Roles of Civil Engineers for Disaster Mitigation under Changes of Natural and Social Environments

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1. Introduction

The natural environmental changes such as global warming, heat island phenomena in mega cities, the decrease of the forest, desertification and erosion of rivers, are resulting in extremely heavy rains and snows, huge typhoons and hurricanes, abnormally high temperature, and high tidal waves. In addition to the change of natural environment, our social environment is also changing and it is becoming fragile against natural disasters. Those are highly congested urban areas, depopulation of rural areas, human habitation on disaster-prone lands, lack of cooperation and communication among recent urban societies, and insufficient infrastructures for disaster mitigation. The characteristics of the natural disasters are changing due to the changes of the natural and social environment.

This paper briefly reviews the recent natural disasters in the world and associated subjects. Furthermore, the author discusses the basic concept of the policies for the natural disaster mitigation and the roles of civil engineers.

2. Natural Disasters and Climate Change in the World

2.1 Recent Earthquake and Tsunami Disasters in the World

During recent few years, the disastrous earthquakes and tsunamis have attacked the Asian countries. The 2004 Sumatra earthquake and consequent tsunami killed more than 2 hundred thousand people in the areas around the Indian Ocean[1]. In the same year, a devastating earthquake caused serious damage to Niigata Prefecture, Japan[2] due to extensive slope failures in mountainous areas. In 2005, about 70 thousand people were killed in Pakistan[3], and last year, a disastrous earthquake attacked the Java Island, Indonesia.

Figure 1 shows the number of earthquakes and tsunamis with more than one thousand casualties in each five years period during the last 60 years in the world. The number of events has drastically increased in the last two decades.

The number of earthquakes with magnitudes more than 7.0 and more than 6.0 in the world during the last 60 years is shown in Figure 2. On the contrary of the increase of the earthquake and tsunami disasters, the number of

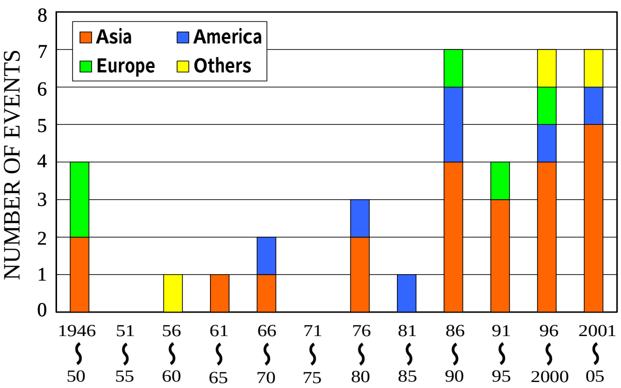

Figure 1 Damaging Earthquakes and Tsunamis in the World in the Last 60 Years (Events with more than 1000 casualties)

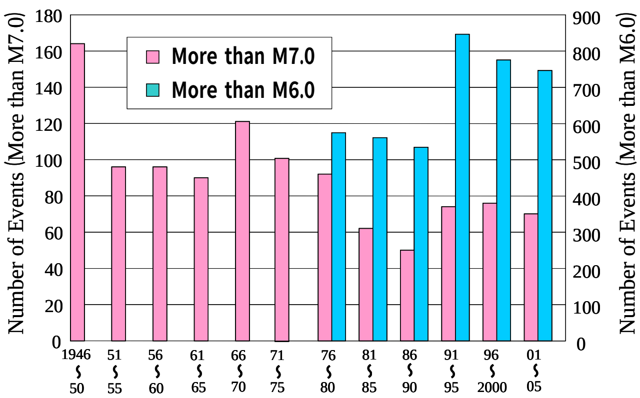

Figure 2 Number of Earthquakes with Magnitudes More than 7 and More than 6

occurrences of earthquakes with magnitudes more than 7.0 has been decreasing during the last 60 years. The number of the earthquakes with more than 6.0 slightly increased during the last decade, but was not consistent with the rapid increase of the number of the earthquake and tsunami disasters. This suggests that the reason of the increase of the earthquake and tsunami disasters is the increase of the vulnerability of our human societies. The regional ratio of the number of the earthquake and tsunami disasters and of the number of causalities during the last two decades is shown in Figure 3. 25 earthquake and tsunami disasters occurred in the world. Among them, 16 events were in Asian region. About five hundred thousands people, which are almost 90% of the total number of casualties in the world were killed in Asian region.

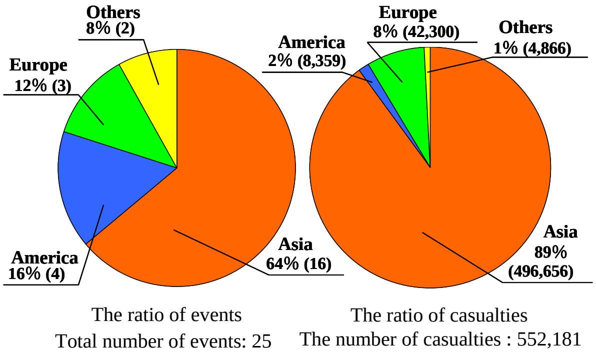

Figure 3 Regional Ratio of Earthquake Tsunami Events and Casualties (1986–2005 Events with More than 1000 Casualties)

2.2 Recent Storm and Flood Disasters in the World

Storm and flood disasters also have suffered the people in the world in recent years. During the last decade, 21 disasters killed one hundred thousands people. Most of the storm and flood disasters were concentrated in the Asian region and Central America. In 2005, Hurricane Katrina attacked Louisiana in United States, and killed more than 5 thousand people. In 2004, the Asian countries such as Japan, Philippines, India and Bangladesh suffered from many typhoons and heave rains, and about four thousand lives were lost.

Figure 4 shows the number of storm and flood disasters with more than one thousands casualties in each five years period during the last 60 years. The storm and flood disasters in the world have also increased during the last two decades. And, the disasters in Asia are dominant. The regional ratio of the number of the storm and flood disasters and the number of causalities is shown in Figure 5. 31 events occurred during the last two decades in the world, and 23 events, which was about three quarters of the total number, attacked the Asian region. About two hundred thousand lives, which is almost 80% of the total causalities were lost by storm and flood disasters in the Asian region.

There may be two main reasons for the increase of the flood and storm disasters. One is the increase of the vulnerability of the human societies against disasters, which is particularly remarkable in the Asian countries. Another reason may be the global climate change. Figure 6 illustrates the change of air temperature and seawater temperature in the world during the last 40 years. The air temperature raised about 0.5 degree in centigrade and the sea water temperature raised 0.3 degree. The rise of seawater temperature can be considered to be one of causes of the occurrence of huge typhoons and hurricanes, and high tidal waves.

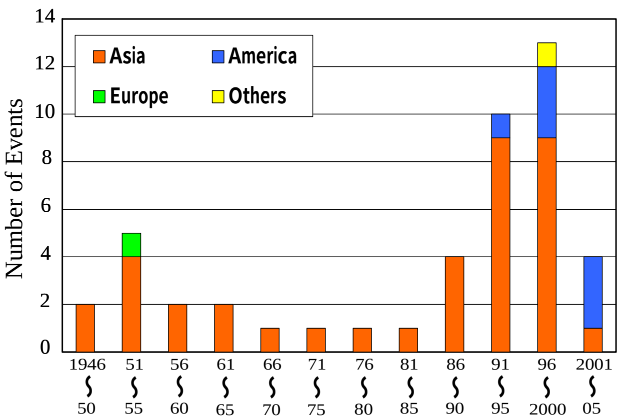

Figure 4 Damaging Storms and Floods in the World during the Last Half Century (Events with more than 1000 casualties)

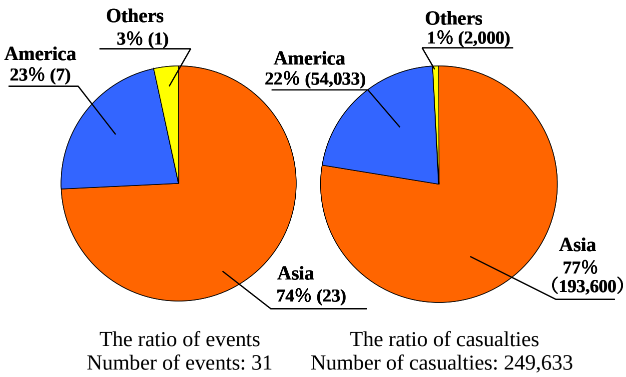

Figure 5 Regional Ratio of Storm and Flood and Associated Casualties (1986–2005, Events with More than 1000 Casualties)

2.3 Recent Natural Disasters and Climate Change in Japan

The locations of earthquake disasters after the 1995 Kobe earthquake are shown in Figure 7. The total 6 thousand and five hundred lives were lost, including the Kobe earthquake. We have learned new lessons from each past earthquake. From the Kobe earthquake, we learned lack of earthquake resistance of concrete bridges, subway structures and buildings against the strong earthquake ground motions in the near field of the earthquake fault. A large man-made island reclaimed from the sea extensively was liquefied resulting in severe damage to structures such as storage tanks, and quaywalls.

The Niigata earthquake in 2004 taught us new lessons, one of which was an overlap of different natural disasters. Three days before the earthquake a huge typhoon attacked the same area with heavy rains. The slopes in the mountainous area and embankments were saturated. The earthquake ground motion caused huge landslides and embankment failures. Liquefaction also caused severe damage to lifeline systems, and strong ground motion in the vicinity of the fault derailed the bullet train, Shinkansen. This derailment of Shinkansen exposed a serious social subject, which is how to balance the risk with a large benefit of the high-speed train for the society and the people.

The recent flood and storm disasters in Japan are shown in Figures 9 and 10. Flood and storm disasters with casualties meaningfully occurred twice a year, and about 5 hundred lives were lost during the last decade. Last year, a huge mudflow, which was caused by a heavy rain, attacked residential area in Nagano Prefecture, and killed 12 people. In 2004, Itsukushima shrine, one of national treasures was severely damaged by high tidal wave and strong wind by a large-scale typhoon. In 2005, a downpour with 100 mm rain per hour flooded a wide area of the downtown of Tokyo. This is considered to be caused by the heat island phenomena in highly urbanized mega cities.

Figure 11 shows the change of the temperature and the rain falls in Japan. The mean temperature in whole area of Japan raised about 0.7°C during the last 30 years, and 1.0°C in Tokyo. The number of the rainfalls with more than 100 mm per hour in Japan

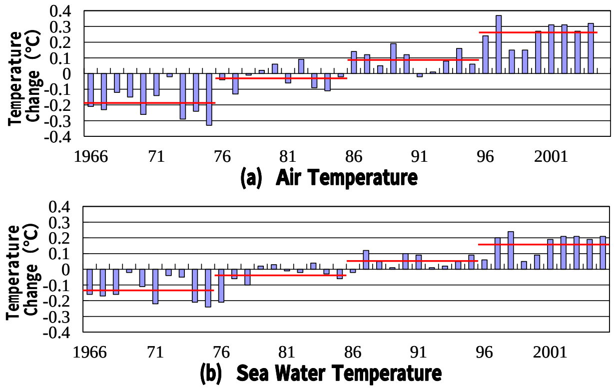

Figure 6 Temperature Change of Air and Sea Water in the World [4)]

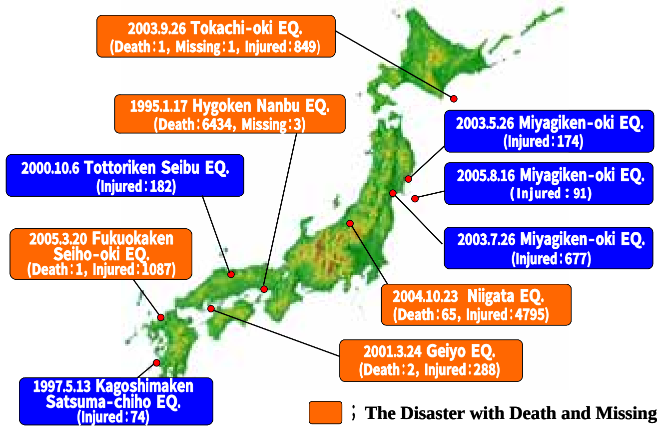

Figure 7 Recent Earthquake Disasters in Japan (1995–) (The Number of Death and Missing : 6507)

(a) Slope Failure

(b) Embankment Failure

(c) Uplift of Sewage Manholes

(d) Derailment of Shinkanse (Bullet Train)

Figure 8 Disaster by the 2004 Niigata Earthquake has been increasing during the last decade.

3. Basic Concepts of the Policy against Future Disasters under the Change of Natural and Social Environments

The natural environment is changing. Those changes are global warning, heat Island phenomena in urbanized area, deforestation, desertification and erosion of river and seashore. The change of natural environment is increasing natural disasters. Those are extremely heavy rains and snows, huge typhoons, hurricanes and cyclones, drought, abnormally high temperature and high tidal waves due to the rising of sea water level. In addition to the change of natural environment, our social environment is also changing, becoming fragile against natural disasters. Those are too congested urban areas, depopulation of rural area, human habitations on fragile ground, lack of cooperation and communication among the recent urban societies, budget deficit of central and rural governments, and finally poverty. The poverty is the most important factor for the increase of the natural disasters in the Asian countries. The poverty is expanding the disaster, and the disaster is worsening the poverty.

The characteristics of natural disaster are changing due to the change of natural and social environments. What is the basic policy against these kind of natural disasters? The key point for the measures against future disasters is how to prepare unexpected natural phenomena and against external forces largely exceeding the design level. In another word, how to prepare against natural disasters with a huge scale,

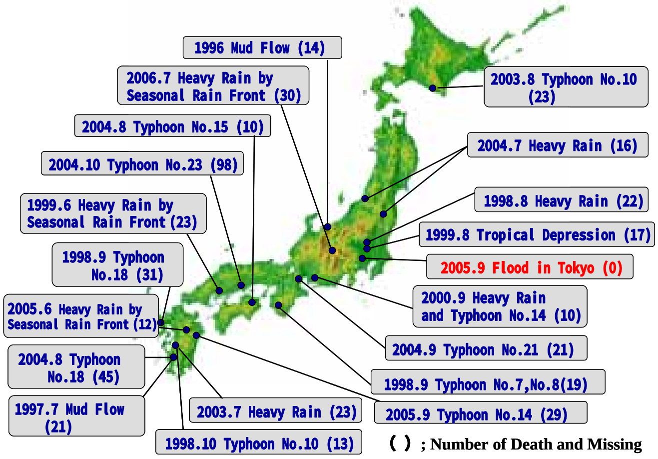

Figure 9 Recent Floods and Storm Disasters in Japan (1996–) (The Number of Death and Missing : 477)

(a) 2006 Mud Flow by Heavy Rain (Nagano)

(b) 2004 Itsukushima-shrine which was Destroyed by Typhoon No.18 (Hiroshima)

(c) 1999 Tidal Wave by Typhoon No.18 (Kumamoto)

(d) 2005 Flood by Heavy Rain (Tokyo)

Figure 10 Recent Flood and Storm Disaster in Japan

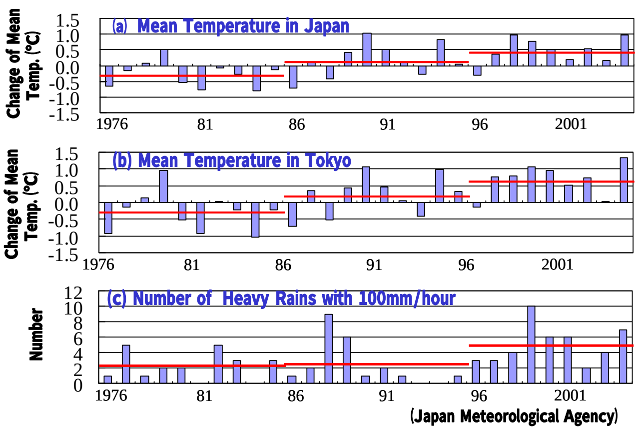

Figure 11 Change of Mean Temperature and Rain Falls in Japan [4] (1976–2004)

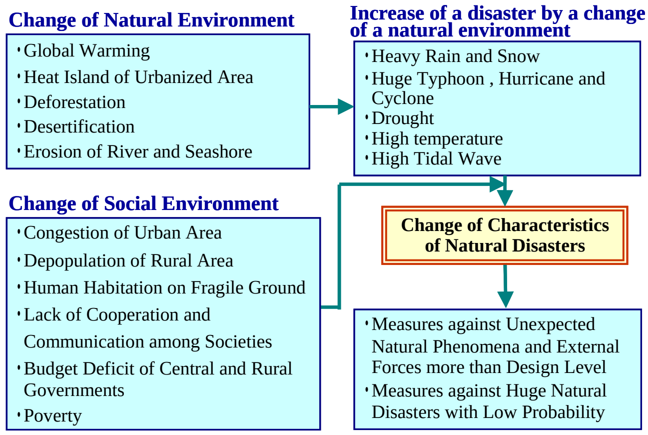

Figure 12 Basic Concepts of the Policy against Future Disasters under the Changes of Natural and Social Environment

but low probability of occurrence.

Figure 13 illustrates a basic concept for the measures against huge natural disasters with low probability of occurrence. That is a combination of hardware measures and software measures. Hardware measures mean, for an example, reinforcement of dikes against floods, and the soft ware measures are evacuation systems during flood and the education of people. Moderate disasters with medium probability are prevented mainly by hardware measures. However, against huge disasters with low probability, the disaster is reduced both by hardware and software measures.

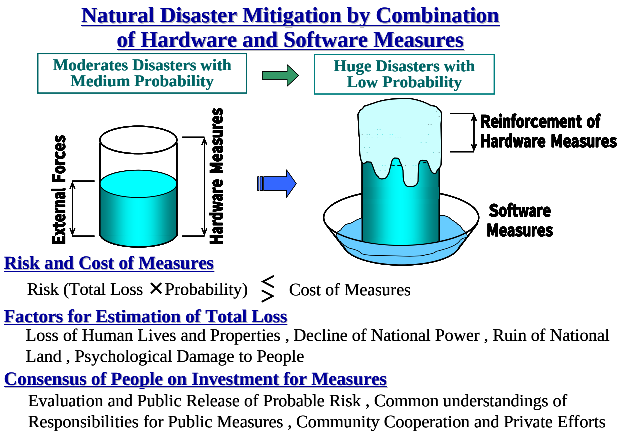

Figure 13 Measures against Huge Natural Disasters with Low Probability

The problem is how to determine the rational level of the investment for disaster mitigation. One of methods to judge the rational level of the investment is the comparison of the risk with the cost of the measures. The risk is estimated as the product of the total loss with the probability. For the estimation of the total loss, we have to take into consideration, various factors, not only loss of human lives and properties, but also probable national power decline resulting from the disaster, ruining of national landscape and furthermore, psychological damage to people. And the consensus among the people is essential to determine the rational level of disaster mitigation measures.

4. Future Earthquakes Threatening Japanese Mega Cities

As shown in Figure 14, large earthquakes, which have high probabilities of occurrence, are threatening the Japanese mega cities such as Tokyo, Nagoya, Osaka and Sendai. Figure 14 shows the source areas of those future earthquakes. The three earthquakes along the Nankai trough in the Pacific Ocean, Tokai, Tonankai and Nankai earthquakes have large magnitudes of 8 or more. The probabilities of the occurrence of these earthquakes are predicted to be very high. In the case of Tokai earthquake, the probability of occurrence in the next thirty years is more than 80%.

The northern Tokyo Bay earthquake with a magnitude of 7.3 has also high probability, 70% within next thirty years. In the case of Miyagi earthquake with a magnitude of 7.5, which is threatening the Sendai City, the probability is estimated as 99%. As shown in the figure, many mega cities of Japan are under the threat of being hit by disastrous earthquakes in very near future.

Table 1 shows the result of the damage assessment by the Northern Tokyo Bay earthquake by the National Council of Disaster Prevention of Japan under a condition, that is, the wind speed is 15m/s. If the earthquake did

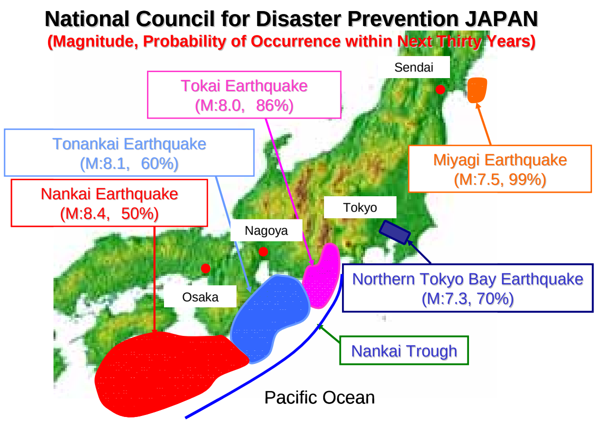

Figure 14 Future Earthquakes with High Probabilities to Hit The Mega Cities in Japan [5]

Table 1 Assessment of Damage by the Northern Tokyo Bay Earthquake [5]

- Tokyo and The Neighboring Three Prefectures - (Wind Speed 15 m/s)

Items		5:00 AM	6:00 PM	Kobe Earthquake
Number of Collapsed or Burnt House and Buildings	Ground Motion	150,000	150,000	110,000
	Fire	160,000	650,000	7,000
	Liquefaction, Slope Sliding, etc	35,000	50,000	46
	Total	360,000	850,000	117,000
Death	Collapse of Houses	4,200	3,100	4,915
	Fire	400	6,200	550
	Slope Sliding	1,000	900	37
	Total	5,600	11,000	5,520
Number of People unable to go home (12:00AM)			6,500,000	
Refugees			4,600,000	237,000
Economic Loss			$ 1.1 Trillion	$ 110 Billion

occur at 6 PM, the Council estimated the number of collapsed or burnt houses and building as about 850,000 in Tokyo area, including the neighboring three prefectures, that would be about seven times of the damage caused by the Kobe earthquake. The resulting fires would burn more than 650,000 houses and buildings. The total number of the death is estimated as 11,000, and among them about 6,000 people would be killed by the fire after the earthquake. Furthermore, if the earthquake occurred at noon, 6.5 million people could not go home on the day of occurrence of the earthquake due to the destructive damage to the transportation systems. And the number of refugees is estimated to be 4.6 million, which is about 20 times of the number in the case of the Kobe earthquake. The total economic loss reaches over 1.1 trillion US dollars, which is almost 1.5 times of the total amount of national budget of Japan.

5. Roles of Civil Engineers for Natural Disaster Mitigation

The first role of civil engineers for the natural disaster mitigation is the development of technologies for enhancement of infrastructures, such as technologies for the improvement of soft soil, high-performance structures, and warning and rescue systems. The second role is actual construction of infrastructures with high natural disaster resistance. The third role of civil engineers is the involvement in the rescue operation, and restoration and reconstruction works after natural disasters.

A large number of infrastructures such as highways, railways, port-harbor facilities have been constructed on improved soft alluvial and man-made ground along the seaside of the Tokyo Bay. Various kinds of methods for improvement of soft alluvial and artificial ground have been developed. Technologies such as passive and active control systems have been developed to reduce the dynamic effects on buildings and bridges during earthquakes, and have been applied to a large number of structures.

The 1995 Kobe earthquake destroyed a huge amount of infrastructures. Therefore, Reinforcement of existing infrastructures against future earthquakes has been one of most important roles of civil engineers after the Kobe earthquake. A numerous number of infrastructures such as railway and highway bridges, and subway stations have been reinforced.

The real time earthquake warning system has been developed and applied to some practical uses as shown in Figure 16. In this system, the magnitude and the epicenter of earthquakes will be judged by the ground motion records in the vicinity of earthquake faults, and if the earthquake has such a large magnitude as to cause serious damage, the warning will be sent to various organizations before the arrival of the main ground motion of the earthquake. Based on the warning, the high-speed trains will be stopped, and the road and air traffic will be carefully controlled. The operation of the various kinds of plants will be shutdown, and the water gates will be closed against the tsunami. In the case of Tokai earthquake, the time allowance before arrival of the main shocks is estimated as about 50 seconds in Tokyo area.

In low land areas in Tokyo, which has lower elevation than river water level, so-called “super levee” has been

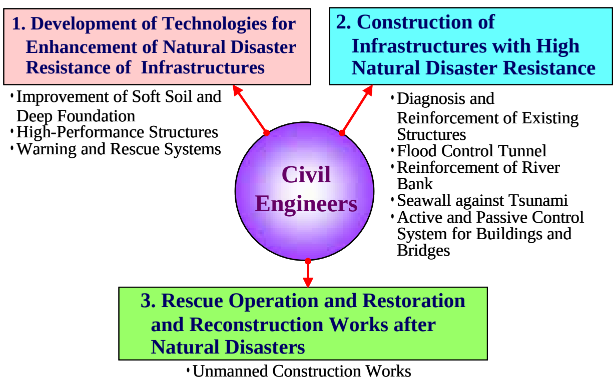

Figure 15 Roles of Civil Engineers for Natural Disaster Mitigation

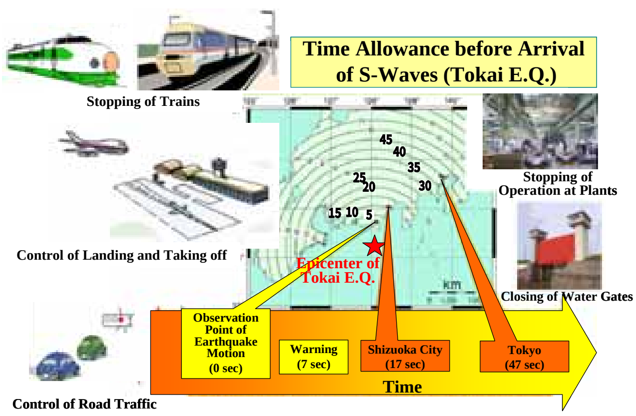

Figure 16 Real Time Earthquake Warning System

constructed against future earthquakes and for development of the areas with high natural disaster resistance, as shown in Figure 17. New banking behind the original riverbank elevated a wide area and the area was redeveloped to enhance the natural disaster resistance, by creating open spaces for the rescue operation and by constructing high earthquake resistant buildings.

6. Cooperation and Collaboration of Civil Engineers in the Asia-Pacific Region for Natural Disaster Mitigation

As mentioned previously, natural disasters are increasing, and the environments are destructed, particularly in Asian countries. The roles and the responsibilities of civil engineers are increasing. The transfer of the technologies for natural disaster mitigation and environment protection should be strongly promoted, and furthermore, we civil engineers should work together on the education of the people for natural disaster mitigation, and should more actively participate to the technical support activities for reconstruction and restoration of the areas damaged by natural disasters. For these activities, we have to further advance the cooperation and collaboration among our civil engineers societies in the Asia-Pacific region.

JSCE is encouraging its members to participate to the technical assistance activities for the areas damaged by natural disasters and to the education for natural disaster mitigation. JSCE and its members have continued to provide assistances and aid activities in Northern Sumatra after tsunami disasters. In response to the request from the Indonesian Government, JSCE prepared a technical recommendations on the plan of reconstruction of the road along the west coast of north Sumatra, most of which had been washed away by the tsunami. JSCE also proposed a regional tsunami warning system. This is the request from the state government. The student members of JSCE have been educating children in Sumatra on the earthquake and tsunami disaster mitigation.

Figure 18 illustrates the basic concept of a regional tsunami warning system for Sumatra Island, proposed by JSCE. In this warning system, the epicenter and the magnitude of the earthquake will be estimated from the seismic records at the stations along the west coast of Sumatra. The warning, which will be transmitted from the tsunami-warning center to the regional mosques through the satellites, is conveyed to the people. One of the characteristic points of this warning system is utilization of mosques, which are closely associated with the regional people, and have comparatively high resistance against tsunami and earthquake motions.

The student members of JSCE are carrying on education programs for children of Banda Ache and other areas in the northern Sumatra. They are teaching the mechanism of the occurrence of earthquakes and tsunamis and how to save lives from the future disasters. Japanese students are conducting their activities under a close corporation

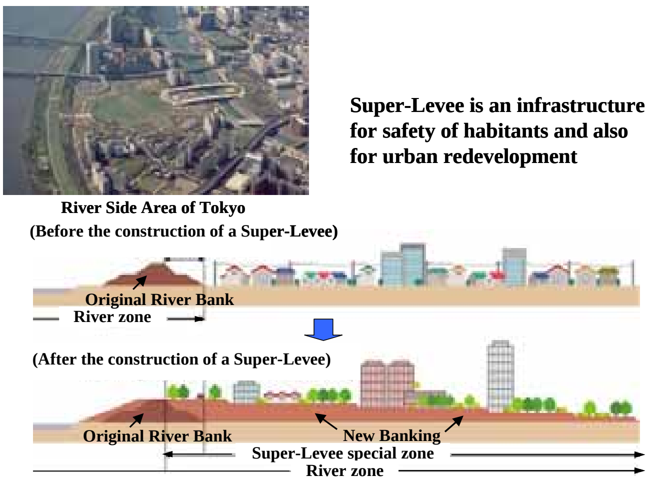

Figure 17 Construction of the Super-Levee in Low Land Area of Tokyo against Future Earthquake

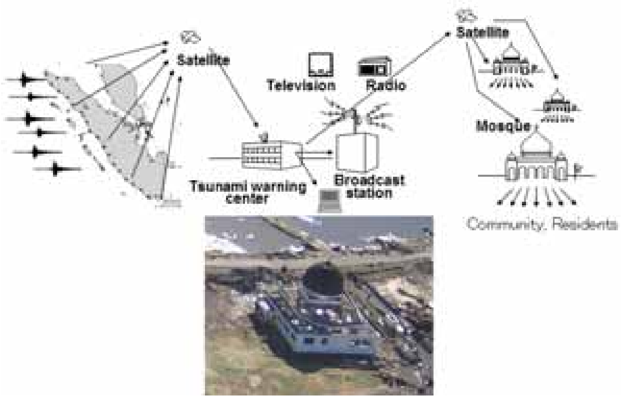

Figure 18 Plan for Regional Tsunami Warning System by JSCE (For North Sumatra Provincial Government)

with Indonesian student groups. These young civil engineers' activities are expanding internationally. The technical assistances by JSCE have been carried out in Indonesia and Pakistan for the areas attacked the recent disasters. In Nias Island, Indonesia, technical seminars for temporary restoration of bridges damaged by liquefaction have been held, while In Pakistan, the members of JSCE held conferences on the reconstruction of damaged structures, under a cooperation with the Pakistani engineers. In these conferences, JSCE introduced the reconstruction procedures based on the experiences gained from Kobe earthquake.

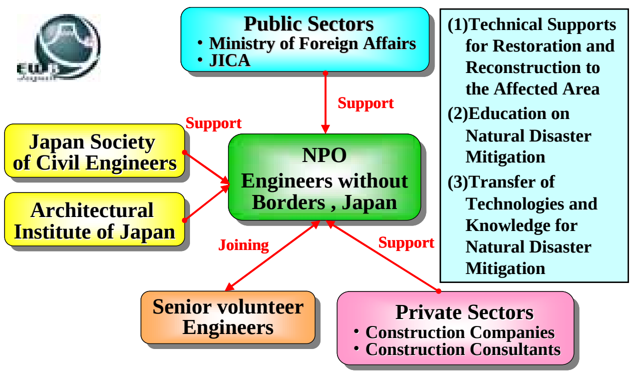

Figure 19 NPO : Engineers without Borders , Japan

Recently, members of JSCE and Architectural Institute of Japan established a NPO, named "Engineers without Borders, Japan". The objectives of this NPO are to provide technical supports for restoration and reconstruction of the damaged areas, and to carry out education on disaster mitigation. Another important role of this NPO is the transfer of the technologies and knowledge for natural disaster mitigation. JSCE is going to strongly promote assistance and aid activities under a close cooperation with this newly established organization.

7. Conclusions

Natural disasters such as earthquakes and tsunami, and storm and flood disasters have been increasing during last two decade, particularly in the Asian countries. Furthermore, due to the change of natural and social environments, the scale of the natural disasters is expanding. For the mitigation of the future natural disasters, the roles and the responsibilities of civil engineers are increasing. Furthermore, the cooperation and collaboration of civil engineers in the world are essential to accomplish these errands.

JSCE and the other organizations of civil engineers in the world have been in a good partnership during decades, and have served people for the safe living and welfare. However, the recent natural disasters into world taught us again that the development and application of technologies and knowledge for natural disaster mitigation are the urgent subject for civil engineers. We have to strengthen and to further advance the cooperation between two societies.

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