Preliminary Report: Mid-Niigata Prefecture Earthquake

Preliminary report on damage caused by the Mid-Niigata Prefecture Earthquake on October 23, 2004

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Introduction

Main shocks of magnitude 6.8, 6.0 (provisional) and 6.5 struck the Chuetsu region of Japan in Niigata Prefecture at 17:56, 18:12 and 18:34, respectively, on October 23, 2004. The Japan Society of Civil Engineers (JSCE) requested support from its Earthquake Engineering and Concrete Engineering committees as well as from the Japanese Geotechnical Society (JGS). The organizations jointly dispatched an emergency damage investigation team (to carry out a primary investigation). Later, a secondary investigation team was dispatched to cover other aspects of the earthquake such as its social impact. This preliminary report outlines the earthquake and gives details of earthquake-related damage observed by the primary investigation team.

Earthquake motion

To give an idea of the size of the earthquake source fault, the distribution of aftershock hypocenters is shown in Fig. 1.[1)] As this figure indicates, the hypocenters are concentrated in a fault valley between the Tokamachi and Muikamachi seismogenic faults. Figure 2 is a cross-sectional view in a northwest-southeast direction of the distribution of aftershock hypocenters (in red) and micro earthquakes preceding the main shocks (in blue). As is apparent from the distribution of micro earthquake hypocenters, several active fault planes exist in the region. Judging from the fault mechanism as determined from the main shock records, the fault that triggered the earthquake is a reverse fault.[2)] Similarly, the distribution of aftershock hypocenters in Fig. 2 indicates that fault movement occurred between a foot wall with a relatively steep angle of about 60° to the southeast and a hanging wall to the northwest.

Figure 3 shows the distribution of estimated seismic intensities. As announced by the Japan Meteorological Agency (JMA), intensities were 7 on the Japanese seismic intensity scale of 0-7 at Kawaguchi in Kawaguchi town and Upper 6 at Jonai in Ojiya city and Hosaka in Niigata Oguni town.[3)] In addition, seismic intensities observed at K-NET seismic observation points operated by the National Research Institute of Earth Science and Disaster Prevention were 7 at NIG 019 Ojiya and Upper 6 at NIG 021 Tokamachi.[4)]

At a seismic intensity of 7, seismic motion causes damage to not less than 30% of residential structures. In this earthquake, it was reported that many houses on soft ground in Kawaguchi were damaged, where a seismic intensity of 7 was observed. Meanwhile, the damage ratio was not as high but liquefaction and landslides occurred in the city of Ojiya. The K-NET seismograms are compared with typical seismograms of the 1995 Hyogoken-Nambu Earthquake in Fig. 4. Pseudo velocity response spectra of seismograms recorded at NIG 021 Toukamachi (in blue), NIG 019 Ojiya (in red), JMA Kobe (in black) and Japan Railway (JR) Takatori Station (in green) are shown.[5)] The response spectra of seismograms recorded at JR Takatori Station, in an area heavily damaged by the Hyogoken-Nambu Earthquake, and at NIG 019 Ojiya are almost equal in peak velocity response. The periods, though, are different, with 1.2-2 seconds at JR Takatori Station and 0.7 seconds at NIG 019 Ojiya. This difference in period is considered the cause of the difference in damage to residential structures.

Fig. 1 Distribution of aftershock hypocenters and active faults

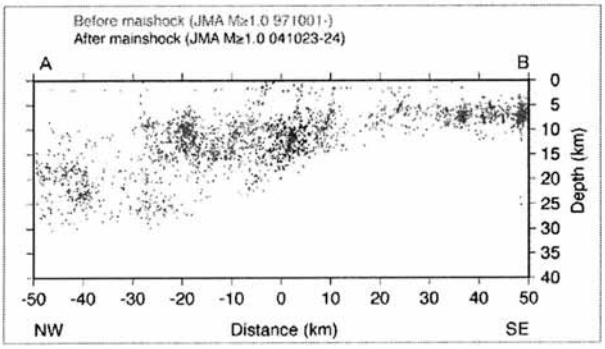

Fig. 2 Distribution of aftershock hypocenters and micro earthquakes preceding the main shocks

Fig. 3 Distribution of estimated seismic intensities

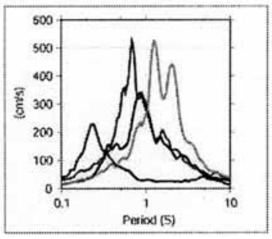

Fig. 4 Comparison of pseudo velocity response spectra

Damage and topography

The topography of the Chuetsu region is characterized by active folds. (Fig. 5 (A), de Martonne, 1927[3)]) Generally speaking, sedimentary rocks become fragile under tension in anticlines, where the strata form a convex arch, and become hard under compression in synclines, where the strata form a concave arch. If the ground undergoes repeated upheaval, the fragile strata (in anticlines) are subjected to differential denudation and the topography reverses such that anticline ridges become valleys and original valleys in the synclines become ridges. However, the hills of the Chuetsu region are geologically young and most remain in the state shown in Fig. 5 (A). It can be determined from topographic maps that some anticline strata have been subjected to differential denudation. For example, Yamakoshi village lies on a mass of old landslides in a valley formed by denudation of the Higashiyama anticline. The area is dotted with rice paddies and carp ponds and people of the village had led normal lives. The mountainous district of which Yamakoshi forms part is known as a landslide hazard area during the spring snow melt because of these geological conditions. The sad devastation of Yamakoshi is thought to have resulted from extensive failure of fragile slopes. It should be noted that the region had been affected by a series of typhoons immediately before the earthquake.

In the densely-inhabited disaster-stricken districts along the Sinano and Uono Rivers, meandering watercourses gradually carved away the differentially denudated land and left the river plain as a series of horseshoe-shaped areas of flat land (incised meanders). With repeated upheaval, portions of the horseshoe-shaped areas lining the rivers formed terraced cliffs. Earthquake damage was concentrated on railways and roads that follow the rivers. (Fig. 6, Photo 1)

There are horseshoe-shaped remains of old river courses near the city of Ojiya. Mount Funaoka, in the center of the city, is a hill that has been carved out by water and is surrounded by one horseshoe-shaped old watercourse. The city's central district surrounds Mt. Funaoka. There are new residential areas on old river courses further beyond the hill.

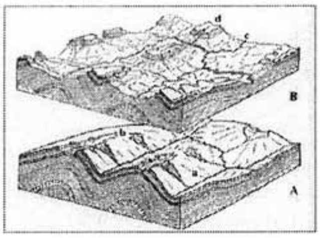

Fig. 5 Differential denudation of active folds (partly from an original drawing by de Martonne, 1927)

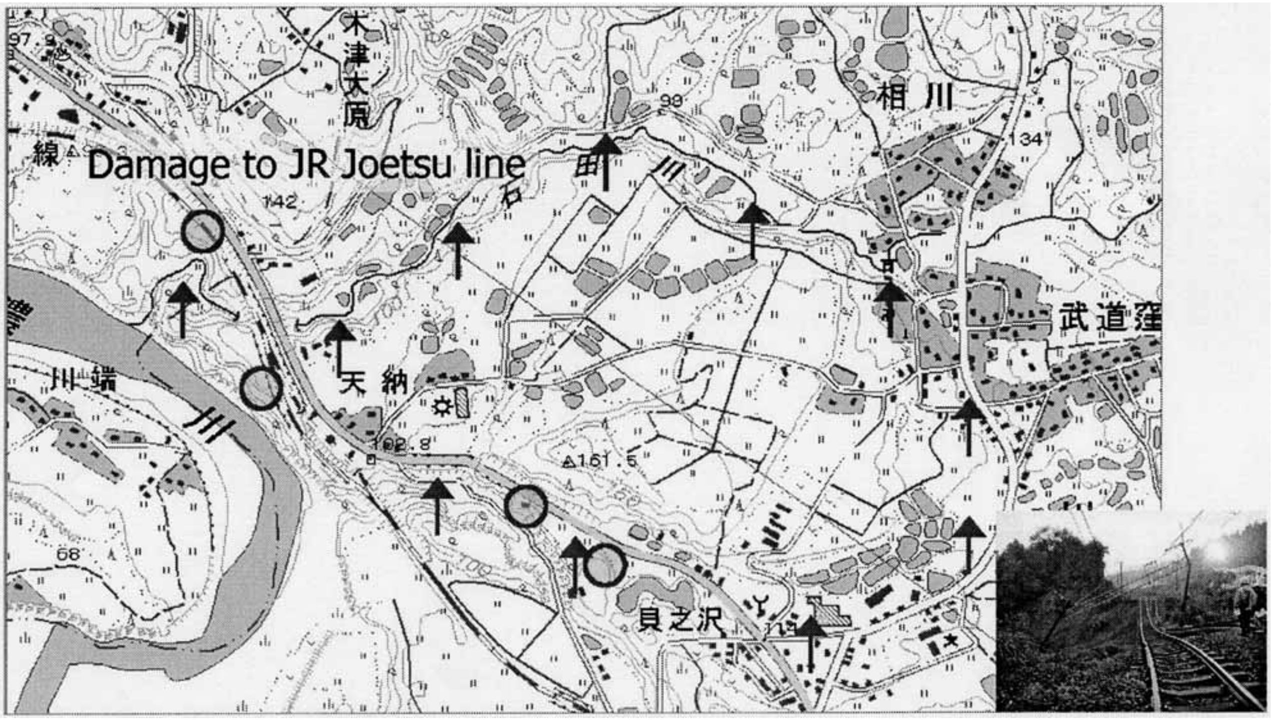

Fig. 6 Meanders left by old watercourses (indicated by arrow) and failed cliff (indicated by circle)
At point (A), the ground underneath National Route 17 and the parallel Joetsu railway line slid together with the concrete retaining wall (Photo 1)
(Data added to topographical map at a scale of 1:25,000 compiled by the Geographical Survey Institute)

Photo 1 Failure of slope at point (A) in Fig. 6, near Tenno, Kawaguchi town (Photo by Kazuo Onagai)

Details of damage

Damage to ground:

Slides consisting of thin, weathered surface layers took place on slopes of soft rock containing Neogene mudstone about 30 m in height and inclined at 30 degrees or more. (Photo 2: Yamakoshi village) Massive slope failures also took place at deep slip planes. Failures of weathered rock strata were identified. (Photo 3: Shiroiwa (white rock) at Myoken; Photo 4: large failure on Prefectural Road 196 on the right bank of the Shinano River downstream from Uonuma Bridge) A cliff was formed on the right bank of the Shinano River by erosion. Failures of talus layers were also identified. (Photo 5: failed residential land in Nigorizawa) But Yamakoshi village is where basic damage was most concentrated. Failures of sloping land reportedly took place at more than 800 points in the village, which has an abundance of terraced rice paddies and uncountable small ponds specific to landslide hazard areas. Some landslides involving rice paddies and ponds, in addition to those on natural slopes, were observed. (Photo 6) Surface and spring water outflows were observed at the sites of slope failures. The heavy typhoon rains just before the earthquake and small ponds located high up are considered possible causes of the outflows.

Large natural dams were created by landslides along the Imo River at five locations. In the northernmost Terano district, a relatively gentle slope (that appears to be the site of an old landslide) on the east side of the river slid out. In addition, a steep slope on the west side failed and blocked the river course. In the Nanpei and Naraki districts, steep slopes failed and blocked the river. The natural dam in the Higashi Takezawa area is the largest in the Yamakoshi area; it was created through extensive failure of a relatively gentle slope on the east side of the river (about 200 m in width and about 300 m in length). The area submerged by this dam stretched about 1 km along the river as of October 30. (Photo 7)

Photo 2 Failure of surface layer on slope comprising Neogene mudstone in eastern Yamakoshi village
(Photo by Kouji Kokusyo)

Photo 3 Massive failure of the so-called Shiroiwa (white rock) at Myoken, Ojiya city
(Web site of Kokusai Kogyo Co., Ltd.)

Photo 4 Major failure along Prefectural Route 196 on the right bank of the Shinano River downstream of Uonuma Bridge
(Photo by Kouji Kokusyo)

Photo 5 Failure of residential land developed on the talus layer in Nigorizawa
(Photo by Kouji Kokusyo)

Photo 6 Landslide involving a reservoir at Higashi Takesawa, Yamakoshi village
(Photo by Kouji Kokusyo)

Photo 7 Natural dam created in the Imo River
(Photo by Susumu Yasuda)

<u>Damage to sewage system:</u>

Although it is thought possible that buried water, sewer and gas pipes have been damaged in many locations, the type of damage identified during the primary investigation was uplifted manholes in the sewage system. (Photo 8) Such damage was extensive in Wakaba, western Ojiya city, where the surface layer consists of peat. In Nagaoka city, similarly, uplifted manholes were observed in Watarisawa in the southeastern part of the city, along the old National Route 17 in the center of Kawaguchi town, and in Tokuda, Horionuchi town.

Photo 8 Uplifted manhole (in Furuya district, Ojiya city)
(Photo by Susumu Yasuda)

Damage to concrete structures (including railway structures):

Some concrete fell away from a shinkansen (bullet train) viaduct just short of Takiya Tunnel between Nagaoka Station and Niigata (near where a shinkansen train “Toki No. 325” was derailed). (Photo 9) Four RC columns of the Wanazu viaduct on the shinkansen line failed between the Uonuma and Horinouchi Tunnels, as shown in Photo 10. Viaducts in this area had yet to be retrofitted with earthquake-resistant reinforcement. The failure mode seems to be shear failure. In addition, an RC pier of the Uonumagawa Bridge suffered damage at a rebar cut-off point. (Photo 11) Finally, an RC pier of the Ojiya Ohashi Bridge over National Route 17 suffered damage at a rebar cut-off point.

Photo 9 Muramatsu viaduct (fallen concrete)
(Photo by Hiroshi Mutsuyoshi)

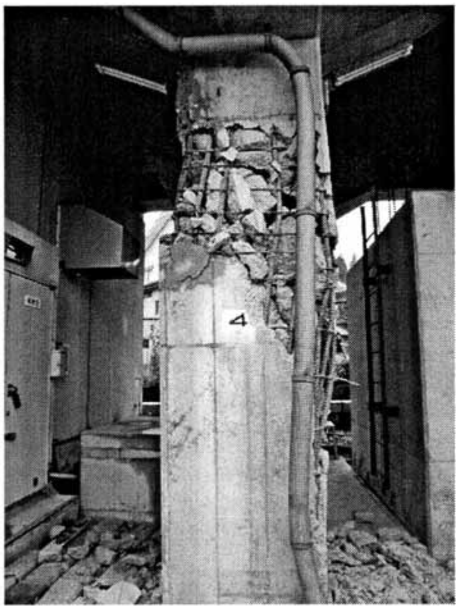

Photo 10 No. 1 Wanazu viaduct (shear failure of RC column)
(Photo by Hiroshi Mutsuyoshi)

Photo 11 Uonumagawa Bridge (damage to RC bridge pier at the rebar cut-off point)
(Photo by Hiroshi Mutsuyoshi)

Conclusions

It must be remembered that the earthquake-stricken region had been affected by a series of typhoons immediately before the earthquake. In this respect, the event can be compared with the 1923 Great Kanto Earthquake, where damage was caused not only by the earthquake but also by firestorms whipped up by strong typhoon winds. The continual rain experienced in the stricken areas of Niigata in November will turn to sleety rain and then snow as the cold season approaches. Some places will receive several meters of snow. Snowfalls will not only hamper recovery efforts; they will also render damaged ground and structures invisible. To prevent this, prompt investigation of damage and restoration efforts are necessary.

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