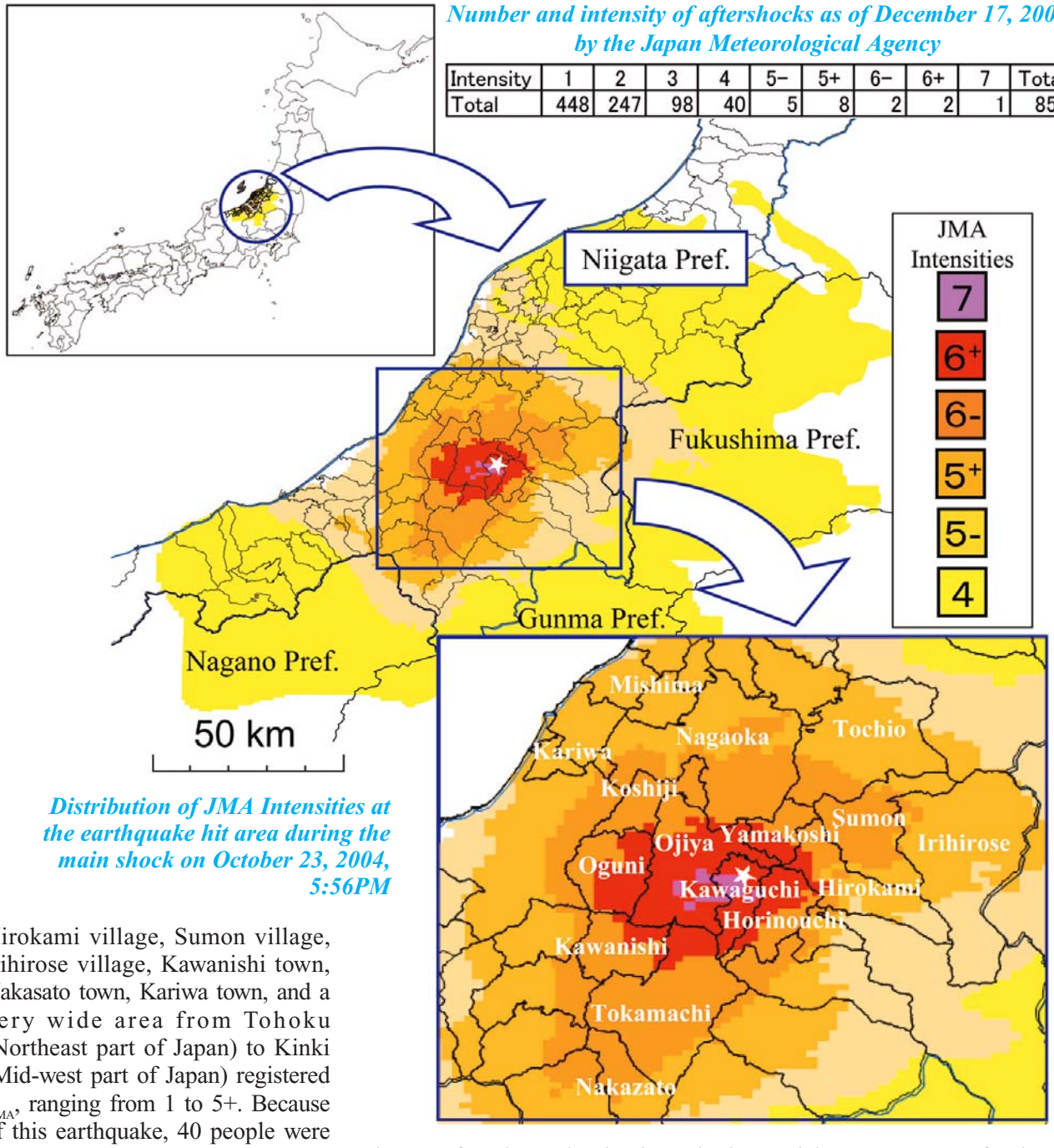
(Urasa-agaoka, Joetsu-Shinkansen, Nagaoka city, 25/10/2004)

The bullet train derailed for the first time since it started operations in 1964.

Very strong ground motion was observed...

Number and intensity of aftershocks as of December 17, 2004 by the Japan Meteorological Agency

Intensity	1	2	3	4	5−	5+	6−	6+	7	Total
Total	448	247	98	40	5	8	2	2	1	851



Distribution of JMA Intensities at the earthquake hit area during the main shock on October 23, 2004, 5:56PM

Hirokami village, Sumon village, Irihirose village, Kawanishi town, Nakasato town, Kariwa town, and a very wide area from Tohoku (Northeast part of Japan) to Kinki (Mid-west part of Japan) registered I_{JMA}, ranging from 1 to 5+. Because of this earthquake, 40 people were killed and 4,500 were injured.

This earthquake was the first event in which the derailment of a bullet train was observed since they entered service in 1964. Fortunately, no fatal victims were reported. This service line is not very congested and at the time of the earthquake only one of the lanes was being used.

One of the most important characteristics of this earthquake is the huge number of large aftershocks. On the same day of the main shock, three aftershocks with magnitude 6 or more stroke. The first occurred at 18:03, just seven minutes after the main shock, and had a M6.3 and a maximum recorded I_{JMA} 5+. Eight minutes after, at 18:11, a M6.0 event with a maximum recorded I_{JMA} 6+ was felt. At 18:34, a M6.5, maximum I_{JMA} 6+ stroke the same region. Beside these three events, three more with I_{JMA} 6+ were felt on October 23, 19:45, M5.7, maximum I_{JMA} 6-, on October 27, 10:40, M6.1, maximum I_{JMA} 6-, and on November 8, 11:15, M5.9, I_{JMA} 5+, as shown in the table at the top of this page. This table shows the number of aftershocks and the corresponding maximum recorded intensities. Because of a large number of aftershocks, landslides and structural damage gradually progressed and consequently affected the life of the people living in the area.

The statistics of human casualties and structural damage are introduced in the table on the next page. Because of this earthquake, 40 people were killed, 9 of them due to structural collapse. The other victims died for other reasons such as shock, exhaustion, stress, and the economy class syndrome. The latter was caused by the long periods that

the residents had to sleep in their cars, in uncomfortable positions, because of the insecurity of their houses and their fear due to the huge number of aftershocks. The number of collapsed, moderately damaged, and slightly damaged houses were 2,800, 10,600, and 88,500, respectively.

The ground motion due to the 2004 Mid-Niigata Prefecture Earthquake was very large. Peak ground accelerations (PGA) up to 1.7g and peak ground velocities (PGV) up to 133kines were observed. The response spectra depicted below shows the earthquake high power in the high frequency, or short period, range, from 0 to 1sec. Response accelerations over 6,000 Gals are observed. This is much higher than the power of the ground motion during the 1995 Kobe Earthquake for a similar frequency range. However, on a longer period range, from 1 to 2 sec, the Kobe ground motion power was higher. The frequency content characteristics of the Mid-Niigata Prefecture Earthquake may partially explain the relatively small structural damage observed as compared to that during the Kobe Earthquake. However, other reasons such as the high structural strength of the dwellings should also be taken into account.

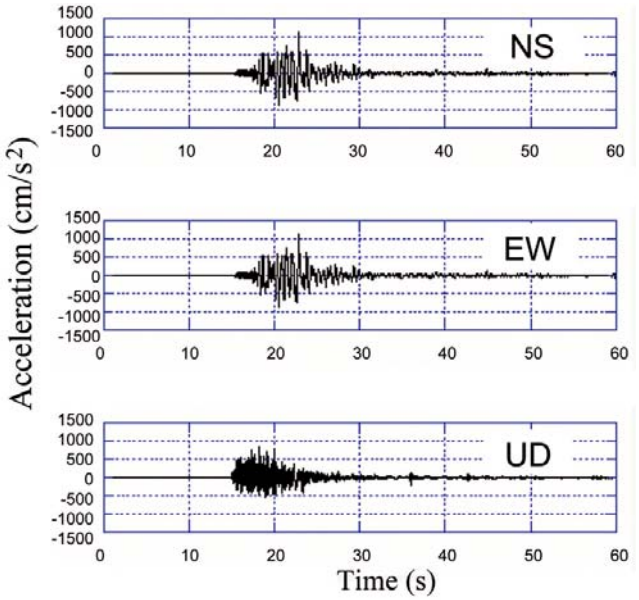
Due to the severe winter and huge snow fall that is common in this area, houses are built with small openings, to keep them warm, and robust foundations and structural elements, to resist the snow weight. These features increase the overall structural strength. It is not surprise to observe that most of the collapsed houses were either old or presented soft stories in the 1st floor were open spaces were allocated. On the other hand, the extremely high power in the high frequency range may explain the huge number of rock falls and landslides, non-tensile material structures, which are more affected by this type of excitations.

Casualties, damaged buildings, and fires caused by the earthquake at different prefectures (as of December 24, 2004 by Fire and Disaster Management Agency)

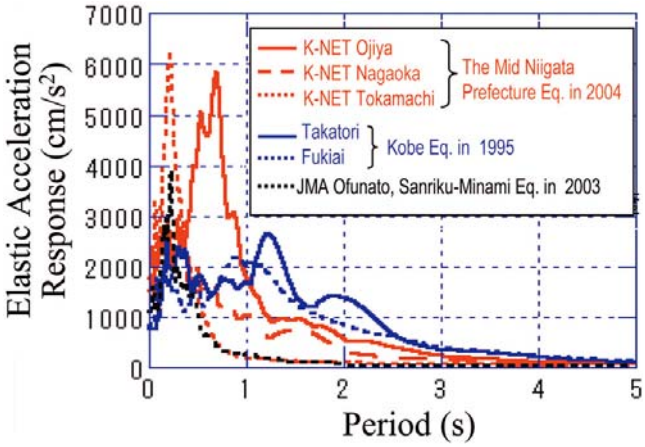
	No. of Casualties		No. of Damaged Residential Houses			
	Death	Injured	Collapsed and Heardly damaged	Moderately damaged	Slightly damaged	Burned out
Niigata	40	4,536	2,842	10,568	87,492	9
Nagano		3				
Saitama		1				
Fukushima					1	
Gunma		6			1,031	
Total	40	4,546	2,842	10,568	88,524	9

(Kawaguchi, Kawaguchi town, 27/10/2004)

Graveyard at Kawaguchi town where I_{JMA} was 7



Strong ground motion recorded at the K-Net Ojiya station (PGA: 1500.7gal, PGV: 133.4kine, I_{JMA}: 6.73)



Response spectra corresponding to the 2004 Mid Niigata Prefecture and the 1995 Kobe Earthquakes

Landslides and rock falls blocked roads...

The 2004 Mid-Niigata Prefecture Earthquake occurred in a mountainous area which was hit by heavy rainfalls and typhoons just prior to the earthquake occurrence. These previous events saturated and loosen the soil, and therefore when the earthquake stroke the mountain slopes where particularly vulnerable. For this reason, the geotechnical related damage was widespread and much more considerable than the structural damage.

Geotechnical related damage to people and buildings.
(as of November 26, 2004
by Ministry of Land, Infrastructure and Transport)

	No. of events	No. of Casualties		No. of Damaged Residential Houses		
		Death	Injured	Collapsed and Heardly damaged	Moderately damaged	Slightly damaged
Debris Flow	21	0	0	0	0	1
Land Slide	131	2	0	15	23	31
Rock Fall	115	2	1	0	1	14
Total	267	4	1	15	24	46

Route 291 which connects Ojiya to Yamakoshi was blocked. (Yokowatashi, Ojiya city, 26/10/2004)

Route 291 which connects Ojiya to Yamakoshi was blocked. (Kawai, Ojiya city, 9/12/2004)

(Myoken, Nagaoka city, 25/10/2004)

Huge landslide on the riverside of Shinano River
View from the riverside opposite to the landslide

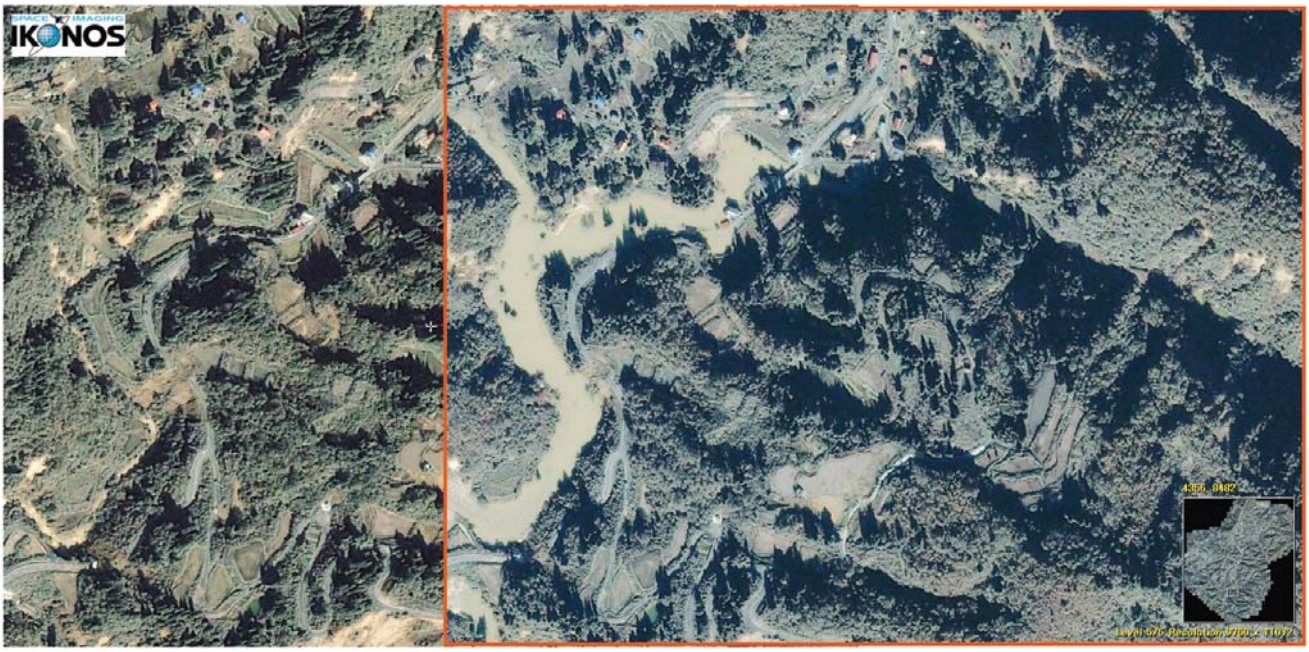
(Myoken, Nagaoka city, 25/10/2004) (Myoken, Nagaoka city, 24/10/2004)

Satellite view of the area before (left) and after (right) the earthquake

(Myoken, Nagaoka city, 26/10/2004)

View of the landslide from the riverside where it occurred

Landslides also blocked riverbeds forming natural dams and causing flooding...



(Higashi-Takezawa, Yamakoshi village, 24/10/2004) (Higashi-Takezawa, Yamakoshi village, 29/10/2004)

Satellite image of the area one (left) and six (right) days after the earthquake

(Higashi-Takezawa, Yamakoshi village, 24/10/2004) KOKUSAI KOGYO CO., LTD.

Aerial view of the landslide affcted area

(Tanesuhara, Yamakoshi village, 24/10/2004) KOKUSAI KOGYO CO., LTD.

(Iketani, Yamakoshi village, 24/10/2004) KOKUSAI KOGYO CO., LTD.

Aerial view of the landslide affcted area

(Uragara, Ojiya city, 26/10/2004)

House turned into dam due to a landslide that blocked the river flowing next to it before the earthquake

(Uragara, Ojiya city, 26/10/2004)

Uragara, Ojiya city was flooded due to over flowed water from the dam shown in the photo on the top of this page.

Liquefaction induced severe damage...

(Wakaba, Ojiya city, 27/10/2004)

Numerous manholes uplifted by the increase in the pore water pressure associated with liquefaction induced by the earthquake

(Katada-cho, Nagaoka city, 29/10/2004)

(Kawaguchi, Kawaguchi town, 27/10/2004)

In the left photo, the concrete belt along the centerline of the road is a snow melting water system. This system is widely used in the affected area and together with other lifeline systems, it was also severely damaged due to liquefaction.

The photo on the right shows a temporary snow melting system prepared for winter.

(Kawaguchi, Kawaguchi town, 09/12/2004)

Weak houses collapsed...

(Kawaguchi, Kawaguchi town, 27/10/2004)

Because of severe winter condition in the affected area, such as cold temperature and heavy snow fall, houses are built with small openings, to keep them warm, and robust foundations and structural elements, to resist the snow weight. The roofs are made of light materials to prevent snow accumulation.

Furthermore, due to the weather conditions in the area, there is less deterioration of wooden structures

(Kawaguchi, Kawaguchi town, 27/10/2004)

(Kawaguchi, Kawaguchi town, 27/10/2004)

...but, new strong houses remained intact.

due to termite attack. These features increase the overall structural strength against earthquake motion.

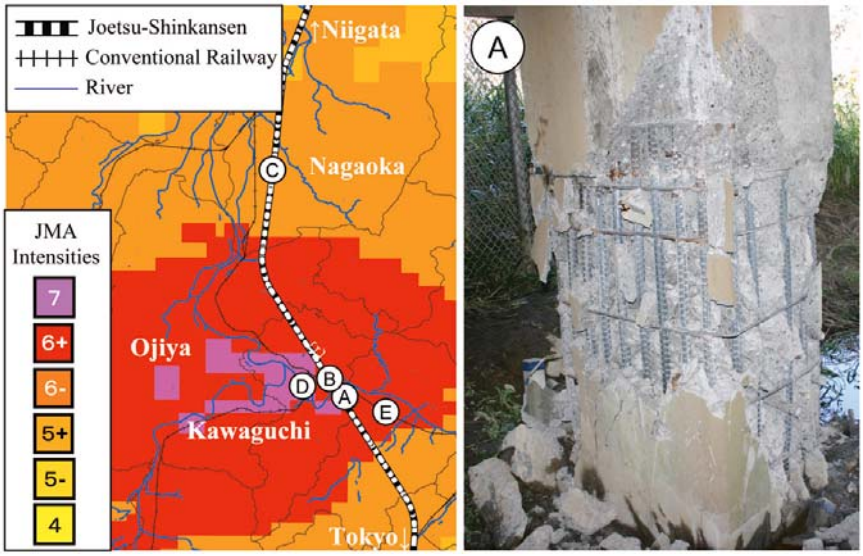
Most of the collapsed houses were old and had soft first story, without enough walls, used for parking or shop. Relatively new and typical houses, constructed considering the winter weather condition in the affected area, remained intact even at the locations where very strong ground motion was recorded.

(Kawaguchi, Kawaguchi town, 07/12/2004)

(Kawaguchi, Kawaguchi town, 27/10/2004)

(Shimojima, Horinouchi town, 26/10/2004)

Bullet train derailed and its service was disrupted...



(Urasa-Nagaoka, Joetsu-Shinkansen, Kawaguchi town, 29/10/2004)

A bullet train viaduct pillar with little transverse reinforcement failed in shear.

(Urasa-Nagaoka, Joetsu-Shinkansen, Kawaguchi town, 26/10/2004)

Bullet train viaduct pillars exhibited concrete spalling at the sections where longitudinal rebars were cut.

The 2004 Mid-Niigata Prefecture Earthquake was the first event in which the derailment of a bullet train, Shinkansen in Japanese, was observed since they entered service in 1964. Fortunately, this service line is not very congested and at the time of the earthquake only one of the lanes, the one bound for Niigata, was being used. No fatal victims were reported. If two trains had been running in opposite directions when the earthquake stroke, most likely the consequences would have been more severe. The photos show damage to the pillars of the bullet train viaduct. At several columns, concrete cover spalling was observed at the points where a portion of the longitudinal rebars were cut. On others, the few amount of transverse reinforcement caused column shear failure.

The Urgent Earthquake Detection and Alarm System, UrEDAS, system, whose objective is to stop running bullet trains before the major earthquake wave reaches them, was in operation during this earthquake. This system is very useful when the distance between the epicenter and the running train is long enough so

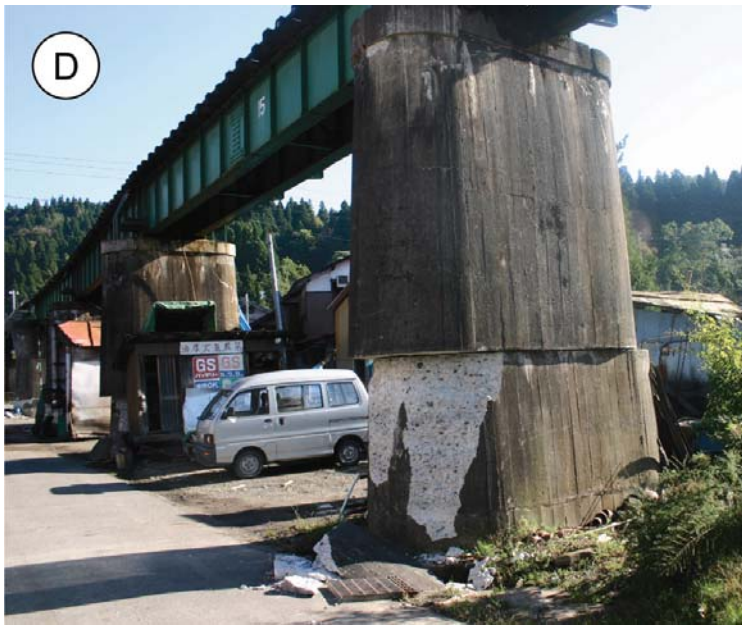
(Urasa-Nagaoka, Joetsu-Shinkansen, Nagaoka city, 25/10/2004)

The bullet train derailed for the first time since it started operations in 1964.

...other train facilities were also disrupted.

that the alerting signal arrives before the earthquake motion. However, when the train is too close to the epicenter, as in this event, the UrEDAS system cannot accomplish its objective.

Not only the bullet train but also local lines were disrupted. Landslides blocked railways, embankments settled and left railways hanging, and pillars constructed according to old standards failed.



(Echigo-Kawaguchi-Uchigamaki, Iiyama-line, Kawaguchi town, 29/10/2004)

Pillars constructed according to old standards failed.

(Echigo-Kawaguchi-Uchigamaki, Iiyama-line, Kawaguchi town, 29/10/2004)

Embankments settled and left railways hanging.

(Kita-Horinouchi-Echigo-Kawaguchi, Joetsu-line, Horinouchi town, 26/10/2004)

Railway facilities were damaged at many locations by landslides.

Highways and roads were damaged...

(Ojiya-ohashi bridge, Route 17, Ojiya city, 26/10/2004)

A bridge pillar suffered concrete spalling at the location where the longitudinal rebars where discontinued and where there was a drastic change of the pillar cross section.

(Ojiya-Tokamachi, Route 117, Ojiya city, 26/10/2004)

Settlement of the bridge abutment caused damage to the bridge access section.

(Horinouchi-Echigo-Kawaguchi, Kanetsu Expressway, Horinouchi town, 24/10/2004) KOKUSAI KOGYO CO., LTD.

(Ojiya-Yamakoshi, Route 291, Ojiya city, 26/10/2004)

Geotechnical related damage caused disruptions at several locations along highways (top) and national roads (bottom).

Lifelines were disrupted...

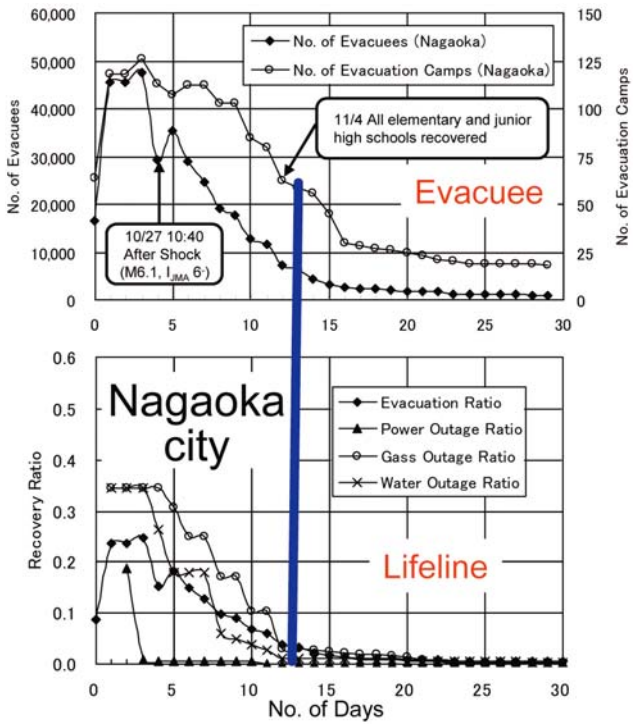
Another feature of the Mid-Niigata Prefecture Earthquake is the large number of evacuees if the extent of the structural damage is considered. The main reason for this is the large number of aftershocks, which caused 100,000 people to flee to evacuation centers. The graph below shows that after lifelines were restored, the number of evacuees dramatically decreased. The city with the largest number of evacuees was Nagaoka.

As mentioned in the previous paragraph, this earthquake evacuees were people who flee to evacuation centers due to fear of the aftershocks and lifeline disruption. After these factors were eliminated, most of them were able to promptly return to their homes. During the Kobe earthquake, evacuees were people whose houses collapsed and therefore had no place to go. As result, the earthquake indirect victims were numerous. This phenomenon will most likely not be observed for the Mid-Niigata Prefecture Earthquake.

The Mid-Niigata Prefecture Earthquake also put in evidence the importance of coordination among lifeline recovery activities for efficient recovery operations.

(Misawa, Nagaoka city, 01/11/2004)
THE JAPAN GAS ASSOCIATION

Gas pipe line was filled with leaked water from damaged or under reparing water supply system



Relation between number of evacuees and recovery ratio of lifeline system in Nagaoka city

(Echigo-Kawaguchi Station, Kawaguchi town, 30/11/2004)
NOMURA RESEARCH INSTITUTE, LTD.

Damage to power supply system

... but life continues in the affected areas

Quick inspection of buildings was carried out to determine damage levels. Seals - red, yellow, and green, in order of damage severity - were posted accordingly.

(Honcho, Ojiya city, 27/10/2004)

A center for collection of relief material sent to the affected area

(Tamugiyama Branch of Higashii-Kawaguchi Nursery, Kawaguchi town, 07/12/2004)

A disaster relief operation center at Nagaoka city hall

(Nagaoka city hall, Nagaoka city, 07/12/2004)

Life of the victims in the affected areas

Portable kitchen facilities prepared by Self Defense Force

(Kawaguchi, Kawaguchi town, 07/12/2004)

Tents prepared by Self Defense Force

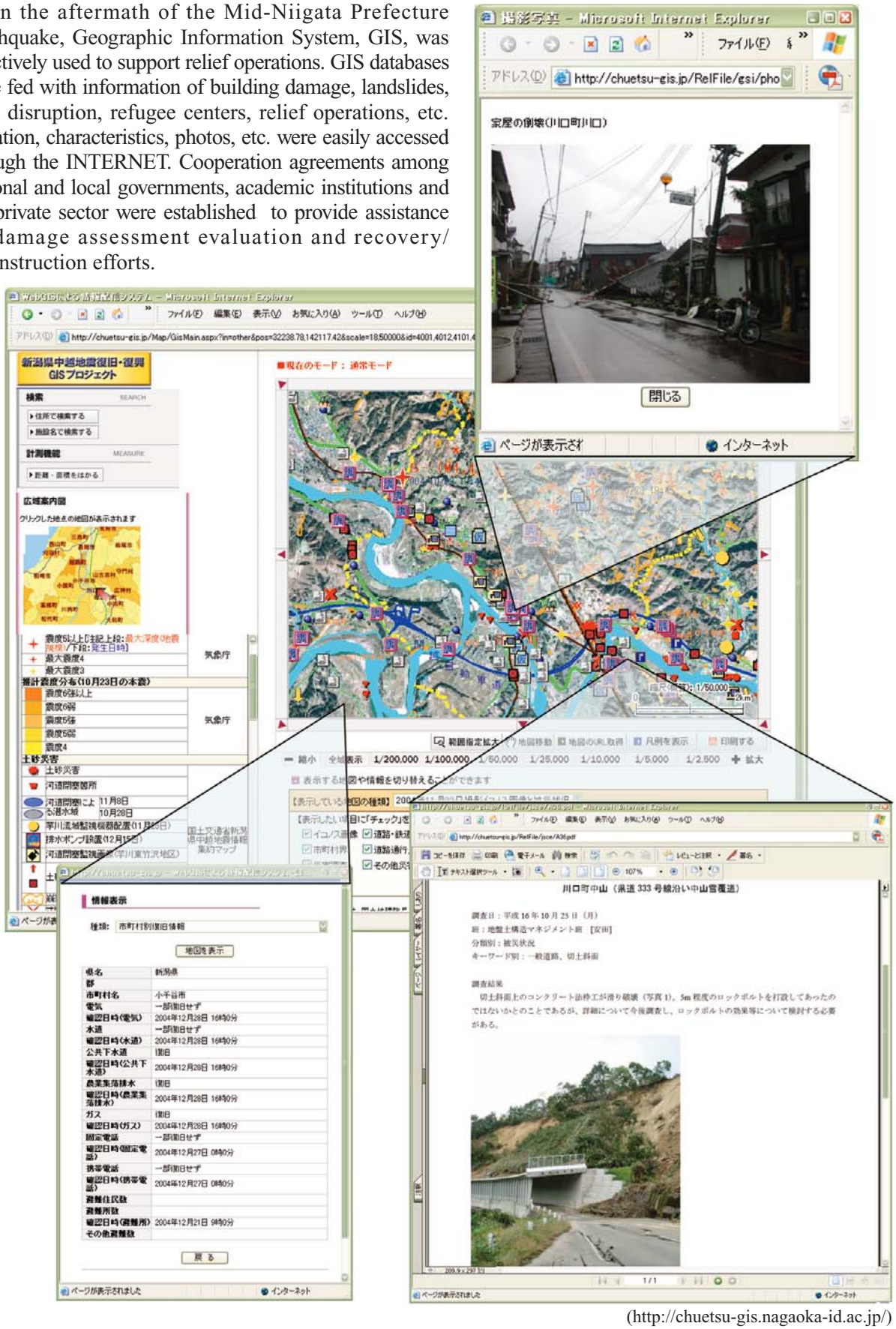
(Asahi-cho, Ojiya city, 07/12/2004)

Temporary housing for the people displaced by the earthquake was set up before the arrival of the winter season.

(Tamugiyama, Kawaguchi town, 07/12/2004/)

Geographic Information System greatly contributed for damage assessment, quick recovery and reconstruction activities

In the aftermath of the Mid-Niigata Prefecture Earthquake, Geographic Information System, GIS, was effectively used to support relief operations. GIS databases were fed with information of building damage, landslides, road disruption, refugee centers, relief operations, etc. Location, characteristics, photos, etc. were easily accessed through the INTERNET. Cooperation agreements among national and local governments, academic institutions and the private sector were established to provide assistance on damage assessment evaluation and recovery/ reconstruction efforts.



(http://chuetsu-gis.nagaoka-id.ac.jp/)

GIS database was quickly set to assist the relief operations.

Editor's Note

The 2004 Mid-Niigata Prefecture Earthquake was characterized by high seismic intensities and a large number of aftershocks. In spite of this, the observed structural damage was relatively minor. This is clearly showing us that structural strength is the key issue to reduce overall earthquake damage. Obviously, other issues, which have not been previously discussed, such as the economy class syndrome, were observed. However, if the structural damage would not have been so minor, these issues would have not been highlighted.

Because the stricken area was mountainous and huge number of landslides occurred, many areas and its residents were isolated. Under these circumstances, the use of helicopters proved to be essential. In the future, similar situations will be faced in mountainous areas and therefore we should device procedures to deal with them.

Another lesson learnt from this earthquake is related to how to perform recovery activities when a severe winter season is very close to the earthquake occurrence. In this case, there is a very short time period to perform reconstruction activities and furthermore, heavy snow loads acting on already damaged structures are enough to cause their collapse. In the case of the Mid-Niigata Prefecture Earthquake, all recovery/ reconstruction activities have been postponed until spring. Up to that time, how to maintain the remaining structures and how to prevent more damage needs to be addressed. Lifeline recovery, especially the water snow melting system, which is currently stopped, should also be given careful consideration for future events. As observed during the Kobe Earthquake, coordination among the entities in charge of repairing different lifelines was essential for an efficient and prompt service restoration.

Another point that needs to be addressed is the issue of house damage certificates. According to the current system in Japan, the authority in charge of emitting damage certificates is different from the one that provides the financial compensation to the house owner. The amount of the compensation is decided according to the damage certificate. Because two entities are involved in this process, it is difficult to conceal their approaches. This may eventually lead to an unrealistic large number of highly damaged structures, which are eligible for huge financial compensations. Because damage was limited during the Mid-Niigata Prefecture Earthquake, this problem did not cause a huge burden to the government. However, if a larger scale event strikes Japan, the financial compensation system may collapse.

The photos shown in this special issue were taken by members of ICUS unless otherwise stated. The institutions that kindly granted permission for using their materials are gratefully acknowledged.

Dr. Paola Mayorca, Post Doctoral fellow, and Mr. Shinya Kondo, Ph.D candidate of Meguro research group of ICUS contributed to the preparation of this special issue.

(K. Meguro)

International Center for Urban Safety Engineering, ICUS
Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
Tel: (+81-3)5452-6472, Fax: (+81-3)5452-6476
E-mail:icus@iis.u-tokyo.ac.jp
http://icus.iis.u-tokyo.ac.jp/

PRINTED MATTER

ICUS/INCEDE
INSTITUTE OF INDUSTRIAL SCIENCE THE UNIVERSITY OF TOKYO
International Center for
Urban Safety Engineering