Learning from Earthquakes

Noto Peninsula (Japan) Earthquake of March 25, 2007

This preliminary report summarizes available information on the March 25, 2007, M_w 6.7 earthquake, and findings of a damage survey on April 1 in the high-intensity near-epicentral region. It was prepared for EERI by Shingo Nishida, Charles Scawthorn, Junji Kiyono, and Takahiro Tsutsumiuchi, all of Kyoto University. The publication of this report is supported by the National Science Foundation through EERI's Learning from Earthquakes Program, Grant #CMMI-0650182.

Earthquake and Affected Area

The earthquake struck on Sunday, March 25, 2007, at 00:41:57 (UTC) or 9:41:57 a.m. (local or JST), with epicentral coordinates of 37.281°N, 136.602°E and a depth of 5 km (USGS). The magnitude, as determined by the Japan Meteorological Agency, was M_j 6.9 (or M_w 6.7, USGS). The event does not appear to have occurred on a known active fault. As inferred from the fault plane solution (USGS) and areal distribution of aftershocks (see **http://www.seisvol.kishou.go.jp/eq/2007_03_25_noto/index.html**), the fault mechanism is oblique mostly reverse faulting on a plane dipping about 45° to the SE and striking NE. A source model has been developed by Y. Yagi (Tsukuba University), which has a fault size of 30 km × 15 km, top depth of fault of 1 km, and a focal mechanism with strike = 47º, dip angle = 51º and slip angle = 115.8º. Average slip on the fault was 1 m. The seismic moment is 2.3 x 10^19 Nm (M_w = 6.8). Maximum observed JMA intensity was 6+ (corresponding to MMI X-XI).

The earthquake was centered about 12 km offshore from the Noto Peninsula, Ishikawa Prefecture (pop. 1.7 million), in the Sea of Japan (Figure 1). The northern part of Ishikawa prefecture consists of the Noto Peninsula, while the southern part is wider and consists mostly of wooded low mountains, with the prefecture's chief city of Kanazawa (pop. 455,000) located in the coastal plain. The Noto Peninsula is generally mountainous and sparsely populated, with most of the population located at river mouths along the coast. The nearest major city is Kanazawa (epicentral distance 80 km, no damage); the closest jurisdiction is the township of Monzen (pop. 7,500), and the closest populated area is the village of Doge, located approximately 12 km east of the epicenter. Table 1 summarizes the earthquake impacts.

Historic earthquakes near the Noto peninsula have typically been shallow events, e.g., 1933 and 1993 (Earthquake Research Committee, 1998). The 1993 earthquake was centered farther north and was caused by reverse faulting (Ito et al., 1994) similar to the current event.

Strong Ground Motion

Though the M_w 6.7 earthquake was centered offshore approximately 12 km from the nearest population, in the area closest to the epicenter

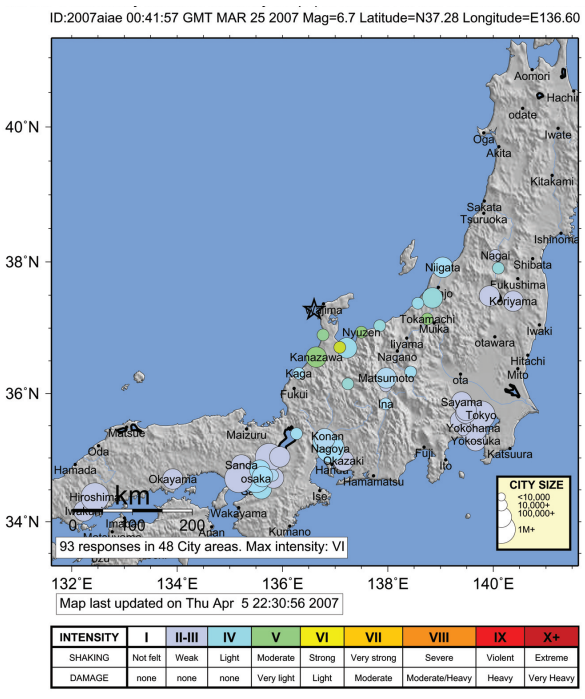

Figure 1. *USGS Community Internet Intensity Map (48 miles N of Kanazawa, Honshu, Japan)*

Table 1. Damage Statistics, Ishikawa Prefecture (as of 6 April 2007)
(消防庁災害対策本部 http://www.fdma.go.jp/data/010703041756229749.pdf)

	Dead and Injured				Damaged Houses			
	Total Pop.	Dead	Serious Injury	Other Injury	Total No. Households	Totally Destr.	Half Destr.	Partial Damage
Nanao City	62,665		7	107	21,732	28	34	622
Wajima City	34,062	1	12	80	13,232	373	463	3,511
Suzu City	38,378			3	6,855			21
Kaga City	75,759				28,239			6
Hakui City	24,517			1	8,117		2	42
Kahoku City	35,383				10,759	3	2	3
Tsubata Town	36,398			1	11,362			1
Shika Town	24,670		4	11	8,007	3	39	493
Hodatsushimizu Town	15,622				4,940		2	1
Nakanoto Town	19,967		2		6,273	3	4	8
Anamizu Town	10,547			39	3,744	66	74	222
Noto Town	22,632		1	11	8,140			30
Total	**1,169,571**	**1**	**26**	**253**	**425,571**	**476**	**620**	**4,960**

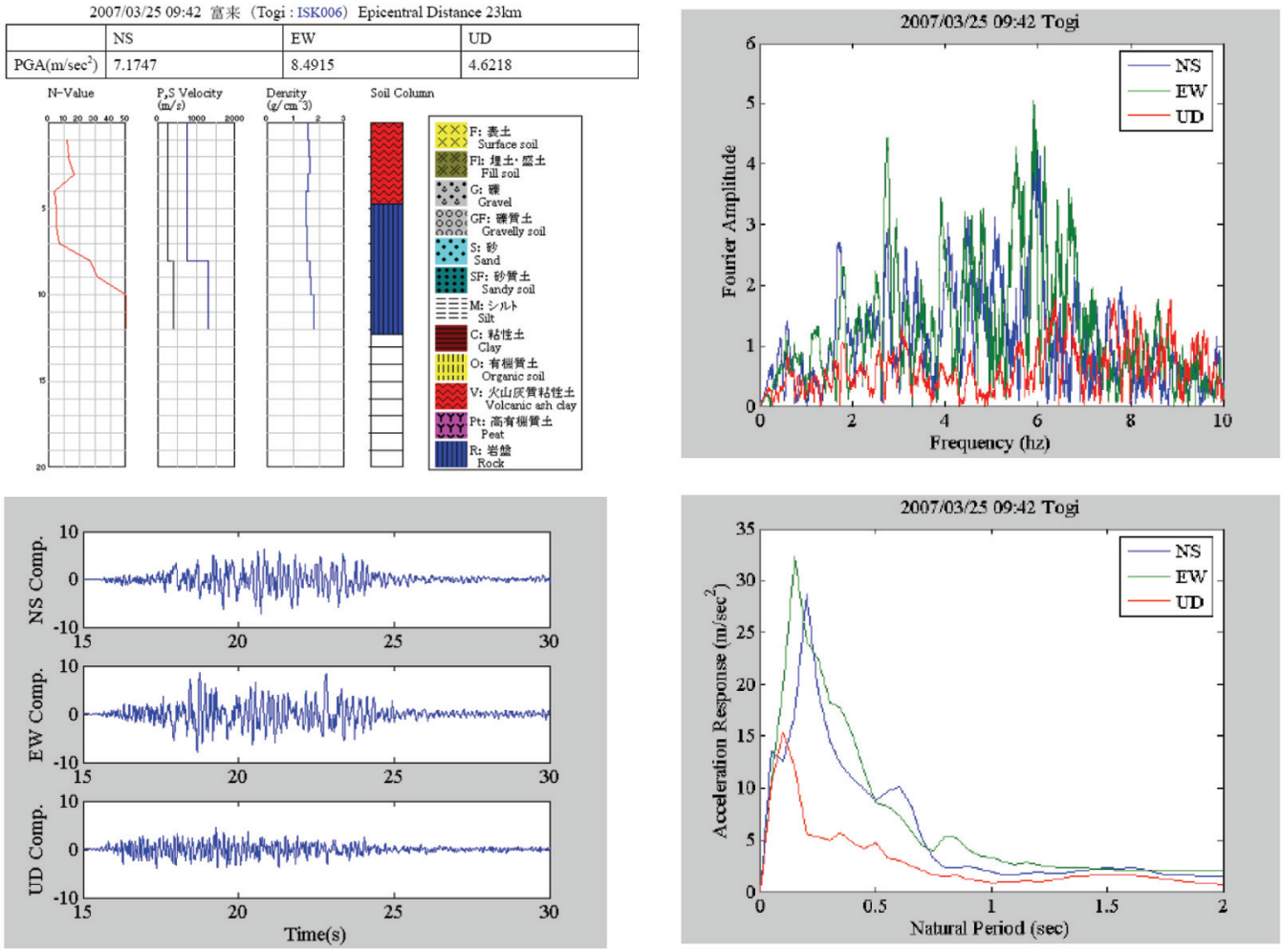

Figure 2. *Togi site conditions, time history, Fourier amplitude spectra, and 5% damped response spectra (other records available at* ***http://www.kyoshin.bosai.go.jp/k-net/****).*

recorded ground motions were quite high. Long-period effects were not evident. The maximum PGA was recorded at the Togi K-NET station, where a single maximum component of 849 gals (three vector component max PGA 945 gals) was observed. Figure 2 shows the site conditions, time histories, and Fourier amplitude and acceleration response spectra for this record.

Geotechnical Effects

The geology of the western Noto Peninsula is rounded hills of 100-200 m elevation formed of Miocene and Pliocene materials, with younger Holocene deposits in the valleys. Relatively few landslides were observed in the hills, the largest being an arcuate rotational slump with approximate dimensions of 100 m width at the bottom at the roadway, and a 15 m height. No sand boils or other direct evidence of liquefaction were observed during our damage survey, although others reported finding such evidence (see Yoshida, 2007, where photographs of sand boils at Wajima port are presented). However, a number of manholes were observed to have “risen,” and indications of lateral spread were observed in a number of locations (Figure 3).

A lateral spread was observed along a river embankment in the village of Doge, and a bridge across the river about 50 m upstream had abutment settlements, but no other damage. Many other small bridges at various locations sustained similar abutment settlements, which were quickly repaired (Figure 4).

A tsunami advisory was immediately issued for the Noto Peninsula and nearby coasts, and waves of 10-20 cm were observed 30-60 minutes later, depending on location.

Performance of Structures

Japanese commercial and industrial buildings are typically steel or reinforced concrete (RC) construction, or a combined steel reinforced construction (SRC). Larger multifamily residential buildings are typically RC, while smaller residential buildings may be steel or wood-frame. Single-family dwellings are almost exclusively wood-frame.

Engineered structures performed well, with little or no observed damage, including a number of larger buildings strengthened after the 1995 Hanshin earthquake. Older Japanese wood-frame buildings were the most significant segment of the built environment

Figure 3. *Lateral spread and manhole deformation in minor roadway built over rice paddy, village of Doge (photos: Scawthorn).*

damaged by the earthquake, with a number of collapses.

Engineered buildings. Despite the high recorded ground motions, engineered buildings generally performed well. An exception was an older steel-framed industrial shed building at a lumber yard in Doge, which collapsed (Figure 5). It had steel columns with tie rod bracing, wood secondary framing, and a heavy tile roof. Failure appeared to be due to shear in the single bolt connections of the tie rod bracing. Whether the building had actually been engineered is questionable.

Figure 4. *Bridge abutment settlement and temporary repairs to bridge in Doge (photo: Scawthorn).*

School and municipal buildings in Monzen (the closest location to the epicenter) typically performed very well. The worst problem appears to have been settlement and lateral spreading on the west side of the main building of the middle school, adjacent to a drainage channel (Figure 6). An intensity meter at this location registered IJMA 6+ (equivalent to MMI X). Several of these buildings had been seismically strengthened, and appear to have performed very well.

Residential wood-frame dwellings. In Japan, wood-frame houses fall into three categories: 1) the traditional Japanese house (post and beam, mud walls), 2) an intermediate type with stucco over wood lath walls, and 3) a recent primarily post-Kobe type, having continuous or monolithic foundations, bolted wood connections with hold-downs and/or some steel framing, and lightweight roofs and cladding. Wood buildings in Monzen varied in their seismic performance; Figure 7 shows performance of various wood-frame buildings. If a modicum of bracing was provided, most buildings did well; modern housing performed excellently, with no signs of distress of any kind.

Other Structures. About 1 km distant from the Togi instrument was a modern, approximately 80 m-tall windmill, which appeared undamaged. The foundation of this tall can-

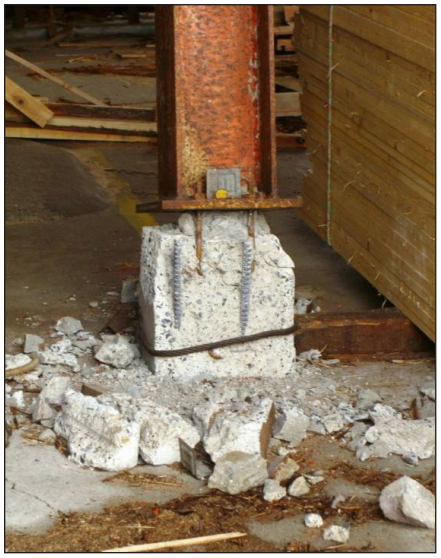

Figure 5. *Collapse of steel industrial building, Doge (photos: Scawthorn).*

Figure 6. *Monzen Middle School: ground settlements around underground tanks west of main building (photo: Scawthorn).*

tilever structure was notable for no signs of rocking. Immediately adjacent to the structure were utility poles, which appeared to have disturbed foundations.

Traditional Japanese stone monuments throughout the region sustained minor to moderate damage. Typical was a shrine where the wood building was undamaged, but the

Figure 7. *Monzen: (top) undamaged building, due to bracing; (middle) neighbor collapsed; (bottom) pancake collapse of traditional wood-frame house (photos: Scawthorn).*

stone monuments showed evidence of sliding.

Post-Quake Fires. The Monzen Fire Department reported no fires as a result of the earthquake, although two buildings showed signs of smoke. The lack of fires was attributed to the weather and time of day (mild; mid-morning and thus no heating and cooking). The Monzen FD is almost totally a volunteer department, with 16 stations and approximately 400 personnel.

Lifelines

Aside from pavements disrupted by permanent ground displacements, our damage survey did not find significant damage to lifelines. Wajima City reported 281 households lost water service, as of April 2, with 187 having decreased pressure. In Shika district, 52 households lost service. Sewerage damage was 220 m in Yoda town, 86 m in Nakahata, and 330 m in Bungome. Electric power was lost for 110,000 households in Ishikawa Prefecture and 50,000 in Toyama Prefecture, with service restored by 4 p.m. the next day.

There were numerous minor disturbances to local roads due to minor ground failure. As of April 6, the Noto toll road from Tokudaotsu to Anamizu was closed. Route 249 sustained a major landslide, with damage at a total of seven locations. Limited service was restored to all roads by April 6, with the exception of the Noto toll road.

JR West reported some displaced rails on the Nanao line, but no damage to the Hokuriku line. Service was restored by the next day. The Noto Rail line sustained some significant damage at 25 locations, but limited-speed service was restored by March 30.

Wajima Harbor sustained liquefaction on reclaimed land, with some settlement behind quay walls. Nanao Harbor sustained similar damage, with sand boils evident at several locations. Noto Airport sustained many cracks on the runways and taxiways, but operations were back to normal by the next day. Telephone service in Wajima City was lost on 80 lines, with service restored by the next day. Gas service is provided by several companies in the region, with no significant damage reported.

Socioeconomic Impacts

Injuries were relatively few, presumably due to the time of day of the earthquake as well as the generally low population in the high-intensity areas. A woman of 52 died after being crushed by a stone lantern in her garden. Serious injuries totaled 29; a total of 268 of all kinds of injuries were reported as of April 6.

In Wajima City, 18 shelters provided facilities for a total of 515 persons. Anamizu opened two shelters for a total of 57 persons. Shika Town opened three shelters for a total of 45 persons.

Agriculture, forestry, and fishery losses totaled approximately 5.6 billion Yen (approximately US$50 million). Farm facilities were damaged in three prefectures at 172 locations, totaling 1.2 billion Yen (US$10 million). Forestry assets were damaged in four prefectures at 345 locations, totaling 1.6 billion Yen (US$13 million). Fishery facilities at 35 harbors sustained damage totaling 2.6 billion Yen (US$20 million) (MAFF, 2007).

References

Earthquake Research Committee, 1998. *Seismic Activity in Japan,* Headquarters for Earthquake Research Promotion, Prime Minister's Office, Government of Japan, p. 222.

Ito, K., Wada, H., Watanabe, K., Horikawa, H., Tsukuda, T., and Sakai, K., 1994. "1993 Off Noto Peninsula Earthquake," *Annuals*, Disas. Prev. Res. Inst., Kyoto Univ. (No. 37 B-1, in Japanese) (available at **http://www.dpri.kyoto-u.ac.jp/dat/nenpo/no37/nenpo37b1_e.html**).

Ministry of Agriculture, Forestry and Fisheries (MAFF), 2007. Summary as of 30 March.

Research Group for Active Faults in Japan, 1991. *Active Faults in Japan,* University of Tokyo Press, Tokyo (in Japanese).

Yoshida, N., 2007. *Preliminary Report Noto Earthquake* (**http://www.civil.tohoku-gakuin.ac.jp/yoshida/inform/noto_eq/report-2.pdf**).

A more extensive report, photographs, and other data collected during the April 1 survey are available at **http://quake.kuciv.kyoto-u.ac.jp/vch/**.