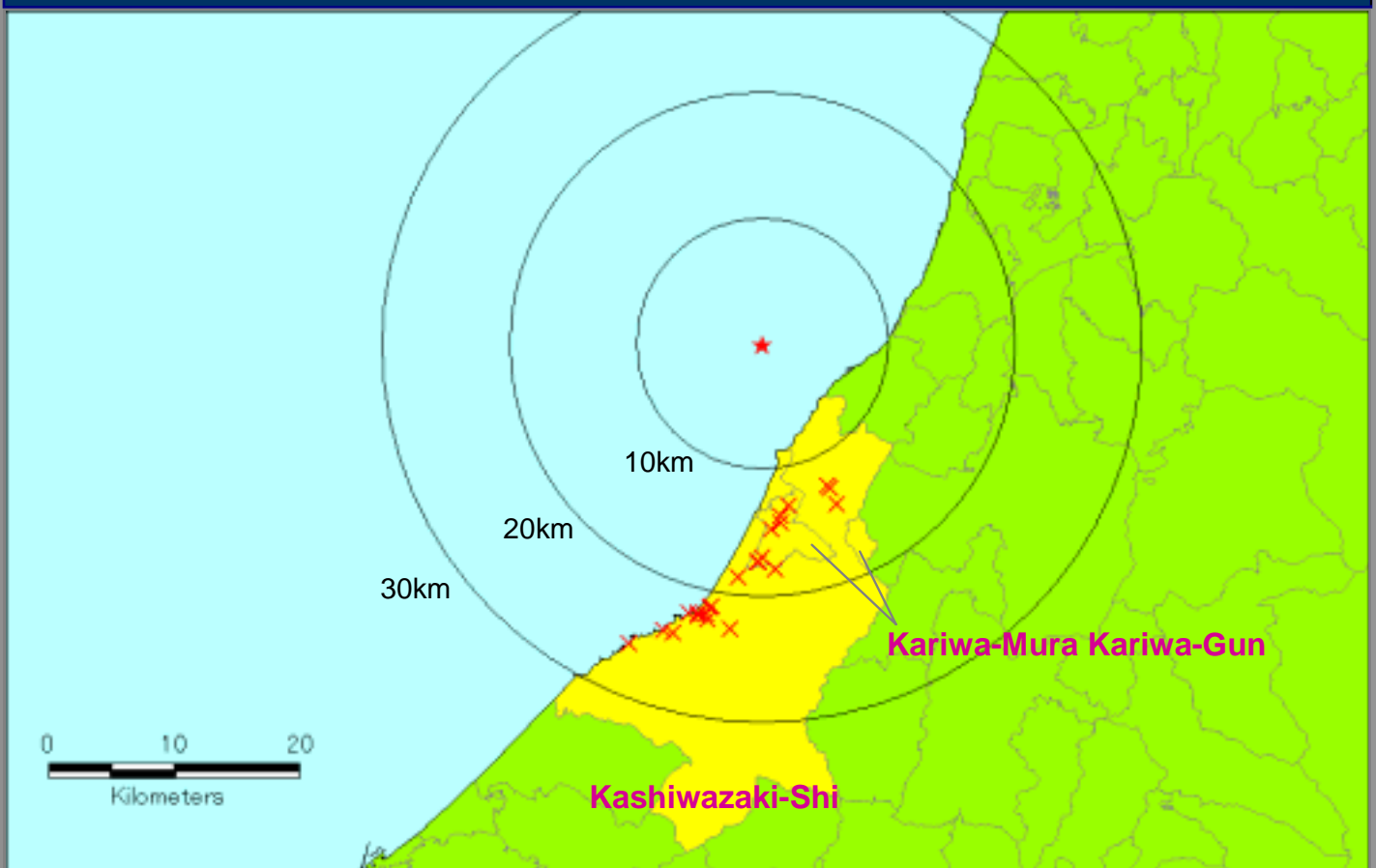


# Flash Report on The Niigata-ken Chuetsu-oki Earthquake



## **Summary of the Niigata-ken Chuetsu-oki Earthquake**

On July 16, 2007 a major earthquake (Mjma = 6.8) occurred offshore, north of the Niigata-prefecture. The earthquake epicenter was located at latitude 37.5 degrees and longitude 138.6 (60 kilometers southwest of Niigata), which depth is 17 kilometers. The seismic intensity (JMA = 6+) was recorded at Nagaoka-city, Kashiwazaki-city and Kariwa-village in Niigata-prefecture and in Iizuna-town in Nagano-prefecture. The earthquake caused 11 deaths and 1,843 injuries and resulted in complete collapse of 961 houses and partial collapse of 838 houses (information obtained from the General Affairs Department of the Fire Bureau on July 24 at 15:30).

On July 16, ABS Consulting sent two structural engineers (Mr. T. Ogawa and Ms. M. Ozawa) to the affected areas in Kashiwazaki-city and Kariwa-village for three days to investigate the damage caused by the earthquake. The areas marked 'X' in the Figure 1 show the locations investigated.

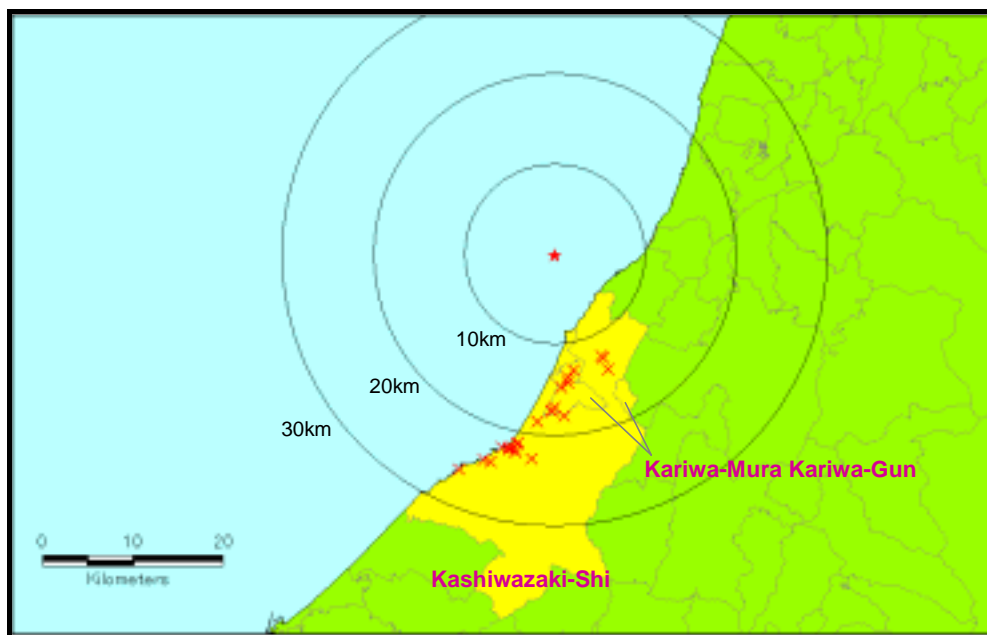


Figure1: Earthquake's epicenter and the areas investigated (marked by 'X')

## **Earthquake Dynamics And Its Related Damages**

The earthquake mechanism is a reverse fault, which has a compression axis running in the Northwest to the Southeast direction. It is a shallow fault where the movement of the tectonic plate stretched from the Northeast to the Southwest. This earthquake is considered to be caused by the release of built-up active tectonic forces and stresses along the eastern part of the Sea of Japan. From GPS records, it was observed that there was a strong movement in the earth's crust around the Kashiwazaki area. The recorded movement was approximately 160 millimeters in the Northwest direction along the coast of Kashiwazaki. The recorded seismic intensity (JMA = 6+) was as strong as the intensity recorded in the 2007 Noto Hanto Earthquake. Ground acceleration exceeded  $1,000 \text{ cm/s}^2$  at Nishiyamacho, Ikeura and Kashiwazaki-city. Since the epicenter originated from the bottom of the seabed, minor tsunamis that were approximately 200 to 300 millimeters high hit the coastal areas from Kashiwazaki to Ogi in Niigata-prefecture (information from The Headquarters for Earthquake Research Promotion).

## **Survey Summary**

- The earthquake, with its epicenter located offshore of Niigata, had a recorded seismic intensity of JMA = 6+. This intensity was the same as the intensity of the Noto Hanto Earthquake that occurred in March 2007.
- Many old wood houses collapsed. It is postulated that the earthquake ground shaking frequency closely matched the natural period of the houses. Retrofit of old wood houses should be a high priority.
- Relatively new reinforced concrete chimney collapsed. It may have had similar frequencies as the old wood houses.
- The Geiyo Earthquake in 2001 showed that ceiling systems in large spaces are easily damaged. The Ministry of Land, Infrastructure and Transport recognized this problem and made announcements about the necessity to reinforce large ceiling system. However, this recommendation was not adequately publicized.
- Liquefaction was the one of the main causes for the extensive damage seen in the Kashiwazaki area. The amplified earthquake ground motion in this liquefiable area caused serious damage to buildings.
- The earthquake occurred just after the Typhoon 04W (Man-Yi) hit the same area. The resulting soft ground conditions compounded the earthquake damage since the wet ground resulted in numerous landslides.
- This was the first time a nuclear power generation plant has been damaged by an earthquake that was located near the facility. The recorded ground acceleration of  $680 \text{ cm/s}^2$  was higher than the design criteria of the nuclear power plant. The plant also had damage to many of the auxiliary equipment. Earthquake retrofit strengthening and ground condition improvements should be a high priority at this type of facility.

## **Buildings**

### ***Kashiwazaki-city***

Kashiwazaki-city is located at the center of the coastline in Niigata-prefecture and in the Kariwa plain and the city is surrounded by mountains. The urban areas have been developed on sand dunes and liquefaction was seen in many places.

The collapsed houses were mostly old wood buildings. The traditional heavy black roofing tiles, which are typically in the Northeastern costal areas of the Sea of Japan, were used on the traditional and old wood houses. Many of the roofs retained their shapes even if the other parts of the houses completely collapsed (Photo 1). The roofs are traditionally constructed using a thin layer of clay to keep the tiles in place. However, the clay is likely used more for insulation purposes since Niigata has cold and snowy winters.

There were many examples that showed that the first story of houses collapsed when the level had many window and door openings while the second story of the same houses maintained its shape and integrity (Photo 2). After the 2007 Noto Hanto Earthquake, similar damage patterns were observed in wood houses.



**Photo 1**

Also, one of the reasons for increased damage was the use of Oya stones (large blocks of masonry stones) or unreinforced concrete blocks that were used as fences in these areas.

In the Nishimotocho areas, numerous garden lanterns and tombstones located in shrines and temples had toppled. The garden lantern at the Kannonji Temple near Ugawa River was found lying in the Southwest direction. About 500 meters away, the temple's tombstones had toppled but were facing the Northwest direction. This indicates the complex nature of the shaking, which obviously depends on the ground characteristics during the earthquake.



**Photo 2**

Reinforced concrete buildings in the urban areas were also damaged. At the Kashiwazaki-city office building some of the columns were found to be damaged (Photo 3). On the second-story parking level of a big supermarket, a water tank was found to have suffered damage (Photo 4).



**Photo 3**



**Photo 4**

Furthermore, at the Kashiwazaki-city's rubbish incinerating facility a 59 meter high by 4.6 meter wide reinforced concrete exhaust chimney was found broken stretching vertically for 10 m long, at slightly below the center of the chimney (Photo 5). Based on the condition of the protruded reinforcing, the chimney broke at the lapped reinforcing joint (Photo 6).



Photo 5



Photo 6

#### ***Nishiyamacho Kashiwazaki-city Areas***

Nishiyamacho Kashiwazaki-city is located in a mountainous area, which was incorporated from Kariwa-county in 2005.

The General Affairs Office in Nishiyamacho Kashiwazaki-city is located in the middle of this mountainous area. It appeared to have received relatively little damage during the earthquake. However, the pipes in the surrounding area were found to protrude about 400 millimeters above the ground level, which was probably caused by the change in ground level by the earthquake ground motion (Photo 7).

In the same area, many warehouses are constructed with walls made of mud and it was found that many of these walls had peeled off (Photo 8).



Photo 7



Photo 8

Gymnasium of Katsuyama Meeting Hall (Photo 9) is a reinforced concrete building, which suffered damage at the column-girder joints (Photo 10), broken windows, fallen ceiling panels (Photo 11), fallen external cladding and broken steel braces (Photo 12). Although the meeting hall had not collapsed, it will take a long time to restore it to its original state. Likely, the lateral forces induced by the earthquake were much greater than the design forces. No braces were seen in the ceiling system during our inspection. In recent major earthquakes, the inadequate strength of ceiling systems in large spaces was noted.



**Photo 9**



**Photo 10**



**Photo 11**



**Photo 12**

## **Infrastructure**

### ***Highways***

#### **Hokuriku Highway, Joetsu IC - Nagaoka IC**

Immediately following the earthquake, the Hokuriku Highway was closed to all vehicles in both directions between Joetsu IC and Nagaoka IC because of spalling concrete, cracks and uneven surfaces inside the highway tunnel. Due to rapid repairs after the earthquake, the highway was opened to traffic again on July 18.

National Highway, Route 8 , 116 and 352

The National Highway Route 8, 116 and 352 passing through Kashiwazaki-city and Kariwa-village had many cracks, uneven surfaces and ground subsidence. Route 8 passing through Kujiranami Kashiwazaki-city was especially badly damaged with a 100 meter stretch of its embankments slipping more than two meters (Photo 13).



**Photo 13**

Due to rapid repairs, the National Highways were open to traffic quickly and were soon fully functional.

Prefectural and City Roads

The roads across the city were found to be damaged and had cracks and uneven surfaces in many places. It was also observed that many of the collapsed wood houses along these roads had blocked the road access (Photo 14). Many of the overpasses over rivers had subsided near the bridge abutments, which impeded traffic (Photo 15).



**Photo 14**



**Photo 15**

***Railroads***

JR Shinetsu Mainline, Oumigawa Station Area

At JR Shinetsu Mainline's Oumigawa station, the largest earthquake induced landslide happened (Photo 16). The heavy rains during the previous day by Typhoon 04W (Man-Yi) may have contributed to this landslide. The landslide caused a large amount of soil and stones from the steep hill behind the railway station to be washed into the nearby coastline. Part of the railway lines and the station's platform were completely buried under the debris. Fortunately, there was no one injured by the landslide. Since there are many steep hills around the JR Shinetsu Mainline's Oumigawa station, there were many similar large landslides (Photo 17).



Photo 16



Photo 17

### JR Echigo Line, Arahama Station Area

Between Arahama Street and Nishiyama Street on the JR Echigo Line, the rails were found to have deformed in several places due to soil deformation. The most seriously bent rails were bent approximately 800 millimeters (Photo 18).

The Arahama station's platform was also completely damaged (Photo 19).



Photo 18



Photo 19

### Train Carriages



Photo 20

One train car of a two car train on the Echigo's line was stopped at the JR Kashiwazaki Street platform and was derailed by the earthquake (Photo 20). At the time of the earthquake, the train car held one railway worker and two passengers. Fortunately, the earthquake injured no one.

The Shinetsu mainline, the Echigo line and other similar railway lines suffered extensive damage. It may take some time before the train service is resumed..

### ***Port and Harbors***

#### Kashiwazaki Port (Kashiwazaki Area)

At the west wharf, settlements of the embankments opened joints in the aprons and deformed the ground in the yard area behind the banks (Photo 21). The embankment settled 200 millimeters and moved 500 millimeters from the bank's edge towards the sea.

The central wharf area had cracked asphalt, deformed quay walls and uneven surfaces (Photos 22 and 23). Also, in many places around the harbor remains of blown-out sand caused by liquefaction were observed (Photo 24).



**Photo 21**



**Photo 22**



**Photo 23**



**Photo 24**

### ***Nuclear Power Station***

#### Kashiwazaki Kariwa Nuclear Power Station

Tokyo Electric Power Company's (TEPCO) Kashiwazaki Kariwa nuclear power station is located 16 kilometers away from the epicenter of the earthquake. This nuclear facility had been designed to withstand an earthquake with induced acceleration of  $273 \text{ cm/s}^2$ . During this earthquake, the nuclear facility was subjected to accelerations as high as  $680 \text{ cm/s}^2$ , which is more than twice of the design value. Four of the seven reactors were in operation at the time of the earthquake and these reactors were stopped immediately after the earthquake by emergency the shutdown system. Immediately following the earthquake, the No. 3 reactor suffered a fire in one of its transformers. The fire was likely caused by sparks igniting the transformer's flammable oil that had leaked out of the transformer. It was also discovered that radioactive water from the No. 4 reactor's condenser (equipment used for condensing steam during generation of electricity) had a 3.5 meter long crack at a piping valve. Other incidents included: radioactive discharge from the exhaust stack, about 100 drums containing low radioactive waste drums toppled, fluid spilled from the used nuclear fuel pool and an ineffective fire fighting system. There were more than 50 incidents reported at the nuclear facility that involved damage to its auxiliary equipment. Newspapers also reported that landslides occurred at a hill that was created by the grading of the power plant. The nearby roads exhibited ground subsidence of up to 1.6 meters.

## **Lifelines**

### ***Electricity***

Tohoku Electric Power was not able to supply 40,000 kW of electricity immediately after the earthquake. Eight cities and villages in the Niigata Prefecture, including Kashiwazaki-city and Kariwa-village, have 35,344 households. These did not have electricity until electric power was restored at 21:59 on July 18, 2007.

### ***Water Supply***

Niigata-prefecture suffered water pipe breakage in many locations, which causing an estimated 60,000 households to be without water. In the whole of Kashiwazaki-city it was estimated that 43,000 households did not have water. The restoration started soon after the earthquake and at 9:00 on July 24, the water supply was restored to about 50% for Kashiwazaki-city. However, Kariwa-village only had 3 % of its water supply restored.

### ***City Gas Supply***

Kashiwazaki-city estimated that 35,000 households suffered from gas supply disruption. Similar gas disruptions were reported in Nagaoka-city. Gas supply to Nagaoka-city was restored at 18:43 on the same day as the earthquake. In Kashiwazaki-city, the water supply disruption takes priority over gas supply. The gas supply restoration work started on July 18, two days after the earthquake. As of 9:00 on July 24, the gas supply recovery rate was limited to 2.8%.

## **Ground**

### ***Liquefaction phenomenon***

The earthquake caused many locations of boiling sand in Kashiwazaki-city and Kariwa-village due to liquefaction (Photo 25). Manholes and sewerage pipes raised out of the ground (Photos 26 and 27). According to the National Geography and Crustal Dynamics Research Center, the Kashiwazaki urban area is located between the Yoneyama mountain district and the Nishiyama hill region. The area contains alluvial soils



**Photo 25**

where the sand deposits have flown from the rivers over the soft alluvial formation. These soil profiles were the prime reasons for causing liquefaction to happen in many locations during the earthquake.



**Photo 26**



**Photo 27**

Considerable liquefaction was observed at the Suidobashi Park in Nishimotocho Kashiwazaki-city (Photo 28). This area was transformed into a park during the flood mitigation effort in 1984 when the Ugawa river system was straightened.

As in previous earthquakes, reclaimed land, harbour areas and areas near rivers exhibited liquefaction.



**Photo 28**

As discussed above (JR Shinoetsu Mainline's Oumigawa station area), a large number of landslides was observed. Many landslides were observed not only along steep slopes and the coastline, but also in manmade land constructed of earth fill used for roads and railroads.

### **Acknowledgement**

ABS Consulting would like to thank all the local government staff and the area residents for their kind response to our inquiries, even though they were in the midst of the earthquake recovery work.

<About ABS Consulting>

ABSG Consulting Inc. (ABS Consulting) is a leading independent global provider of risk management services, combining industry specialists, risk modeling and practical engineering and technology solutions to help business, finance, industry and government manage risk. Through a comprehensive and integrated risk management approach, ABS Consulting is committed to helping clients reduce business interruption and manage catastrophic, operational, and security risks.