16th World Conference on Earthquake, 16WCEE 2017
Santiago Chile, January 9th to 13th 2017
Paper N° 4193
Registration Code: S-A1440831921

Misunderstood lessons from the 2011 Great East-Japan Earthquake Tsunami disaster

K. Meguro(1)

(1) Director/Professor, International Center for Urban Safety Engineering, Institute of Industrial Science, the University of Tokyo, meguro@iis.u-tokyo.ac.jp

Abstract

At 14:46 (local time) on March 11th, 2011, an earthquake with moment magnitude 9.0 occurred off the shore of the Sanriku area in the Tohoku (North-East) Region of Japan. It was followed by a "Mega Tsunami" which hit deeply indented coastal areas and brought extensive and devastating damage to many cities, towns and villages. These areas have been historically attacked by large tsunamis, such as the 1896 Meiji-Sanriku, 1933 Showa-Sanriku, and 1960 Chili Earthquake Tsunamis and based on these experiences, people in affected areas have been promoting preparation of both structural and non-structural countermeasures against tsunami. It had been reported that this area had literally the highest tsunami disaster countermeasures in the world. The breakwater constructed at the mouth of Kamaishi Port, which was reported in the World Guinness Records and the tsunami levee with 10 m elevation called Taro's great wall were typical examples of such structural countermeasures. However, the 2011 Tsunami exceeded the height of these structures and attacked inland, and caused devastating damage including over 18 thousand fatalities.

Mass media have reported that tsunami disaster countermeasures had limited effects and could not reduce the damage despite the fact that these measures were prepared by spending a lot of money and time, and many people believed such reports. In this paper, I will prove such reports by mass media and lessons that many people believed to have learned from the disaster were not correct based on the quantitative analysis. And I will introduce positive and negative effects of both structural and non-structural measures. Following is one of the examples that is misunderstood by the general public.

At the time of the earthquake, there were approximately 620 thousand people were in all areas inundated by the 2011 Tsunami. Among them, 18 thousand were killed which is 3 % of the total population. While it is important to verify the cause of fatalities and find solutions for them, it is also important to acknowledge that 97% of the people who were in the tsunami inundated areas were saved by the pre-event countermeasures that were in place. Survivors' ratio of 97 % is very high compared to that of other massive tsunami disasters in the past worldwide. Unless we emphasize the importance and effects of pre-event countermeasures, the general public may underestimate their effects and easily forget their importance.

The highest ratio of fatalities in only tsunami inundated area was 12.8 % of Rikuzen-takata City and that in whole municipality area was 9.46 % of Onagawa Town. These ratios are much smaller compared to the values in the past in areas that did not have well established countermeasures. For example, the fatality ratio was 32.7 % in Unosuma Village, 53.9 % in Kamaishi Ttown, and 66.4 % in Toni Village in case of the 1896 Meiji-Sanriku Tsunami disaster when the population of Japan was 42 million, one third of the current population and 22 thousand people were killed. The fatality ratios of Taro when compared among three disasters in 1896, 1933 Showa-Sanriku, and 2011 Great East-Japan Tsunami disasters, were 83.1%, 32.5 %, and 3.9 %, respectively. This is a proof that people could reduce the damage drastically by well-established pre-event countermeasures.

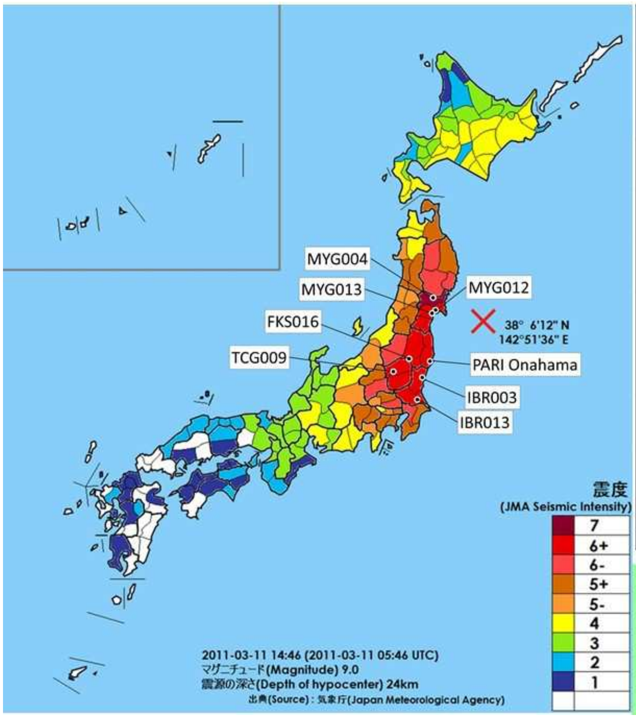
Keywords: 2011 Great East-Japan earthquake, Tsunami disaster, Structural and non-structural countermeasures

1. Introduction

An earthquake with moment magnitude 9.0, which is the largest among all earthquakes scientifically recorded in Japan, occurred at 14:46 (local time) on March 11th, 2011. The Japan Metrological Agency (JMA) named this earthquake "the 2011 off the Pacific coast of Tohoku Earthquake (but it is generally called the Great East-Japan Earthquake) and it induced "Mega Tsunami". The tsunami hit deeply indented coastal areas and brought extensive and devastating damage to many cities, towns and villages. The Cabinet Office of Japanese Government named this extensive and devastating damage as Great East-Japan Earthquake Disaster.

The affected areas have been historically attacked by large tsunamis, such as the 1896 Meiji-Sanriku, 1933 Showa-Sanriku, and 1960 Chili Earthquake Tsunamis. Based on these experiences, people in affected areas have been promoting preparation of both structural and non-structural countermeasures against tsunami. It had been reported that these affected areas had literally the highest tsunami disaster countermeasures in the world. The breakwater constructed at the mouth of Kamaishi Port, which was reported in the World Guinness Records and the tsunami levee with 10 m elevation called Taro's great wall were typical examples of such structural countermeasures. However, the 2011 Tsunami exceeded the height of these structures and attacked inland, and caused devastating damage including over 18 thousand fatalities.

Mass media have reported that tsunami disaster countermeasures had limited effect and could not reduce the damage despite the fact that these measures were prepared by spending a lot of money and time, and many people believed such reports. In this paper, I will prove such reports by mass media and lessons that many people believed to have learned from the disaster were not correct based on the quantitative analysis. And I will also introduce positive and negative effects of both structural and non-structural measures, and some important points for proper reconstruction from large disaster.



Maximum Horizontal Peak Acceleration (cm/s²)	Observation point
2,765	MYG004 (K-NET Tsukidate)
1,970	MYG012 (K-NET Shiogama)
1,913	PARI Onahama
1,844	IBR003 (K-NET Hitachi)
1,802	MYG013 (K-NET Sendai)
1,614	IBR013 (K-NET Hokota)
1,425	TCG009 (K-NET Imaichi)
1,425	FKS016 (K-NET Shirakawa)

Relation between JMA and Modified Mercalli Intensity Scale

MMI	1	2	3	4	5	6	7	8	9	10	11	12
JMA	0	1		2	3	4	5−	5+	6−	6+	7	

Fig. 1 – Distribution of seismic intensity (left) and peak ground accelrations (right) recorded during the 2011 Great East-Japan Earthquake [2]

2. Outline of the damage due to the 2011 Great East-Japan Earthquake and Tsunami

The 2011 Great East-Japan Earthquake generated strong ground motions and huge tsunami that hit wide area of East-Japan region. Maximum inundation depth and run up height of tsunami reported were 21 m and 43.3 m, respectively [1]. About ground motion, seismic intensity 7 of JMA intensity scale was observed, which is the highest ground motion level in JMA scale and is same as intensity 12 of MMI scale as shown in Fig. 1 [2]. The Peak Ground Acceleration (PGA) recorded in affected areas were very high. Top eight largest PGAs recorded locations and their values are shown in Fig. 1. Quite high PGAs with approximately 1.5 to 2.8 G were observed in wide areas but structural damage was so minor because of the following two reasons. First, predominant period of the ground motion was around 0.5 sec or shorter and the period between 1 to 3 sec, which affects a lot normal buildings and civil infrastructure, was not strong. The other reason was that preparation against earthquake had been carried out well in the affected areas. This was due to a probability of the earthquake occurrence reported by JMA as 85 % within 20 years and 99 % within 30 years with magnitude 7.5 or more in Miyagi Prefecture and nearby location.

The number of death toll and missing was over 22,000 including 3,460 people killed by indirect cause after the quake as shown in Table 1 and 99.5 % were in Miyagi, Iwate and Fukushima Prefectures. Among 3,460 indirect death toll, 2,037 victims were in Fukushima Prefecture during the prolonged refugee life under stressful conditions. Among the direct death toll, 92.4 % were caused by tsunami. The total direct monetary loss by the 2011 Great East-Japan Earthquake was 16.9 trillion yen as shown in Table 2 and it is 1.7 times larger than that by the 1995 Kobe earthquake. The maximum damage was that of buildings mainly caused by tsunami and it was 10.4 trillion yen ([3], [4]).

Five years have already passed since the 2011 Great East-Japan Earthquake, its induced damage was so serious that the Japanese people are still recovering from it and facing many issues. Activities in response to the accident of the Fukushima Dai-ichi (First Fukushima) Nuclear Power Station are difficult and insufficient to alleviate its impact to both inland and marine environments.

Table 1 – The number of fatalities in each prefecture affected (by National Police Agency [3])

Prefecture	Death toll	Missing	Total (direct)	Indirect death	Total
Hokkaido	1	0	1	0	1
Aomori	3	1	4	0	4
Iwate	4,673	1,142	5,815	441	6,256
Miyagi	9,537	1,280	10,817	971	11,788
Yamagata	2	0	2	1	3
Fukushima	1,607	207	1,814	2,037	3,851
Ibaraki	24	1	25	41	66
Tochigi	4	0	4	0	4
Gunma	1	0	1	0	1
Saitama	0	0	0	1	1
Chiba	21	2	23	1	24
Tokyo	7	0	7	0	7
Kanagawa	4	0	4	0	4
Total	15,882	2,668	18,550	3,460	22,010

Table 2 – Monetary loss by the 2011 Great East-Japan Earthquake [4]

Item (details)	Loss (trillion yen)
Building structures (residential structures, stores, offices, factories, etc.)	10.4
Lifeline facilities (water, gas, electricity supply systems, communication and broadcast systems)	1.3
Civil Infrastructure (river, road, ports, airport, sewerage systems, etc.)	2.2
Agriculture, Forestry and Fisheries related	1.9
Others (education, health, medical, welfare facilities, and other public facilities)	1.1
Total	16.9

3. Positive and negative effects of structural and non-structural countermeasures

As Table 3 shows, there are two types of disaster countermeasures, one is structural and the other is non-structural. In this chaper, I will explain the positive and negative effects of these two countermeasures.

Table 3 – Positive and negative effects of structural and non-structural disaster countermeasures

	Positive effect	Negative effect
Structural countermeasures	-Breakwater at Kamaishi Port -Tsunami levee at Taro	It provides a sense of security, especially with underestimated tsunami warning information.
Non-structural countermeasures	-Tsunami education (Kamaishi's miracle)	Hazard map influences people's decision to evacuate and it can provide exessive sense of safety depending on the evacuation of hazard.

3.1 Positive and negative effects of structural countermeasures

Prior to 2011, based on the past tsunami disaster experiences, the areas affected by the 2011 Tsunami had been promoting preparation of both structural and non-structural countermeasures and their preparation level became the world's highest. The breakwater constructed at the mouth of Kamaishi Port and the tsunami levee in Taro area were the typical examples of such structural countermeasures. But, the 2011 Tsunami exceeded the height of these structures and attacked inland, and caused devastating damage including over 18 thousand fatalities.

By showing the failed image of such facilities (Fig. 2), mass media conveyed that tsunami disaster countermeasures, which were prepared by spending a lot of money and time, could not reduce the damage, and many people believed the news. However, this is not correct.

Fig. 2 – Damage to structural countermeasures against tsunami, breakwater at Kamaishi Port (left) and tsunami levee at Taro, Miyoko-City, Iwate Prefecture

At the time of the earthquake, there were approximately 620 thousand people existing in all areas inundated by the 2011 Tsunami. Among them, 18 thousand people, which is 3 % of the total population, were killed just after the earthquake and tsunami. While it is important to verify the causes of fatalities and find solutions for them, it is also quite important to acknowledge that 97% of the people who were in the tsunami inundated areas survived owning to the pre-event countermeasures that were in place. Survivors' ratio of 97 % is very high compared to that of other massive tsunami disasters in the past worldwide as well as the same areas. Unless we emphasize the importance and effects of pre-event countermeasures, the general public may underestimate their effects and easily forget their importance.

Table 4 shows the fatality ratios in whole municipality area and only tsunami inundation area in each municipality. The highest fatality ratio in only tsunami inundation area was 12.8 % of Rikuzen-takata City and that in whole municipality area was 9.46 % of Onagawa Town [5]. These ratios are much smaller compared to these values in the past, when tsunami countermeasures was not yet established. Table 5 shows that the fatality ratios in case of the 1896 Meiji-Sanriku Tsunami disaster that were 32.7 % in Unosumai Village, 53.9 % in Kamaishi Town, and 66.4 % in Toni Village, respectively. The population was 42 million, one third of the current population and 22 thousand people were killed [6]. The fatality ratios of Taro when compared among three disasters in 1896, 1933 Showa-Sanriku, and 2011 Great East-Japan Tsunami disasters, were 83.1%, 32.5 %, and 3.9 %, respectively, as shown in Table 6 [7]. This is a proof that well-established pre-event countermeasures can reduce the damage, especially human loss.

The effects of the breakwater constructed at the mouth of the Kamaishi Port, which mass media negatively reported that it could not be functional, was evaluated by the Port and Airport Research Institute (PARI) [8]. Figure 3 shows the result of breakwater effect evaluated by high accuracy numerical tsunami simulation. From the research results of PARI, arrival time of tsunami could be delayed by 6 minutes which was a long time from the viewpoint of the people who were trapped by tsunami. The impact by the tsunami to inland facilities and structures was reduced by decreased velocity of tsunami wave. With drastic reduction of the amount of seawater coming into bay, inundation depth and run up height could be reduced by 30 to 50 %. If there had not been a breakwater, they might have been 1.43 to 2.0 times higher than actual. Also, during backwash of tsunami, by the dam effects of the breakwater, rapid backwash with high velocity could be prevented and save a lot of people.

Table 4 – Fatality ratios in municipalities and inundated area [5]

Prefecture	Municipality c:city, t:town, v:village	Population (2010.4)	Maximum inundation depth (m)	Inundation area (km^2)	Population in inundated area	Total (death + missing)	Death ratio to the municipality population (%)	Death ratio to the population in inundation area (%)
Aomori	Misawa-c	42425	8.4	6		2	0.0047	—
Aomori	Hachinohe-c	244700	6.4	9		2	0.00082	—
Iwate	Hirono-c	21164	15.1	1		0	0	—
Iwate	Kuzi-c	41094	8.6	4		4	0.0097	—
Iwate	Noda-t	5303	14	2		38	0.72	—
Iwate	Fudai-v	3374	22.8	1		1	0.030	—
Iwate	Tanohata-v	4465	28.6	1		33	0.74	—
Iwate	Iwaizumi-t	12539	28.8	1		7	0.056	—
Iwate	Miyako-c	65682	7.3	10	18378	554	0.84	3.01
Iwate	Yamada-t	21180	9.7	5	11418	854	4.03	7.50
Iwate	Otsuchi-t	17468	12.6	4	11915	1449	8.30	12.16
Iwate	Kamaishi-c	44632	9.3	7	13164	1180	2.64	8.96
Iwate	Ofunato-c	43682	11.8	8	19073	448	1.03	2.35
Iwate	Rikuzen-takada-c	26018	18	13	16640	2122	8.16	12.75
Miyagi	Kesennuma-c	73541	12	18	40331	1417	1.93	3.51
Miyagi	Minamisanriku-t	17339	15.9	10	14389	987	5.70	6.86
Miyagi	Ishinomaki-c	160252	7.4	73	112276	4043	2.52	3.60
Miyagi	Onagawa-t	10032	17.5	3	8048	949	9.46	11.79
Miyagi	Higashi-matsushima-c	42760	10.3	37	34014	1150	2.69	3.38
Miyagi	Matsushima-t	15187	2.9	2	4053	2	0.013	0.049
Miyagi	Rifu-t	33795	2.9	0.5	542	2	0.0059	0.37
Miyagi	Shiogama-m	56859	4.9	6	18718	21	0.037	0.11
Miyagi	Shichigahama-m	20495	12	5	9149	72	0.35	0.79
Miyagi	Tagajo-c	63728	5	6	17144	191	0.30	1.11
Miyagi	Sendai-c	1035651	8	52	29962	737	0.071	2.46
Miyagi	Natori-c	72606	8.3	27	12155	993	1.37	8.12
Miyagi	Iwanuma-c	44448	8.8	29	8051	184	0.41	2.29
Miyagi	Watari-t	34867	7.7	35	14080	261	0.75	1.85
Miyagi	Yamamoto-t	16802	12.2	24	8990	693	4.12	7.71
Fukushima	Shinchi-t	8822	7.6	11	4666	110	1.25	2.36
Fukushima	Soma-c	38624	9.1	29	10436	459	1.19	4.40
Fukushima	Minami-soma-c	73853	16.3	39	13377	673	0.91	5.03
Fukushima	Namie-t	22053		6		184	0.83	—
Fukushima	Futaba-t	7381	15	3		35	0.47	—
Fukushima	Okuma-t	10995		2		74	0.67	—
Fukushima	Tomioka-t	16091		1		26	0.16	—
Fukushima	Naraha-t	8208		3		13	0.16	—
Fukushima	Hirono-t	5581	8.7	2		3	0.054	—
Fukushima	Iwaki-c	356165	7.4	15	32520	347	0.097	1.07
Ibaraki	Kita-ibaraki-c	51180	6	3		5	0.0098	-----
Ibaraki	Tokai-v	35604	4.2	3		4	0.011	-----
Ibaraki	Hitachinaka-c	155336	4.4	3		2	0.0013	-----
Chiba	Asahi-c	68774	7.6	3		13	0.019	-----
		3150755		522.5	483489	20344	0.65	4.21

On the other hand, there was negative effects of structural measures that gave relief to the people so that they could have been hesitant to evacuate from tsunami. Especially, the areas with high protection facilities, such as huge breakwater or levee, evacuation was delayed due to JMA's underestimated height of tsunami warning. The main reason for underestimating tsunami height was that JMA estimated the magnitude of the 2011 Great East-Japan Earthquake as 7.9 while it was actually 9.0. JMA estimated the tsunami height based on magnitude 7.9 that tsunami height would be 6 m for Miyagi Prefecture and 3 m for Iwate and Fukushima Prefectures that were much smaller than real tsunami and much lower than tsunami protection facilities that they had. It may be said that this is a negative effect by having had substantial structural measures.

Table 5–Fatality ratios in the 1896 Meiji-Sanriku Earthquake [6]

		Population	Death Toll	Heavily injured	Slightly injured	No. of Survivors	Fatality Ratio	Municipality level
Unoshumai-v	Ryoishi	939	790	12	13	179	84.1	32.7
	Unoshumai	712	174	9	20	538	24.4	
	Hakozaki	930	15	0	2	921	1.61	
	Katagishi	563	49	3	8	514	8.70	
Kamaishi-t	Kamaishi	5687	2907	68	243	2780	51.1	53.9
	Hirata	1299	858	16	292	441	66.1	
Toni-v	Oishi	323	10	0	0	318	3.10	66.4
	Arakawa	260	115	2	9	145	44.2	
	Katagishi	156	98	9	9	58	62.8	
	Koshirahama	629	475	18	6	154	75.5	
	Honngo	873	769	6	3	104	88.1	
	Kerobe	294	217	0	13	77	73.8	

Table 6–Fatality ratios in Taro in the past disasters ([6], [7])

Earthquake (Mw) (Y.M.D)	Population	No. of death and missing	Ratio of death and missing (%)	No. of houses	No. of houses collapsed or washed away	Ratio of house collapsed or washed away (%)
Maiji-Sanriku Eq. (M8.5) (1896.6.15)	2,248	1,867	83.1	345	345	100
Showa-Sanriku Eq. (M8.4) (1933.3.3)	2,773	911	32.5	559	500	89.4
Great East-Japan Eq. (M9.0) (2011.3.11)	4,302	166	3.9	1,467	979	66.7

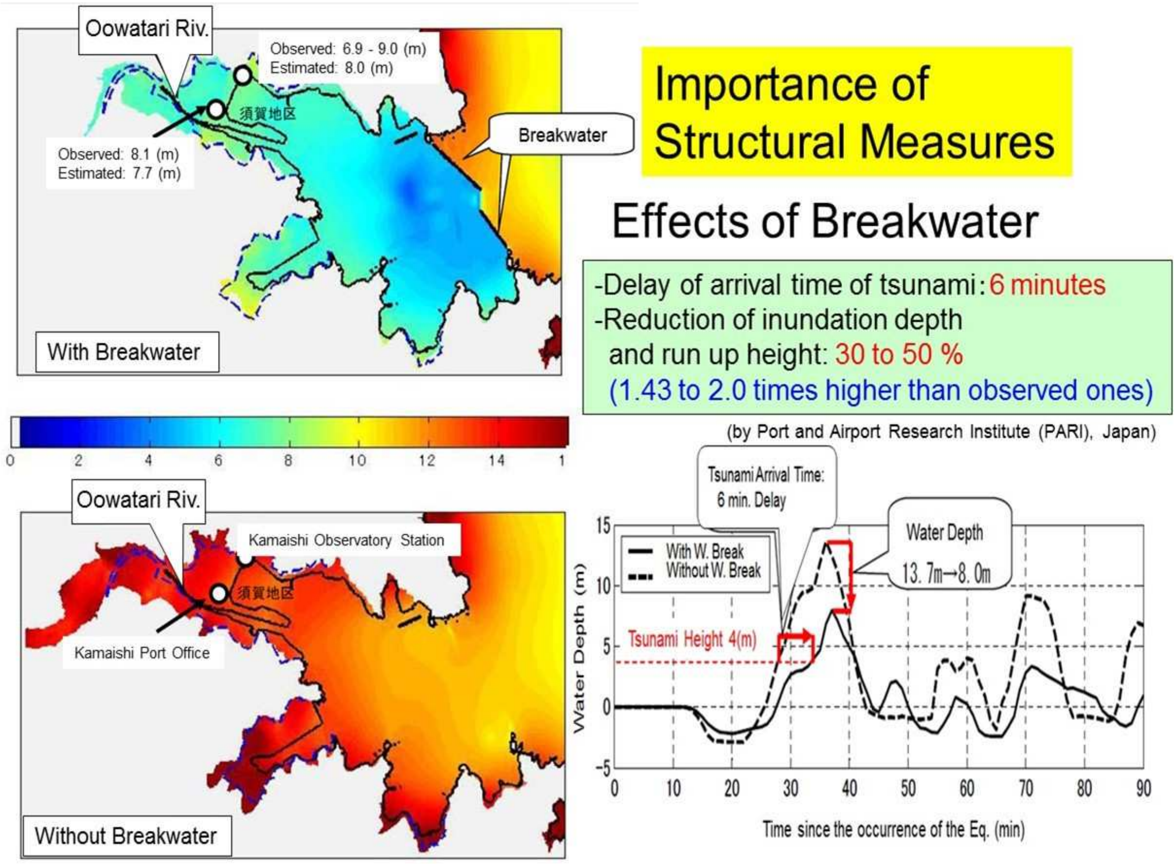


Fig. 3 – Numerical simulation of the effects of breakwater at the mouth of the Kamaishi Port [8]

3.2 Positive and Negative Effects of Non-Structural Countermeasures

So-called “Kamaishi’s miracle” is a typical example of the positive effects of non-structural measures [9]. At the time of the 2011 earthquake, there were 2,926 students in all elementary schools and junior high schools in Kamaishi City. Among these students, 2,921 students survived and five students were killed. All of these five students were either absent on that day or evacuated with their parents independently from their classmates immediately after the earthquake. Survivor ratio of students in Kamaishi City was 99.83 % and this was called “Kamaishi’s miracle.”

Behind this miracle, there was a great contribution of Professor Toshitaka Katada from Gunma University who had been giving an excellent disaster education to students in Kamaishi City. He proposed “three principles for safety evacuation” which were 1) Don’t believe damage estimation, 2) Never give up and do your best with your situation, and 3) Be an evacuee who guides others. With the support from teachers and education committees of Kamaishi City, he educated the students using three principles. Typical good example was the evacuation behavior by the students of Kamaishi-Higashi junior high school and Unosumai elementary school. These two schools were located in same area and they had carried out disaster drill together. Just after the 2011 earthquake, the students of Unosumai elementary school evacuated to the roof of school building but the senior students of Kamaishi-Higashi junior high school were in the schoolyard and called elementary school students to come. And all students of the two schools evacuated to planned evacuation place but they found slope failure near the place and decided to move to the higher place. Again, they considered that place was not safe enough, they moved to higher place taking pupils of kindergarten and aged people living nearby. If they had been in the planned evacuation place, they would have been trapped by tsunami, but because of their good decision and activities, all students could survive.

Next, I will introduce negative effects of non-structural measures. In Kamaishi City, where there was Kamaishi's miracle, hazard maps were distributed to all households before the quake. When we checked the relation between the addresses of the people who were killed by the tsunami and hazard map, one third of the victims were living in high risk areas on the map, but twice larger number of victims were living in relatively safer areas on the map. There was the possibility that hazard map was misused as a safety map by some of the victims. But, we should not forget about the importance of the hazard map and hazard map could save a lot of people. This is also important point that we should never misunderstand.

4. Common lesson leant from past three large earthquake disasters in Japan

Figure 4 shows the causes of the death toll in the past large earthquake disaster in Japan. From the figure, major causes of death are different in each disaster. In case of the 1923 Great Kanto Earthquake, 87.1 % were by fires, in case of the 1995 Kobe Earthquake, 83.3 % were by structural damage by ground motion, in case of the 2011 Great East-Japan Earthquake, 92.4 % were by tsunami [10].

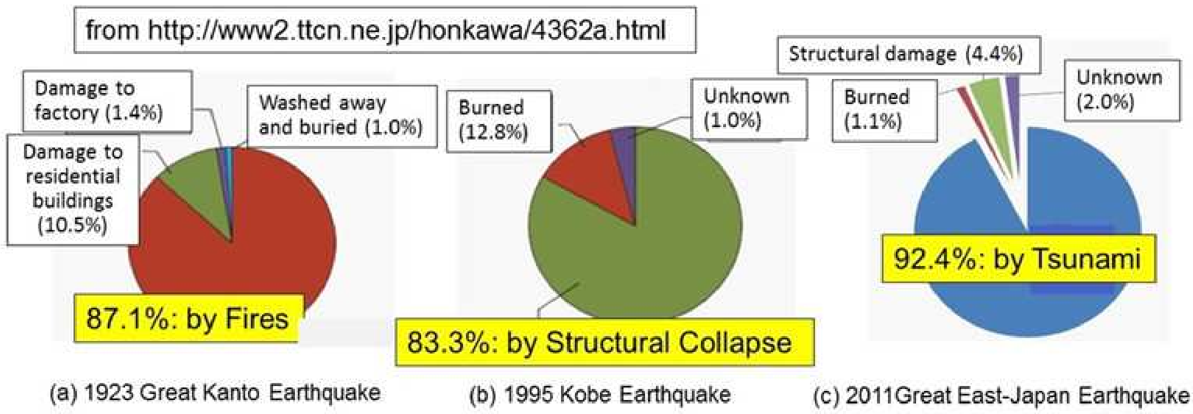


Fig. 4 – Causes of death toll by the past major earthquake disasters in Japan [10]

Lessons from three earthquake disasters in the past seem to be different, but there is a common important lesson when I investigate each cause carefully. It is a seismic capacity of structures and its big effects to whole earthquake disaster.

The biggest cause of the spread of fires in case of the 1923 Great Kanto Earthquake is collapse of the buildings. By structural collapse, possibility of break out of initial fires increased, and condition of extinguishing initial fires became difficult and fires spread. In case of the 1995 Kobe earthquake disaster, the collapse of the old buildings constructed before 1981, when the latest structural code was revised, and over turning of the furniture became a major direct cause of the death toll. In addition, since just after the earthquake to three days later, there were 45 to 50 thousands people trapped under the damaged structures in the whole affected areas.

Among all these people, approximately 8,000 people were taken care by public services, such as firefighters and self-dense force, 27,000 people were by the local people, and 10 to 15 thousands people escaped from the damaged structures by themselves. About the people who were killed by fires, most of them were trapped under the damaged buildings and could not escape from the fires. Direct cause was fires, but if their structures had been strong enough, they could have escaped from fires and survived. In case of the 2011 Great East-Japan Earthquake, there were very few structures heavily damaged by the ground motion, therefore, there were no people who were trapped under damaged structures and could not escape from tsunami. If there had been many people who were trapped under the damaged structures in tsunami stricken area similar to the Kobe earthquake case, many of them might have been killed by tsunami.

5. Effects of long period ground motion

Figure 5 shows the natural periods of structures and facilities. In general, ground motion with predominat period from 0.5 to 2 sec is critical for standard houses and buldings and the structures with long natural period of 3 sec or more, such as super high-rise buildings, large-scale strorage tanks and long span brige, etc. have minor effects against such ground motion. However, when the long period ground motion attacks the structures with long natural period, structural response becomes larger and they might have severe damage.

Long period ground motion by the 2011 Great East-Japan earthquake was observed in wide areas from Central to Western part of Japan including Tokyo metropolitan area. Due to this long period ground motion, structural response of super high-rise buildings became large and amplitude was about one meter. However, it was lucky for Tokyo area because volume of accretionary prism that transmits long period ground motion well is limited in eastern region from Kanto as shown in Fig. 6 [11]. In case that large earthquake happens in western part of Japan, such as the one along the Nankai trough, effects of long ground motion becomes much higher. Therefore, we should not misunderstand that as the effects of long ground motion with magnitude 9 class was not so severe in Tokyo area, magnitude 8 class earthquake along the Nankai trough will not be big problem. The effects from the earthquake in western area becomes much severer compare to that in eastern area.

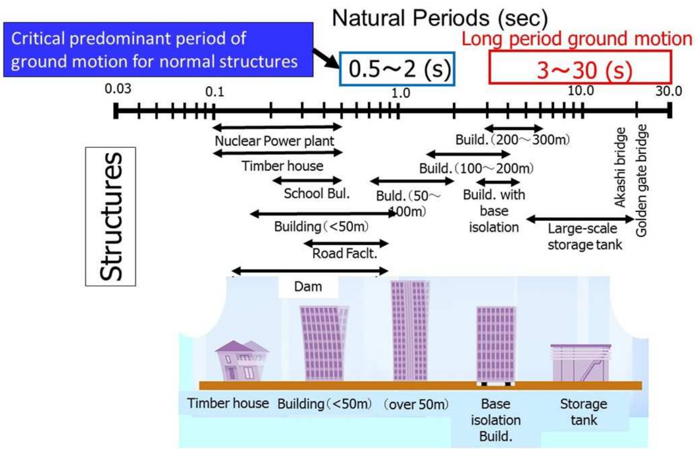
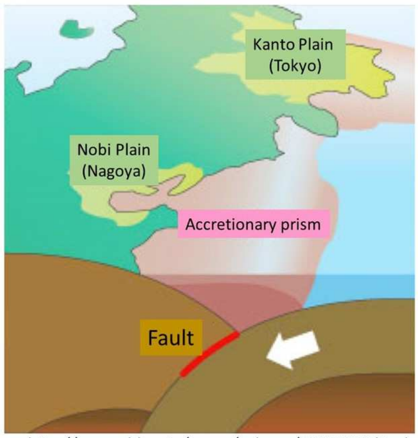


Fig. 5 – Natural periods of structures and facilities



http://www.nhk.or.jp/sonae/column/20121013.html

Fig. 6 – Distribution of Accretionary prism [11]

6. Important points for proper reconstruction from the huge disaster

Two days after the earthquake, I was invited to come to national strategic office of the Japanese government to give some advices to disaster response by the government. For proper quick response towards recovery and reconstruction of affected areas, I explained the followings. 1) Imperial Capital Reconstruction Department and Dr. Shinpei Goto's Tokyo reconstruction plan and four principles after the 1923 Great Kanto Earthquake, 2) Pairing system carried out after the 2008 Sichuan earthquake in China, 3) Issues and limitations of Disaster Countermeasure Basic Act of Japan, and 4) Proper system that Japanese government should establish for future

Tokyo metropolitan inland earthquake and Tokai, To-Nankai, and Nankai earthquakes along Nankai trough. Based on the next meeting held three days after the first meeting, I summarized my ideas and proposed the vision of reconstruction as follows.

Vision of reconstruction: Creative revival to become the foundation of the future prosperity and development
Four principles:
1) Reconstruction for showing solutions for Japanese future issues as well as implementation of rich and safe built environment of affected areas
2) Reconstruction carried out jointly by national and local governments, private sectors, NPO/NGO, the people in affected areas as well as the other parts of the country by sharing ideas and resources
3) Reconstruction considering low environmental load, sustainability, and local industrial revival
4) Reconstruction based on the re-examination of the preconditions

Fig. 7 – Vision of reconstruction and four principles for reconstruction

Under the vison of reconstruction that is a creative revival to become the foundation of the future prosperity and development, I put four principles. I will briefly explain meaning of each principle. About the first one, it is primary important to implement rich and safe built environment of affected areas, but the affected areas are problem advanced areas, such as depopulation and aging society, their reconstruction should show the solutions for the other areas which will face similar problem in future. Big disaster has unique characteristics that it shorten the time and show the potential problems that affected areas have with or without disaster. Therefore, recovering what it was before the earthquake is not enough although affected people are saying that they want to have same built environment as before the quake. Disaster is very unfortunate event, but unfortunate event should be used for solving the problems that affected areas had. This is a concept of 'Build Back Better (BBB)' that was declared in Sendai statements at the 3rd UN World Conference on Disaster Risk Reduction (3WCDRR) in March 2015 in Sendai, Miyagi Prefecture.

Then, does the reconstruction, which is being carried out at a stricken area of Sanriku, satisfy this condition? I have considerable doubt.

The reason why people moved to high land and made their town after the 1896 Meiji-Sanriku and 1933 Showa-Sanriku earthquake and tsunami disasters were that it was the only way for them to have enough elevation to escape from tsunami attack. Now, we have technology to have enough height without moving on the hill. But people in affected areas are constructing new town and new civil infrastructure on the high land excavating large hill. Also, they are constructing very high banking on the lower area to build a new space for business using big amount of soil from hill excavation. These are very expensive not only for their construction but also for maintenance. When they use current technology and construct high rise buildings, 15 to 20-story buildings in affected areas, people can have safe and enough floor area with much lower cost and there is no need to construct new civil infrastructure. With some rule, lower floors, such as from the ground to 4th or 5th floors are used only for public purpose and residential people live only from 6th or higher floors, they can enjoy tsunami safe life. The following problem can also be solved that when huge tsunami protection facilities are constructed, people cannot see the ocean. It is often pointed out by the people, mainly fishermen. If my proposed new type evacuation centers, which I plan to introduce at 16 WCEE presentation, are constructed in lower land, people can use lower area with safe condition without making high elevation banking. Considering the expected changing of the society, there are many positive effects from economical, ecological and health care's viewpoints. As one of various types of reconstruction, if people in affected areas accepted this type of the reconstruction, it would give some good solution for the future disaster reconstruction.

About the second principle, in case of disaster with normal scale, disaster response activities are mainly done by affected local governments and people, and national government. But the 2011 disaster was huge and their colaboration is not enough. Therefore, it is important for all stakeholders in Japan to respond jointly sharing ideas and resources to help affected areas for quick recovery. Especially, supports from the people who had disaste rexperiences. But, there is another important meaning of the second principle that supporting activities are very usefull for the people, who visited affected sites and helped disaster reponse activities, to have real experience on disaster response. For reduction of damage due to future large earthqukes, it is important to learn what disaster management is through supporting activities in affected areas.

About the third principle, the meaning is simple as it is written. About the forth, this is a warning for the possibility of unexpected situation. We should recognize that there was blind belief in our scientific knowledge and technologies and that they were not enough. We should always question our knowledge and never forget the sense of awe and humble feeling to nature for implementation of a disaster safe society.

7 Conclusions

Although five years have already passed since the 2011 Great East-Japan Earthquake, its induced damage was so serious that the Japanese people are still recovering from it and facing many issues. I believe that it is quite important to consider the recovery from this disaster as a national important issue and to tackle this issue seriously by whole country for reducing damage by future big earthquakes, such as Tokyo metropolitan inland earthquake and gigantic earthquakes along the Nankai trough, as well as for the victims in affected areas due to the 2011 Great East-Japan Earthquake disaster. Since the occurrence of the earthquake, I have been recognizing that there are many problems which cannot be solved by the results in some small number of specialties, great power of nature, and sense of the awe and humble feeling to nature which we, researchers in disaster management, should not forget.

In this paper, I have introduced misunderstood ideas that the general public believed based on negative reports from mass media and corrected them. In actuality, the fatality ratio and the number of fatalities due to the 2011 Great East-Japan Earthquake were much lower than those in the past tsunami disasters in the world as well as in the same location, and structural measures, such as breakwater and tsunami levee, played important roles and reduced the fatalities. Also, I have introduced by using some examples that both structural and non-structural measures have positive and negative effects. Moreover, I have explained the reasons of minor structural damage considering high PGA, effects of long period ground motion, and some points that are important for proper recovery and reconstruction from large disaster.

References

[1] Yutaka Honkawa (2011): Tsunami height due to the 2011 Great East-Japan Earthquake, Honkawa Data Tribune, http://www2.ttcn.ne.jp/honkawa/4363b.html (in Japanese)

[2] Japan Meteoroidal Agency (2011) Database of seismic intensity in Japan, http://www.data.jma.go.jp/svd/eqdb/data/shindo/index.php (in Japanese)

[3] National Police Agency of Japan (2016): Damage Situation and Police Countermeasures, 10 February, 2016. Retrieved 4 March, 2016 (in Japanese)

[4] Cabinet Office of Japan (2011): Estimation of monetary loss due to the 2011 Tohoku earthquake and tsunami disaster, http://www.bousai.go.jp/2011daishinsai/pdf/110624-1kisya.pdf (in Japanese)

[5] Ministry of internal affairs and communications (2011): Information related the 2011 Great East-Japan Earthquake disaster, http://www.soumu.go.jp/shinsai/index.html (in Japanese)

[6] Fumio Yamashita (1982): Tragic history of Sanriku Tsunami Disasters, 413p, Seijisha (in Japanese)

[7] Crisis Management Office of Miyako-City (2012): Damage Situation in Miyako-Citydue to the 2011 Great East-Japan Earthquake and Tsunami, website, http://www.city.miyako.iwate.jp/cb/hpc/Article-490-1167.html (in Japanese)

[8] Takehiko Fujita (2011): Tsunami Impacting Eastern Japan and Preparedness for Extraordinary Natural Disaster, http://www.pari.go.jp/files/items/3459/File/2011052327IAPH.pdf

[9] Toshitaka Katada (2011): No miracle that 99.8% of the schoolkids survived, How the children of Kamaishi got through the tsunami, WEDGE REPORT (May 10, 2011)

[10] Cabinet Office of Japan (2012): White Paper on Disaster Management 2011 (in Japanese)

[11] K. Koketsu: What is a long period ground motion?, Basic knowledge on long period ground motion, NHK website, http://www.nhk.or.jp/sonae/column/20121013.html (in Japanese)