QUICK REPORT ON THE GREAT EAST JAPAN EARTHQUAKE AND GIANT TSUNAMI

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ABSTRACT: "The 2011 off the Pacific coast of Tohoku Earthquake" (Mw 9.0) is the largest earthquake among all recorded events in Japan. The damage due to the Mega tsunami was not restricted only to buildings and houses, but the resulting fires destroyed many communities and even nuclear power plant facilities have suffered complicated and serious damage. This paper is a quick report on the investigation of damage by the authors conducted from March 26th to 27th, and from March 31st to April 2nd. Due to the large scale of the earthquake damage and issues such as fuel shortage and damage to transportation infrastructure, the investigated area was limited to just the Tohoku area and the metropolitan area.

Key Words: *Disaster survey, the 2011 off the Pacific coast of Tohoku Earthquake, Earthquake motion, tsunami*

INTRODUCTION

At 14:46 JST (5:46 UTC) on March 11th, 2011, an earthquake of moment magnitude 9.0, the largest earthquake ever recorded in Japan, struck off the shore of the Sanriku area in the Tohoku Region. The "mega tsunami" which followed hit deeply indented coastal areas and brought extensive and devastating damage to many cities and villages in this area. Mega tsunami damage was not restricted only to buildings and houses, but the resulting fires destroyed many communities and even nuclear power plant (NPP) facilities have suffered complicated and serious damage due to this mega tsunami. This earthquake was later named "The 2011 off the Pacific coast of Tohoku Earthquake" by the Japan Meteorological Agency (JMA). The total number of dead and missing continues to increase relative to the 1995 Kobe Earthquake due to the large magnitude and killer tsunami of the earthquake (Figure 1). As of August 12th, 2011, the numbers of dead and missing were 15,694 and 4,669, respectively, and that of complete building damage was 112,962 (Table 1).

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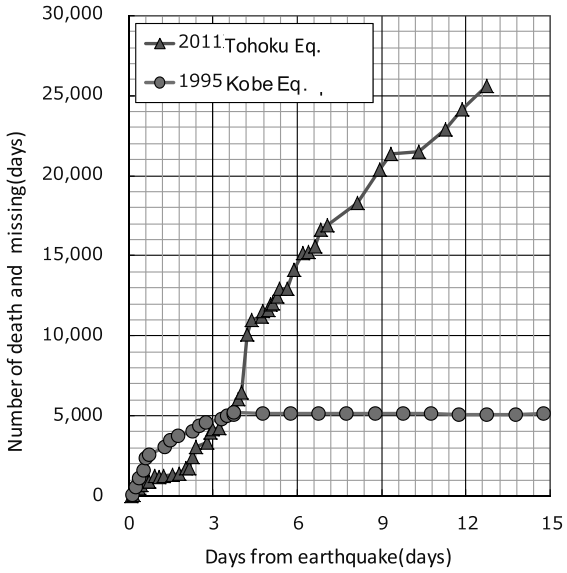


Figure 1 Comparison between the numbers of dead and missing during 1995 Kobe Earthquake and 2011 Tohoku Earthquake (Dr. Hada, University of Yamanashi)

Table 1 Overview of damages as of August 12th, 2011 (by National Police Agency)

		Human suffering			Building damage			Others			
		Dead	Missing	Injured	Complete	Half	Partial	Road	Bridge	Slope failure	Rail way
Hokkaido		1		3		4	7				
Tohoku	Aomori	3	1	61	307	851	105	2			
	Iwate	4,633	2,038	186	21,019	3,587	5,326	30	4	6	
	Miyagi	9,394	2,377	3,794	70,946	70,673	127,820	390	29	51	26
	Akita			12			3	9			
	Yamagata	2		29	37	80		21		29	
	Fukushima	1,601	250	239	16,940	40,763	127,723	19	3	9	
Tokyo		7		90		11	257	13		3	
Kanto	Ibaraki	24	1	699	2,665	18,290	150,452	307	41		
	Tochigi	4		131	260	2,058	60,613	257		40	2
	Gumma	1		38		7	16,150	7		4	
	Saitama			42		5	1,800	160			
	Chiba	20	2	249	788	8,712	29,422	2,343		55	1
	Kanagawa	4		129		7	279				
	Niigata			3			9				
	Yamanashi			2			4				
	Nagano			1							
	Shizuoka			4			4				
Chubu	Gifu							1			
	Mie			1							
Shikoku	Tokushima										
	Kochi			1							
Total		15,694	4,669	5,714	112,962	145,048	519,974	3,559	77	197	29

Earthquake motion

“The 2011 off the Pacific coast of Tohoku Earthquake” (Mw 9.0) is the largest earthquake among all recorded events in Japan; in global earthquake history from 1900, this is the Fourth-largest earthquake, similar to the Kamchatka Earthquake (1960, Mw 9.0), and following Chile Earthquake (1960, Mw 9.5), Alaska Earthquake (1964, Mw 9.2), and Off-Sumatra Earthquake (2004, Mw 9.1) by which more than 200,000 people were killed. In comparison with other earthquakes which have hit this district in the past, such as Meiji-Sanriku Earthquake (1896, Mw 8.25), Hokkaido East Offshore Earthquake (1994, Mw 8.2), this earthquake had 6 to 16 times greater energy. Compared to the Great Kanto Earthquake of 1923 (Mw 7.9), which caused the worst quake damages in Japan, the energy of this quake was 50 to 60 times greater; compared to 1995 Kobe earthquake (Mw 6.9), the energy was over 1000 times greater. The type of the fault was a reverse fault, with the pressure axis in the west-northwest to east-southeast direction, and the earthquake was an ocean trench type which occurred on the boundary between the Pacific Plate and the Continental Plate. The epicenter depth was 24 kilometers offshore from the Sanriku coast, but the fault area spread widely from Iwate Prefecture down to Ibaraki Prefecture, with a north-south length of about 500 kilometers and east-west length of 200 kilometers. The fault plane had a slight angle (10°) against the horizontal, and the upper side and lower side of the strata were compressed and slid over each other crossing in the west-northwest and east-southeast directions, resulting in large horizontal displacement. This is typical of the trench-type earthquakes occurred in this area. According to the “Earthquake Investigation Committee” of the Ministry of Education, Culture, Sports, Science and Technology, this earthquake is the combination of three independent earthquakes with a potential maximum slippage length of up to 24 meters. The maximum seismic intensity 7 (JMA scale) was recorded at Kurihara city in Miyagi Prefecture, and the maximum acceleration recorded was 2,933 gal (Figure 2). The earthquake motion continued for roughly two minutes. The fault was destroyed over an extended period of time with many aftershocks occurring frequently in a short interval, which resulted in a long and strong earthquake motion time. Vibration above intensity 4 continued for more than 120 seconds over a large area from Aomori to Kanagawa Prefectures; in some areas it reached up to 190 seconds (Onahama, Iwaki city, Fukushima Prefecture). Even outside of the Tohoku area, strong ground motion was observed: intensity 5 in Tokyo; intensity 4 in Nagoya; and intensity 3 in Osaka (Figure 3). Particularly in the Tokyo Metropolitan Area, some high-rise buildings swayed for more than 10 minutes due to the long period ground motion. Aftershocks have been occurring frequently, with epicenters over a 500-kilometer by 200-kilometer area from Iwate Prefecture to Ibaraki Prefecture.

Furthermore, the aftershocks were spread widely, both in the area east of the ocean trench close to the epicenter and also in the shallow waters near the coastlines of Fukushima and Ibaraki Prefectures (Figure 4). From March 11th to April 12th, aftershocks greater than magnitude 7 struck five times (7.7, 7.5, 7.4, 7.1, 7.0); aftershocks greater than magnitude 6 struck 68 times, and aftershocks greater than magnitude 5 struck 408 times. Among these aftershocks, 111 had a recorded maximum intensity, JMA scale 4. Compared to the previous huge earthquake in this area, the number of aftershocks in this case is remarkably high. Additionally, at 11:45 AM on March 9th, before the date of the main earthquake, an earthquake with magnitude 7.3 and maximum JMA intensity 5⁻ occurred just dozens of kilometers away from the main epicenter, with several aftershocks continuing through the next day. It is not certain whether this quake is a foreshock of the main quake or not. In the year 869, the “Jougan” earthquake occurred in an area offshore from Miyagi and Fukushima Prefectures with a magnitude 8.4. The National Institute of Advanced Industrial Science and Technology (AIST) pointed out the similarity of that quake with the March 11th event, and noted that the giant earthquake might be a re-occurrence of the past “Jougan” earthquake. According to the result of investigation of sedimentation in the wide area, AIST pointed out that a giant scale earthquakes like this event have occurred four times in the past: year 390 BC, year 430 AD, year 869 (Jougan), and year 1500. They also estimate that the re-occurrence interval might be 450 to 800 years.

In this huge earthquake, tectonic deformations were also observed. According to the observation results of Geospatial Information Authority (GSI)'s GPS data, electronic reference point of Ojika moved 5.3 meters to the east-southeast and 1.2 meters down.

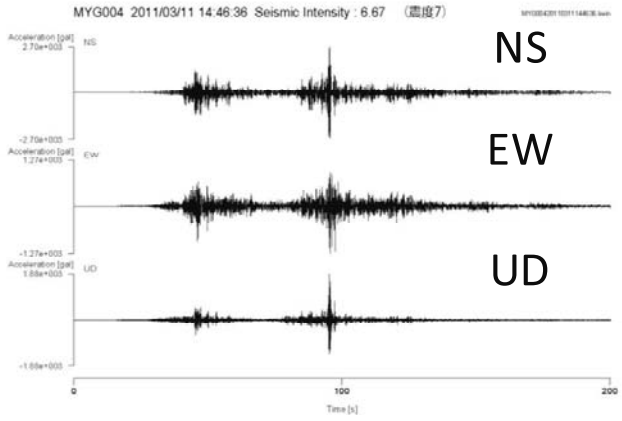


Figure 2 Acceleration record at Kurihara in Miyagi Prefecture (JMA)

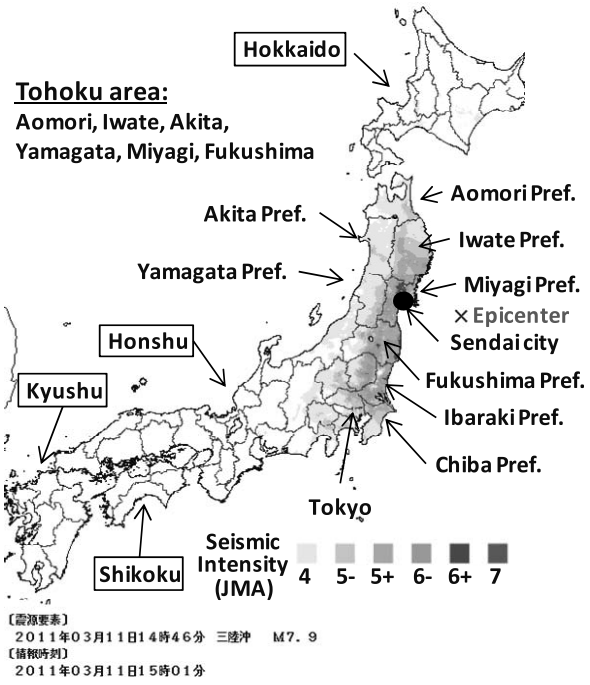


Figure 3 Seismic intensity distribution(JMA scale)

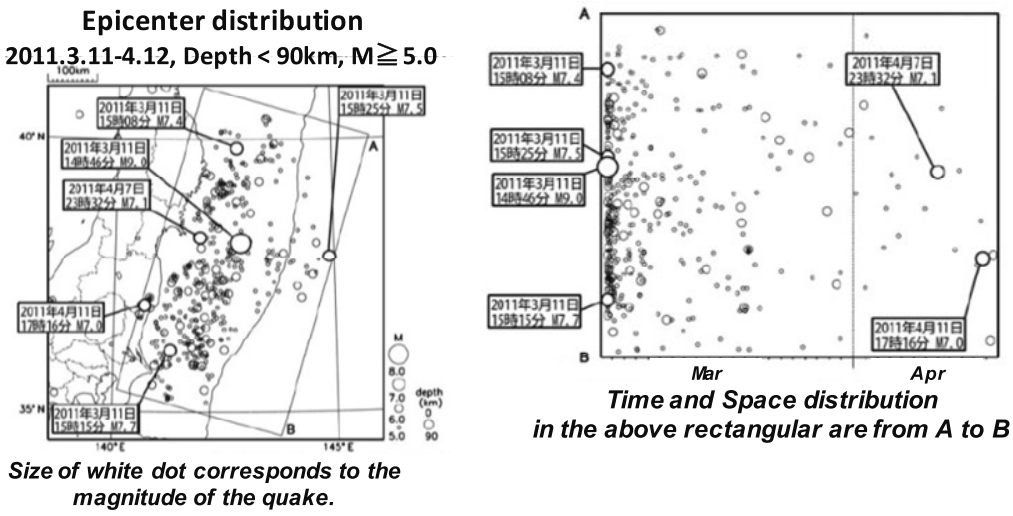


Figure 4　Epicenter Distribution (JMA)

TSUNAMI

A tsunami warning was issued for all coastal areas of Japan by March 12th, 3:20 PM (Figure 5). On March 13th, 5:58 PM, all tsunami warnings were cancelled. The world's largest coastal levee, with a total length of a 2 kilometers and maximum depth of 63 meters, which is recorded in the Guinness Book of World Records as the world's largest levee, was constructed in 2009 offshore from Kamaishi city in Iwate Prefecture, costing 120 billion yen. Although the giant tsunami caused by this earthquake destroyed 70 % of the levee structure, it is reported that the levee was helpful in delaying the tsunami's penetration into Kamaishi city streets by 6 minutes (Port and Airport Research Institute (PARI)). In the Tarou district of Miyako city, Iwate Prefecture, another huge coastal levee with a total length of 2,433 meters and maximum height of 10 meters was constructed following the bitter lessons of tsunami damages after the past Meiji-Sanriku and Showa-Sanriku quakes. This levee played an important role after the Chile earthquake tsunami in 1960, and no damage were recorded in the community. This time, however, the huge tsunami overcame the levee, flooded the plain, and ran up the mountain slope to a height of 38 meters above sea level. 580 meters of the levee itself was also destroyed. In contrast with this tsunami attack, a coastal levee 155 meters in length and 15.5 meters wide, and protected the whole village community of Fudai Village in Iwate Prefecture, resulting in only one missing person. River run-up phenomena due to tsunami were observed in many locations. In the Kitakami River, water level record showed that the tsunami had run up to a point 50 kilometers upstream from the river mouth. In the Tokachi River, tsunami run-up was 13 kilometers. Hachinohe city in Aomori Prefecture to Minami Soma city in Fukushima Prefecture, and the inundated areas were found to total more than 500 square kilometers according to trial calculations by the Geospatial Information Authority. This is based on aerial photographs taken on March 12th and 13th after the quake, from which calculations were carried out. According to the data taken, a maximum tsunami heights of 7.3 meters at Soma, 4.2 meters at Oarai, 4.1 meters at Kamaishi, 4 meters at Miyako, 3.3 meters at Ishinomaki, and 3.2 meters at Ofunato were recorded (Figure 6). Table 2 shows that the tsunami height reached more than 1.5 meters, even in the United States and Chile.

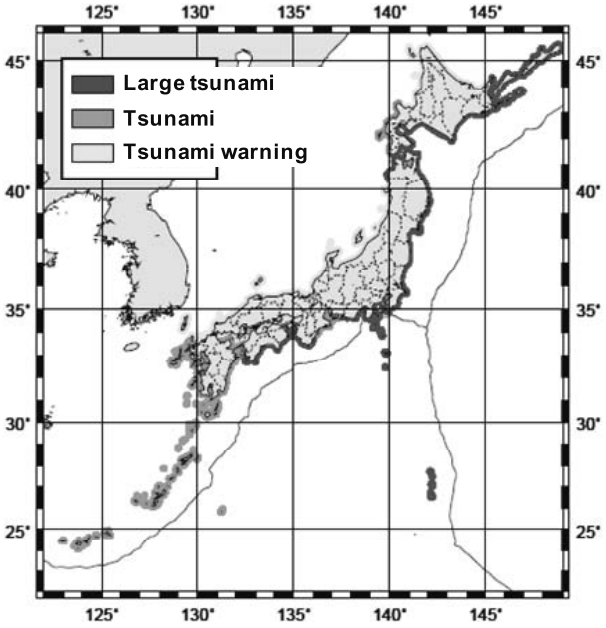
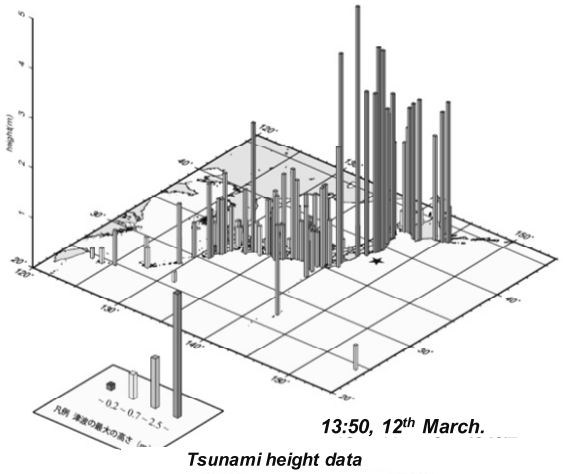


Figure 5 Tsunami Alarm and Warnings (JMA)



Tsunami height data

Place	The first wave			The maximum wave	
Souma	14:55	push	0.3m	15:50	>7.3m
Ooarai	15:15	push	1.8m	16:52	4.2m
Kamaishi	14:45	pull	0.1m	15:21	>4.1m
Miyako	14:48	push	0.2m	15:21	>4.0m
Ayukawa	14:46	push	0.1m	15:20	>3.3m
Oofunato	14:46	pull	0.2m	15:15	>3.2m
Mutsu	15:20	pull	0.1m	18:16	2.9m
Nemuro	15:34	pull	feeble	15:57	2.8m
Tokachi	15:26	pull	0.2m	15:57	>2.8m
Urakawa	15:19	pull	0.2m	16:42	2.7m

Figure 6 Recorded Tsunami Height of March 11, 2011 (JMA)

Table 2　Observed Tsunami Height at Overseas Tidal Measurement Stations (JMA Report 11)

Place	height	Place	height
Crescent City (California, U.S.A)	2.02m	Kaumalapau (Hawaii, U.S.A)	0.91m
Santa Cruz Island (Galapagos, Ecuador)	1.77m	Baltra Island (Galapagos, Ecuador)	0.82m
Kahului (Hawaii, U.S.A)	1.74m	Chatham Island (New Zealand)	0.81m
Callao (Peru)	1.67m	Acapulco (Mexico)	0.77m
Coquimbo (Chile)	1.46m	Kauai Island (Hawaii, U.S.A.)	0.76m
Manzanillo (Mexico)	1.45m	Easter Island (Chile)	0.73m
Caldera (Chile)	1.41m	Iquique (Chile)	0.72m
Hilo (Hawaii, U.S.A)	1.41m	Honolulu (Hawaii, U.S.A)	0.71m
Sand Island (Midway, U. S. A)	1.27m	Vanuatu (Vanuatu)	0.69m
Corral (Chile)	1.25m	Saipan Island (Northern Mariana, U.S.A)	0.65m
Arica (Chile)	1.25m	Christmas Island (Australia)	0.56m
Kawaihae (Hawaii, U.S.A)	1.22m	Kwajaiein Atoll (Marshall Idlsnfd)	0.55m
Talcahuano (Chile)	1.06m	San Felix Island (Chile)	0.54m
Manus Island (Papua New Guinea)	1.04m	Wake Island (U.S.A)	0.39m
Santa Barbara (California, U.S.A)	0.99m	Tern Island (Hawaii, U.S.A)	0.38m

Damages in Various Regions

The following are damage reports from this earthquake, based on quick surveys conducted from March 26th to 27th and from March 31st to April 2nd (Figure 7).

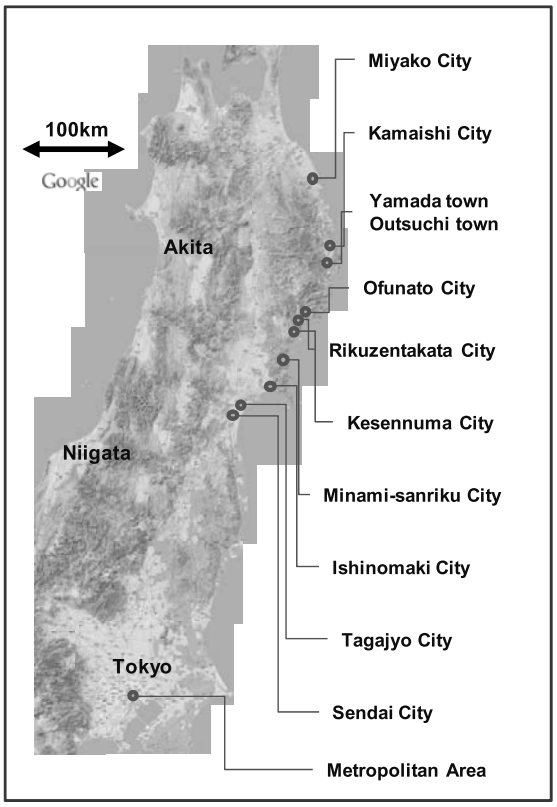
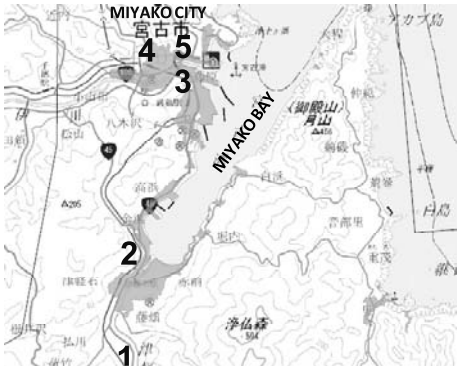


Figure 7　Area of the quick survey

Miyako City, Iwate Prefecture

According to Myakka city, the number of victims due to the tsunami as of June 17th was 33 injured and 195 missing. The number of evacuation centers was 11 with 670 people living there. The number of totally collapsed houses was 3,669, with 1,006 partially collapsed houses, and 176 partially-damaged houses. When we entered this area on March 26th, national route 45 and 106 were usable, although there was a large amount of debris along the road. Figure 8 shows the damage Tsunami-affected area and Photos of Myakka city.



Tsunami-affected area（red colored area, MLIT）

Broken pole in the front of the Showa-kan

The high mark of the tsunami was about 3 kilometers from the mouth of the Tsugaru Ishikawa river.

The boat shown here was swept up the Tsugaru Ishikawa from Miyako bay and stopped by the national road 45 bridge. The tsunami overflowed the river banks on the side of the Miyako city office building.

Damage to a hot spring facility

The anti-disaster headquarter office was set up after the earthquake at the Miyako city office building.

Figure 8 Tsunami-affected area and Photos of Miyako city

Kamaishi City, Iwate Prefecture

In Kamaishi City, the population was about 39,000 as of February 1st; the number of victims due to the tsunami reached 743 (as of April 20th 5:00 PM). The coastal area including Ootsuchi Inlet, Ryouishi Inlet, Kamaishi Inlet and Touni Inlet suffered severe and catastrophic damages, with roughly 6,000 survivors living in evacuation centers as of April 18th according to the city's disaster headquarters office. The tsunami inundated the city street and fire station, and fire engines were also damaged. The tsunami flood reached the 2nd story of the Kamaishi Regional Maritime Safety Headquarters and 8,400 local residents were evacuated. The coastal levee at the entrance of Kamaishi Port was recognized as the world's deepest levee (-63 m) by the Guinness Book of World Records. The mega tsunami destroyed the levy structure, but it is reported by the Port and Airport Research Institute that the levee was helpful in delaying the tsunami's invasion into the city streets of Kamaishi by six minutes. The coastal residential area of Hongou and Touni-cho in Kamaishi City was totally destroyed by two tsunami disasters in the past – the Meiji Sanriku Earthquake Tsunami (1896) and Showa Sanriku Earthquake Tsunami (1933). People learned lessons from these bitter experiences and after developing new land 25 meters or higher above sea level on the mountain side, 100 families built housings and completed relocation. This tsunami easily overran the 10 meter-high coastal levee and the maximum tsunami height reached to 20 meters, but the relocated community had suffered no damage. Conversely, recently-build houses on the lower land were swallowed by tsunami. Figure 9 shows the damages of Kamaishi city.

Huge vessel carried aground by the tsunami.

Local residents looking for survivors

Passenger cars swept off.

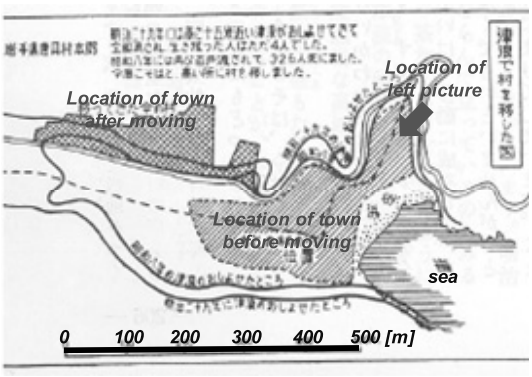
Debris piled up underneath the viaduct.

The extensive damage did not reach Kamaishi station.

Figure 9 Photos of Kamaishi city

The Touni district in Kamaishi city experienced severe damage in two big previous tsunamis in 1896 and 1933. About 100 households were relocated to an elevation of 25 meters, were residents cleared space by carving out the mountain side. These relocated houses were not damaged by the tsunami which overran the 10 meter sea wall bordering Touni Bay. On the other hand, about 50 newer houses built in the lower elevation nearer to the bay zone were damaged by the tsunami. According to the map recorded by Yamaguchi, houses damaged in this tsunami were located in the same area where houses were damaged in past tsunamis (Figure 10).

This photograph shows the damage at Touni-cho. The tsunami approached from the left hand side, overran a 10 meter high levee and destroyed the lower zone. The upper zone on the right hand side is the newly-relocated area after the past experience of tsunami damage, which suffered almost no damage from this tsunami.



Relocation of residents after past tsunamis
(By Yaichiro Yamaguchi)

Aftermath of the tsunami run up the Ayukawa river.

Only slight damage was seen at the railway and station.

Figure 10 Photos of the Touni district in Kamaishi city

Yamada Town, Iwate Prefecture

In Yamada-town, 578 people died, with 267 missing. The number of refugees was 2,135 people as of June 15th. A fire broke out at the same time as the tsunami, and heavy damage occurred. The fishery and sightseeing industries suffered greatly from the damage. Figure 11 shows the damage to the tide embankment at Yamada bay and damage to the bank of Iwate, Yamada branch.

Damage to the tide embankment at Yamada bay

Damage to the Bank of Iwate, Yamada branch

Figure 11 Photos of the Yamada Town

Otsuchi town, Iwate Prefecture

A big fire occurred just after the earthquake, and the dead and missing totaled 1730 in Otsuchi-town as of June 10th. The mayor of this town, Hiroshi Kato, also died in the tsunami. Figure 12 shows the damages in Otsuchi town.

Otsuchi-cho as seen from national route 45

Damage to Otsuchi hospital

Tsunami run-up the Otsuchi river (right bank)

Tsunami run-up the Otsuchi river (left bank)

Figure 12 Photos of the Otsuchi town

Ofunato city, Iwate Prefecture

295 people died, 194 people were missing and the number of injured people was unknown. The number of destroyed houses was also unknown (at the time of 5:00 pm, April 20th). The photos of Figure 13 were taken on March 26th. The tsunami didn't reach the houses located at the higher elevation areas, and the extent of damage was completely different between high and low elevations.

A boat was lifted up to the roof of a two-story building by the tsunami.

Large damages to the area of fishery companies

The tsunami didn`t run up to houses located at higher elevations.

Tsunami damage suddenly appears when moving to lower areas.

A shrine located on a small mountain was not damaged.

Damage was not observed at higher level zone behind of the signal.

Figure 13 Photos of the Ofunato city

Okirai, Sanriku-town, Ofunato city, Iwate Prefecture

Catastrophic damage was seen in Okirai Ofunato city (Figure 14). All houses in the villages were washed away by the tsunami. Rias Line tracks were also damaged by the tsunami. Because of clothes draped on an 8 meters high railway bridge, the tsunami is believed to have reached this height. In addition, the tsunami also destroyed the embankment and scattered concrete blocks.

Figure 15 show the damage to the Okirai elementary school. All 71 students were safe even though the school was overcome by the tsunami. Students went to the top of a cliff using an emergency passage which was constructed before the earthquake (last December) and then evacuated to the Sanriku station. Elementary school and junior high school also succeeded in evacuating. Meanwhile, 70% of students from Okawa elementary school in Ishinomaki city, Iwate Prefecture, were killed or went missing as they were caught by the tsunami due to late evacuation.

Only foundations remained after the tsunami.

An embankment destroyed by tsunami.

Rias line was shifted by the tsunami. The rails fell down from the embankment.

Clothes draped on the railway bridge.

The tsunami ran over the 8m high railway embankment.

Figure 14 Photos of the Okirai, Sanriku-town, Ofunato city

Damage to the Okirai elementary school. The students were safe even though the tsunami came.

Significant damage was not seen in Sanriku station where the Okirai school students evacuated.

Tsunami swept past the Okirai elementary school and damaged the other side of it.

Okirai elementary school

Figure 15 Photos of the Okirai, Sanriku-town, Ofunato city

Yoshihama, Sanriku-town, Ofunato city, Iwate Prefecture

In the Meiji Sanriku Big Tsunami in 1896, 204 people were killed in the Yoshihama district. The village mayor at that time thus decided to move to a higher ground level. As a result, the number of houses swept away by the Showa Sanriku Tsunami in 1933 was only ten. In this tsunami, the paddy field zone where the village was located in the past was totally under water and the coastal levee was destroyed. However, only one totally collapsed house was seen, and only one person, a fisherman, died. Figure 16 shows the damage to Yoshihama.

The tsunami had enough energy to destroy the coastal levee, but didn't reach the residential area due to the energy loss by the coastal levee. In the past, there were houses in the open space seen in the picture.

The tsunami swept behind the house.

The tsunami stopped at the foot of slope.

The tsunami reached the first floor of the gas station.

The tsunami reached the first floor of the house next to the gas station.

Figure 16 Photos of Yoshihama, Sanriku-town

Rikuzentakata City, Iwate Prefecture

Rikuzentakata City (population: about 24,000 people) received catastrophic damage from the tsunami. 1,335 people were killed, 841 people went missing, and 3,368 houses were damaged (as of 17:00, April 20). According to the Iwate prefectural police, 80 percent or more of the downtown area was under water. Figure 17 shows the damage to Rikuzentakata city.

Tsunami-damaged area in Rikuzentakata (red hatch locations, Geographical Survey Institute)

The entire city was damaged by tsunami. Takata-Matsubara-daiichi stadium was also hit.

The tsunami reached up to the 5th floor of the RC apartment building.

The tsunami destroyed the road bridge.

The tsunami reached the the 5th floor.

Sand in the bathroom of the 5th floor

Figure 17 Photos of Rikuzentakata city

Kesennuma City, Miyagi Prefecture

At Kesennuma in Miyagi Prefucture, 815 people were killed, 1,216 people went missing, 6,157 people were evacuated, and a large number of houses were damaged (April 19th, 20:00). Large damage also occurred in the Kesennuma fishing port where marine products were swept up onto land. A fire due to oil leaking from a ship after the earthquake damaged the port area of Kesennuma. Figure 18 shows the damage to Kesennuma city.

No major damage to the RC structure can be seen.

Fish processing facilities near the port were damaged.

Houses swept up the river by the tsunami.

Extensive damage due to the tsunami and fire.

Figure 18 Photos of Kesennuma city

Minami-Sanriku Town, Miyagi Prefecture

Minami-Sanriku town was suffered catastrophic damage due to the tsunami (Figure 19). The dead totaled 474 people, with 647 people missing, and 3,877 totally collapse buildings. The number of evacuees was 6,405 people, and 22 buildings were burnt by fire (15:00, April 20).

Large area of fire damage due to the tsunami

Mass of rubble along the road

Damaged RC structure

Sluice damaged by tsunami

Figure 19 Photos of Minami-sanriku town

Onagawa town, Miyagi Prefecture

Onagawa town is well-known as a fishing port town in Japan. The dead and missing people totaled about 5,000 people. In addition, about 80 percent of the houses were swept away by the tsunami. It is reported that the height of the tsunami in Onagawa reached 14.8 meters. Figure 20 shows the damage to Onagawa town.

The tsunami reached over 20 meters high.

The tsunami reached the top of the wall.

View of damaged town

A four story steel frame building was overturned by the tsunami.

Figure 20 Photos of Onagawa town

Ishinomaki City, Miyagi Prefecture

Ishinomaki city is the second largest affected city with a population of about 160 thousand. 2,818 people were killed, 2,770 people went missing, 11,932 people were evacuated, and 28,000 houses were destroyed (as of April 20th 11:30). Ishinomaki city is one of the largest cities for the fisheries industry, but the fishing and aquaculture facilities were severely damaged by the tsunami. Figure 21 shows the photos of Ishinomaki city.

Bent poles and left over debris

A damaged steel frame structure

An industrial tank was overturned.

Rescue operations by the Self-Defense Force

Cars were swept up into the forest

Figure 21 Photos of Ishinomaki city

Sendai City, Miyagi Prefecture

In Sendai city, the largest city in the Tohoku region with a population of 1.05 million, the tsunami reached roughly 2 kilometers from the coast line and many buildings, houses and cars were washed away. In Wakabayashi word, 200 to 400 dead bodies were found, with the cause said to be drowning. Sendai airport was also inundated and airplanes were unable to take off and land for a month. Also, the tsunami ran up the Natori River and caused heavy damage. Figure 22 shows the damage in Sendai city.

Damage to a 3-story reinforced concrete building due to ground motion

Damage to Sendai airport and the tents of the Self-Defense Force

Damage to a timber house by ground motion

Collapsed ceiling at a gas station

Fire at factory due to the tsunami

Damage to Nakano elementary school. After the earthquake, many people who had evacuated to the gym were inundated by the tsunami.

Damage to Nakano elementary school, located 1.2 kilometers from coast

A house trapped by a bridge located about 2.5 kilometers from the coast

Damage area along the Nanakitagawa River, including fire damage

Houses damaged by slope failure; geotechnical damage was observed in housing development areas.

Figure 22 Photos of Sendai city

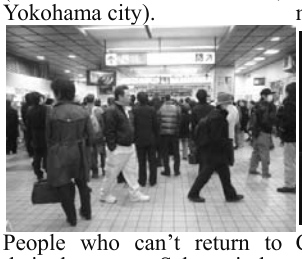
Metropolitan Area

In Tokyo metropolitan area, many people could not return home due to the earthquake, and many other people returned home by walking for several hours due to suspension of railway operations. In addition, the Tokyo Metropolitan Expressway was closed, and road congestion continued past midnight. Figure 23 shows the photos of Metropolitan Area.

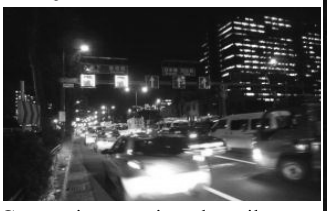
After the earthquake, all subway stations were closed (Nihonodori station, Yokohama city).

After the earthquake, a gasoline shortage occurred not only in Tohoku but also in the metropolitan area.

People returned home by walking.



People who can't return to their home at Sakuragi-cho station.



Congestion continued until past midnight on normal roads.

After the earthquake, Tokyo Metropolitan Expressway was closed and an urgent check was executed at once. 17 days after the earthquake the Tokyo Metropolitan Expressway was re-opened.

After the earthquake, convenience stores ran out of stock all at once (at Gotanda).

Professional baseball was canceled, and the stadium was opened as a refuge (Yokohama Stadium).

Figure 23 Photos of Metropolitan Area

CONCLUSION

For quick and proper response, recovery and restoration of the huge area severely affected by the earthquake and killer tsunami, the following issues should be introduced; 'restoration office and its activities' and Mr. Shinpei GOTO's 'Restoration Plan of Imperial City, Tokyo' and his four principles on the plan after the 1923 Great Kanto Earthquake Disaster, 'Pairing disaster support system' that the Chinese government adopted after the 2008 Sichuan Earthquake, limitations and issues of the current Basic Act on Disaster Control Measures in Japan and important issues that should be improved, and actions that the Japanese government need to tackle for reducing

the damage due to future earthquakes such as the Tokyo inland earthquake and Tokai, To-nankai, and Nankai Earthquakes which may occur in the coming decades. In addition, We propose the vision of restoration from the earthquake disaster as described below.

Goal of restoration: Creative restoration contributing to the future development and happiness of Japan

Four principles:

1)Restoration activities should solve the future problems of Japan as well as contribute to quick recovery for a safe built environment in the affected areas

2)Restoration should be implemented through good cooperation between all stakeholders in Japan, such as national and local governments, private companies, NGOs/NPOs, and all Japanese people including citizens in the affected areas

3)Restoration should be done considering the environment, sustainability and recovery of local industries in the affected areas

4)Reconstruction should consider the potential for unexpected events

The meanings of the four principles can be explained as follows. 1) Of course, the first priority is the quick recovery of a safe built environment in the affected areas. However, the affected areas have many other problems, such as shrinking population, aging society, and weak local industry, and the severity of these problems is much higher than the average of other parts of Japan; therefore, reconstruction should provide solutions to these problems. 2) As the scale of the disaster was huge, restoration by the national and affected local governments and victims was not enough. For a speedy recovery and improvement of disaster management capacity of the whole country, restoration should be implemented through cooperation and giving money and ideas. 3) No need to explain. 4) After the earthquake, many people said ‘this was an unexpected event and beyond the expected conditions;’ however, we should consider unexpected situations when designing and building. Otherwise, we will face the same situation in the future.

Due to the huge magnitude of the earthquake and its induced tsunami, as well as the continuing effects of the nuclear power plant accident, recovery of the affected areas may take 10 or even 20 years. But I believe that the Japanese will work together and recover from the disaster, and that they will take advantage of this opportunity to create a safer and more comfortable built environment. Furthermore, We hope that they will give solutions to the problems which other parts of Japan may face in the future.

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We would like to express our gratitude to all everyone who volunteered, and we hope for swift recovery in the damaged area.

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