Study Trip Report on

ONAGAWA TOWN OBSERVATION

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A great earthquake occurred on March 11th, 2011 Friday afternoon at 2:46:23 PM local time off the east coast of Honshu about 130 kilometers east of Sendai. This massive earthquake's magnitude was 9.0. The Japan Meteorological Agency (JMA) named this earthquake "the 2011 off the Pacific coast of Tohoku Earthquake". This earthquake is the 4th largest earthquake in the world since 1900 to today. Also it is the biggest earthquake for Japan. Nine major events of magnitude 7 or greater have repeatedly occurred within the Japan Trench subduction zone since 1973. It was the third time that intensity of 7 was recorded in Japan following the 1995 Kobe Earthquake (M7.3) and the 2004 Mid-Niigata Prefecture Earthquake (M6.8).

The 2011 off the Pacific coast of Tohoku Earthquake hypocenter locates off Sanriku at 130km ESE of Oshika Peninsula with the focal depth of 24km. This earthquake occurred as a typical inter-plate earthquake which was caused by the rebound of a continental plate (North American plate) against a subducting oceanic plate (Pacific plate) along the Japan Trench. The focal mechanism showed a reverse faulting movement with a compression axis in a WNW-ESE direction (Figure 1).

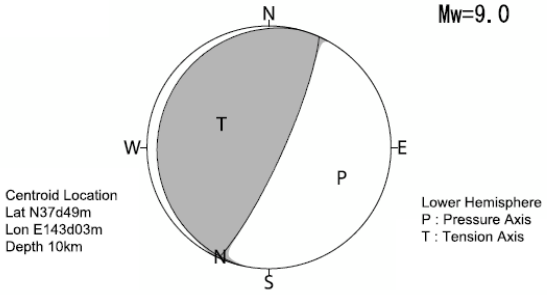

Figure 1. Tohoku earthquake focal mechanism solution (http://www.jma.go.jp)

According to NIED (K-net) records between 11.03.2011 to 15.07.2011 there were 358 earthquakes of M5.0 or over, 57 aftershocks of M6.0 or over, and 5 aftershocks of M7.0 or over in Japan. Figure 2 shows the seismic activity of the main shock and aftershocks of M7.0 or larger earthquakes (Figure 2). A red star mark off Miyagi Prefecture with an index 9.0 denotes the hypocenter of the main shock; the other yellow stars are those for aftershocks of M7.0 or greater. At Tohoku large interplate earthquakes had been predicted to occur in this region with 99% probability within thirty years and the magnitudes ranging from M7.5 to M8.0. The March 11 earthquake was much bigger than predicted, recording M9.0 and the rupture zone stretched 510 km length and 210 km width.

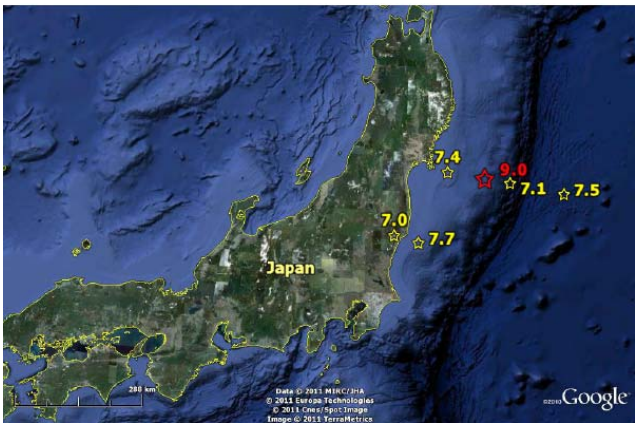

Figure 2. Seismic activity of the main shock and aftershocks of M7.0 or larger which occurred between 11.03.2011 to 15.07.2011 (Earthquake location and magnitude value from NIED web page)

At the latitude of this earthquake, the Pacific plate moves approximately westwards with respect to the Eurasian plate at a velocity of 83 mm/yr. The Pacific plate thrusts underneath Japan at the Japan Trench, and dips to the west beneath Eurasia. The location, depth, and focal mechanism of the March 11 earthquake are consistent with the event having occurred as thrust faulting associated with subduction along this plate boundary. Huge earthquake of M9.0 brought enormous crustal deformation on eastern Japan. Depend on the GPS network of the Geospatial Information Authority of Japan; taking the fixed point at Misumi, Hamada City in Shimane Prefecture, Pacific side of eastern Japan moved several meters

to ESE direction. Displacement of 4.4 m was observed at Shizugawa, Minami-Sanriku Town in Miyagi Pref., and the largest displacement of 5.3m was detected at Ojika, Ishinomaki City, while displacement at Japan Sea side was around 1m causing a large extensional field in the eastern Japan (Figure 3). On the other hand, as to the vertical displacement, subsidence of several tens centimeters was detected in wide area along Pacific coast region. Subsidence of 75cm was observed at Shizugawa, and the largest subsidence of 120cm was detected at Ojika (NIED). The areas hit by the Great Eastern Japan Earthquake are known to be vulnerable to tsunami, as they were recurrently hit by tsunami. Large offshore earthquakes occurred in the same subduction zone in 1611, 1896, and 1933. Each of earthquake caused devastating tsunami on the coast. It is usual that an inter-plate earthquake occurred at trench region accompanies tsunami. Since the magnitude of this earthquake was as large as M9.0, the scale of generated tsunami was also huge one. In Japan, large tsunami attacked the Pacific coast ranging from Hokkaido to Okinawa and the tsunami was also observed at the coast of the Japan Sea, the Okhotsk Sea, and the East China Sea. The tsunami also propagated to the coast of Hawaii, northern and southern America continents, and the Pacific countries.

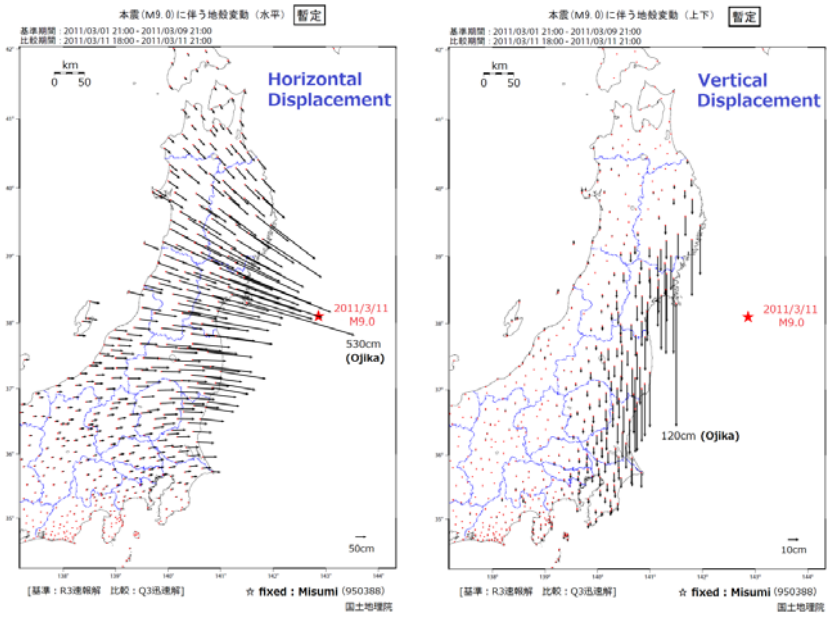

Figure 3. Crustal deformation associated to the 2011 off the Pacific coast of Tohoku Earthquake (GSI)

Onagawa town was one of the most seriously tsunami-engulfed towns/cities along the Sanriku indented coast line. Onagawa town is situated in an area where it is most vulnerable to tsunami because of its geographical location. The Onagawa bay and its shallow bathymetry characteristics was a big factor that made the towering height of the tsunami as high as 15 meters. The inundation was as far as 3 km away from the town. The town had a flat surface with no sufficient embankments. Most residential areas were located few meters away from the shoreline. For these reasons, the town was swept away by the tremendous energy of the tsunami (Figure 4).

There were at least four pile-supported buildings toppled and /or carried over some distances in Onagawa. Buildings were uprooted, floated several meters away from their original positions. A three storey-hotel fronting the pacific was totally inundated. Cars were like papers crumpled and thrown into small pieces with the strong impact of the tsunami. Roads were subsided as well as the port facilities. Besides the massive destruction it brought to the town, 900 people were killed or missing in Onagawa Town. As shown in Figure 5, the hospital was located approximately 14 meters high from the sea level. Based on our observation, the trees were dried up which reveals that the tsunami reached and inundated the hospital

which surpassed the height of the wall surrounding the area of the infrastructure.

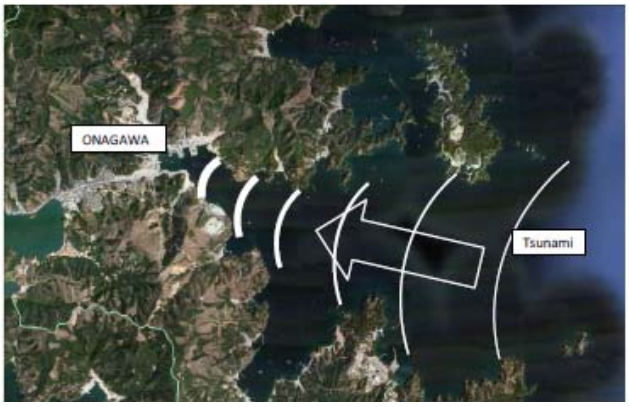

Figure 4. Expected simulation of the tsunami and topographic effect

Figure 5. The high wall just near the hospital about 12 m high. Tsunami exceeded from the wall and washed away first floor of the hospital.

Most of the buildings located near the seashore were completely destroyed and drifted by the strong tsunami waves. Figure 6 shows one of the examples of building which was drifted by the tsunami about 70 meters. Most of the roads in Onagawa town especially those near the seashore were no longer visible. The roads were subsided by approximately 80 cm as shown in Figure 7 which can no longer be used for transportation. Some of the roads were still covered with tsunami debris and covered with sea water. However, many roads were already built by the government to pave for continuous repair and reconstruction of the devastated town. Display of column steel bars was overturned by the backflow of the tsunami wave (Figure 8).

Figure 6. Drifted building with tsunami. It was drifted about 70 meters by the waves.

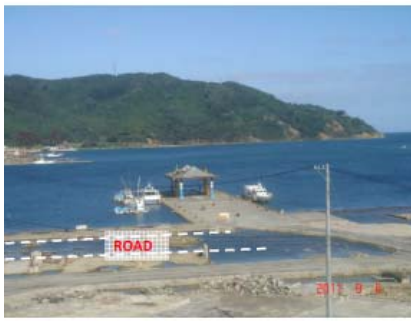

Figure 7. The old road near the port subsided about 80 cm.

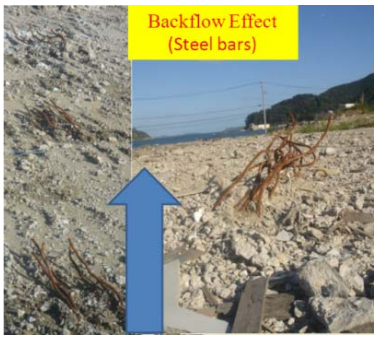

Figure 8. Backflow Effect