# International Comparison of Recent Large-scale Disasters and Recovery Process from Building & Housing Safety and Urban Planning View Points

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**SUMMARY:**
This paper firstly examines outline situations and causes of recent large-scale earthquakes and tsunamis in the world, and analyses the measures of governments and community people. Following earthquake disasters are reported: Indian Ocean Tsunami (2004), Kashmir Earthquake (2005), Java Earthquake (2006), Peru Earthquake (2007), Wenchuan (Sichuan) Earthquake (2008), Padang Earthquake (2009), Haiti Earthquake (2010), the Great Hanshin-Awaji (Kobe) Earthquake (1995) and the Great East Japan Earthquake (2011). Damages to buildings and built environment from earthquakes in different parts of the world are analysed from economic, social and physical view points for sustainable development. Lessons learnt for policy measures from recent disasters are extracted. Control mechanism of development has to be integrated with economic, social, institutional, technical and other tools at the same time. Such mechanisms and tools for building control, city planning and urban development have been mostly developed and accepted after a large-scale disaster based on the past experiences.

*Keywords: Recovery Process, Large-scale Disasters, Kobe Earthquake, Great East Japan Earthquake, Tsunamis*

## 1. INTRODUCTION

The world catalogue of earthquake damages disclosed by the International Institute of Seismology and Earthquake Engineering (IISEE) of the Building Research Institute (BRI) shows 31 disasters have occurred during these 50 years with more than 5,000 casualties as shown in the Table 1. Many of them claimed their lives by being pressed with collapsed their own houses. The Indian Ocean Tsunami triggered by the Off Sumatra Earthquake on 26 Dec. 2004, killed in total approx. 230,000 people in 12 countries. The disaster has provided a global opportunity to acknowledge the earthquake and tsunami.

**Table 1**. Earthquake and Tsunami Disasters with over 5,000 casualties during recent 50 years (1960-2011)

| | Country: Earthquake | Year | Mg | Death |
|---|---|---|---|---|
| 1 | China: Hebei (Tangshan) | 1976 | 7.8 | 242800 |
| 2 | Indian Ocean Tsunami | 2004 | 9 | 226408 |
| 3 | Haiti Eq. | 2010 | 7 | 222576 |
| 4 | Pakistan Kashmir Eq. | 2005 | 7.6 | 73328 |
| 5 | China: Sichuan (Wenchuan) | 2008 | 8.1 | 69195 |
| 6 | Peru: Chimbote, Huaras | 1970 | 7.8 | 66794 |
| 7 | Iran: Manjil Eq., Rudbar | 1990 | 7.7 | 35000 |
| 8 | Iran: Kerman, Bam Eq. | 2003 | 6.7 | 31830 |
| 9 | Armenia: Spitak Eq. | 1988 | 6.8 | 25000 |
| 10 | Guatemala Eq. | 1976 | 7.5 | 22870 |
| 11 | India: Bhuj Eq. (Gujarat) | 2001 | 8 | 20023 |
| 12 | Iran: Tabas Eq. | 1978 | 7.4 | 18220 |
| 13 | Turkey: Kocaeli Eq. | 1999 | 7.8 | 17118 |
| 14 | Japan: Great East Japan Eq. | 2011 | 9.0 | 15840 |
| 15 | China: Yunnan Eq. | 1970 | 7.8 | 15621 |
| 16 | Iran: Dasht-i Biyaz Eq. | 1968 | 7.3 | 15000 |
| 17 | Morocco: Agadir Eq. | 1960 | 5.7 | 13100 |
| 18 | Iran: Buyin-Zahra Eq. | 1962 | 7.2 | 12225 |
| 19 | Nicaragua: Managua Eq. | 1972 | 6.3 | 10000 |
| 20 | India: Latur-Osmanabad Eq. | 1993 | 6.2 | 9748 |
| 21 | Mexico: Mexico City | 1985 | 8.1 | 9500 |
| 22 | China: Hebei, Ningjin Eq. | 1966 | 7.2 | 8064 |
| 23 | Philippines: Mindanao Eq. | 1976 | 7.9 | 8000 |
| 24 | Japan: Kobe (Hanshin) Eq. | 1995 | 7.3 | 6432 |
| 25 | Indonesia: Irain Jaya | 1976 | 7.1 | 6000 |
| 25 | Indonesia: Irain Jaya | 1976 | 7.2 | 6000 |
| 27 | Indonesia: Yogyakarta | 2006 | 6.2 | 5749 |
| 28 | Chile: Chile Eq. (Tsunami) | 1960 | 9 | 5700 |
| 29 | Pakistan: Patan Eq. | 1974 | 6.2 | 5300 |
| 30 | Iran: Ghir (Qir) Eq. | 1972 | 6.8 | 5010 |
| 31 | Equador, Colombia: Quito | 1987 | 6.9 | 5000 |

Note: Events with grey represent the earthquake disasters that have occurred during 2001-2011.
Framed ones are the earthquake disasters introduced in this paper with photos. (data: UNCRD, IISEE/BRI and CODE)

The impact of earthquake on livelihood of people can be reduced by measures such as to comply with earthquake resistant building design and construction standards, proper planning, education and trainings. However, the risk is still increasing as urbanization in developing countries is adding extra pressures on rapid building construction. Although those countries have established each building control system, it can seldom function effectively due to lack of awareness on disaster risk reduction, and lack of regulatory public mechanisms for effective implementation, monitoring and reviewing.
Most of large scale disasters have been happened during 2001-11. This paper tries to comprehensively summarize the reasons of damages and what are the lessons in terms of earthquake safety of building.

## 2. RECENT LARGE-SCALE DISASTERS

### 2.1 Indian Ocean Tsunami 2004

Numerous people including tourists from Europe and North America were drowned and died by Indian Ocean Tsunami caused by the Sumatra Off-shore Earthquake. Particularly Aceh Province of Indonesia was heavily affected. Indonesia is located on the "ring of fire". The tropical climate with heavy rain showers during the wet season can cause floods and landslides. These natural hazards when combined with high population densities, poverty, poorly constructed buildings and deficient urban planning, inadequate warning systems and poor institutional disaster preparedness may influence to natural hazards to turn into disasters. From experiences in the past including in Aceh after the 2004 tsunami, many lessons can be learned. [i]

**Figure 1:** Remained Ship on the roof, 2004 (Indonesia) **Figure 2:** Bamboo Model house, 2005 (Pakistan)

There were remaining ships in the residential area where is located a few kilometers from the coast line of Aceh. There are huge amount of construction sites of new houses in the areas. However, because of so rapid reconstruction of public facilities and houses, some houses were constructed with lower earthquake resistance and lower quality than before, or a set of completed recovery houses were still vacant in some residential zones as no infrastructure was provided in 2007.

### 2.2 Pakistan (Kashmir) Earthquake 2005

Barakot is the most heavily damaged city by the Pakistan Earthquake that occurred on 8 Oct. 2005. More than 70 % of buildings in the city were collapsed. This Kashmir area has been suffered from boundary conflict with India, and it snows in winter as located at the foot of Himalayan Mountains with 7,000 m above sea level. The evacuated people in the tent started reconstruction work in early 2006, as having improved weather in winter. Model houses were built by a Nepali NGO, National Society for Earthquake Technology Nepal- NSET, funded by HABITAT Pakistan and the local government. Since the local construction engineers and technicians are familiar with the construction system of NSET, it may be the best way to construct earthquake resistant buildings and houses in the affected areas. There was a bamboo model house constructed by a local NGO in corporation with a

Bangladeshi NGO using the bamboo imported from Myanmar. However, it has not been disseminated. Most of hospitals were reconstructed within two years while schools were rebuilt during five years as so many schools in the affected area. Almost 20,000 children have lost their lives because of the collapsed school building during school time. Therefore, the United Nations took initiative for a global campaign in 2006-7 that was entitled "Let's Begin at School" after the lessons of Pakistan Earthquake. The seismic damage has concentrated on masonry houses. Buildings that have been constructed with basic rules such as using high quality materials and structural components are firmly connected and maintained properly, no damages were observed even in the heavily affected area. Based on the UN survey, main cause of this huge disaster basically lies in the unawareness of the risks, not only by the heavy quakes. The recovery process of the damaged houses is comparatively in a good momentum.

### 2.3 Java (Yogyakarta) Earthquake 2006

A revenue office building as well as the "Institute SENI Indonesia" were collapsed by the May 2006 Earthquake in the south part of Yogyakarta City. In Bantul region where is the most affected area, the Islamic University of Indonesia (UII) has constructed, with some financial support from the Japanese embassy, a model house for the local people using bricks with reinforced concrete columns and beams (so-called confined masonry structure) in the damaged areas. The model was developed through the technical cooperation to UII by a BRI structural expert before the earthquake. The Gadjah Mada University (UGM) in Yogyakarta evolved several model houses (of bamboo, palm tree and/or wood) for tsunami prone and earthquake prone regions. Utilizing posters, UGM experts are conducting efforts of dissemination of earthquake resistant technologies and tips for reconstructing/ repairing houses of communities. JICA and MLIT have been formulating a team to promote reconstruction of earthquake safe houses with Indonesian national and local government, and resulted in success.[ii]

It is said that most of houses in Indonesia were constructed with timber a half century ago. After the timber became an international commodity, Indonesian people could not use timber as the price has increased at an international level, and people became to use low-cost and low quality bricks that are burnt with rice hulls. This issue resulted in a cause of heavier seismic damages in Indonesia. Therefore, Mr. Ir. Teddy Boen and other structural experts in Indonesia are disseminating localized earthquake resistant construction methods.[iii] Japan should not forget that contrary to such critical issue in Indonesia, Japanese urban environment has been improved in terms of seismic and fire safety by constructing many RC structures utilizing plywood imported from Indonesia.

**Figure 3:** Earthquake damage, 2006 (Indonesia)

**Figure 4**: Damage of rural house, 2007 (Peru)

### 2.4 Peru (Pisco) Earthquake 2007

On 15 August 2007, an earthquake that occurred at approx. 200 km south from Lima, capital of Peru, and many adobe houses were collapsed. (Adobe: sun-burnt block made of mud) However, casualties resulted in a fewer number as the houses are built with light roof and one story. The Japan-Peru Center for Seismic Investigation and Disaster Mitigation (CISMID) of national Engineering University (UNI)

of Peru has recorded seismic waves of this earthquake by using a strong motion recorder that was installed under cooperation with BRI. This seismic record will be utilized to design structures in Peru.
In order to establish CISMID as a JICA technical cooperation project, the IISEE ex-participants played significant roles. During the project, BRI and others have sent many experts to CISMID. These efforts resulted in the well managed response to the earthquake disaster in 2007. Many people became to have strong interests in the safety of houses after the 2007 Peru Earthquake. Therefore, seismic resistant structures using RC sheer walls are used as popular structure for middle- and high-rise apartment.

### 2.5 China, Sichuan, Wenchaun Earthquake 2008

During the Wenchuan Earthquake, occurred on 12 May 2008 in the afternoon, the human damage of the disaster amounted to more than 69,000 casualties except the lost, and several millions of people lost their houses. As it was just before the Beijing Olympic Game, the Chinese government quickly responded, such as the rapid provision of temporary houses. It was ten times larger in number of units within the same period compared with the case of the Kobe Earthquake. The reconstruction of houses has finished within two years although the original recovery plan needed three years. One of the factors why the recovery has been completed so fast is "Partner Assistance" system that has contributed to recovery of a heavily affected city through the support by a designated province in China. This system was applied from the initial stage to whole reconstruction and proved effective, partly because of competitive atmosphere of the system.

The affected area extended from cities that have hundreds of thousand populations to villages in the mountain regions over 500km long range of areas. In China, buildings and houses built with bricks or hollow blocks were major cause of the damages. Then, Chinese government promotes retrofit of vulnerable buildings not only in Sichuan but also in all provinces. Moreover, in addition to human damages, more than half of the economic damages that amounted to approx. 14 trillion yen (in case of Great Hanshin-Awaji Earthquake, it amounted to 10 trillion yen) were mainly due to damage / collapse of houses and buildings including schools.[iv] Chinese government carried out various recovery support measures as well as "Partner Assistant" system, referring to the experiences of the Kobe Earthquake and others. The traumatic care of victims and recovery of cultural heritages are included. Retrofitting of vulnerable buildings remains a major issue as the lesson from this disaster.

**Figure 5:** Damaged wooden/brick houses, 2008 (China)

**Figure 6:** Damage of school, 2009 (Indonesia)

### 2.6 Indonesia, Sumatra, Padang Earthquake 2009

More than 1000 people have died by the Western Sumatra (Padang) Earthquake on 30 September 2009. It is announced that the Padang earthquake hit modern city area in Indonesia for the first time. Though Indonesia had many earthquakes so far, most of the damages were caused by the collapse of low-rise houses in the rural area including May 2006 Java earthquake in Yogyakarta. The Padang earthquake in 2009 hit many RC structures in the center of Padang City where is the capital of the West Sumatra Province. The Institute of Technology of Bandung (ITB) and governmental research institutes such as the Research Institute of Human Settlement (RIHS) have sent investigation teams and found that the damages were concentrated on the hotels and other buildings that did not follow the building code in Indonesia. Some buildings were inadequately extended or rebuilt. Houses without reinforcement and non-engineered schools that were constructed without engineering design were also damaged.

### 2.7 Haiti Earthquake 2010

Haiti Earthquake on 12 January 2010 claimed more than 200 thousand of casualties. Main cause of the huge damage also arose from the collapse of buildings like houses and offices. It is reported that vulnerable RC or reinforced block structure enlarged the damages, because heavy construction materials are common in Haiti to resist against hurricanes. Furthermore, modern buildings represented by the President House have been designed by foreign planners based on the building code of each planner's home country, and it seems that there is no locally adopted seismic standard and code. Numerous international NGOs including CODE in Kobe also sent missions to the affected areas to support to cover all possible emergency assistances.

**Figure 7:** Landslide area, 2010 by CODE (Haiti)

**Figure 8**: Damage of Kobe City Hall, 1995 (Japan)

## 3. THE GREAT HANSHIN-AWAJI (KOBE) EARTHQUAKE

The following description shows the urgent process of urban planning in the case of Kobe city after the Great Hanshin-Awaji (Kobe) Earthquake on January 17, 1995.

1) Selection of the Disaster Recovery Project Area / Method

Firstly in order to decide the project target area and method, the cities, prefectures, and central government have made a decision within two weeks to finalize their urban planning decision within two months.

2) Decision-Making for Urban Planning

In general, to develop a plan, negotiations with the central government are the first step to decide infrastructure. Then, discussion with residents normally takes a few months or a few years. However, damaged people would like to start rebuilding in their own areas as soon as possible, and dense urban areas will be regenerated. Therefore, limitations for construction are necessary, and the maximum period for applying such measures is two months according to the law. Kobe city asked the central government to make a special provision for this law but this was not accepted. The City Planning Law sets construction limitations to be applied to the area where urban plan is decided.[v]

**Table 2**: Damage of Great Hanshin-Awaji Eq.

Damages of Kobe Earthquake (Total, Hyogo and Kobe)

| Damages | | Total (incl. Osaka) | Hyogo pref. | Kobe city |
|---|---|---|---|---|
| Human (person) | Dead | 6,434 | 6,401 | 4,571 |
| | Missing | 3 | 3 | 2 |
| | Injured | 43,792 | 40,092 | 14,678 |
| | Evacuees (peak) | 320,000 | 316,678 | 236,899 |
| Houses (building) | Totally collapsed (families) | 111,123 (191,617) | 104,906 (186,175) | 67,421 ( - ) |
| | Partially collapsed | 144,274 | 137,289 | 55,145 |
| Emergency Response (building) | Publicly Dismantled Houses | 108,672 (Total 136,730) | 87,289 | 61,392 |
| | Temporary Houses | 49,800 | 48,300 | 32,346 |

Source : 2008.1.1 (Kobe city) http://www.city.kobe.jp/cityoffice/06/013/report/index-e.html
2006.5.19 (Total) http://www.bousai.go.jp/1info/kyoukun/hanshin_awaji/earthquake/index.html

In the case of Kobe city in 1995, limitations can be applied by deciding land readjustment project areas and urban redevelopment project areas within the first 2 months since the earthquake. Then, longer time could be taken for planning such as road placements with resident participation. This is the “two-step urban planning”.

3) Financial Support Strategy for Earthquake Recovery

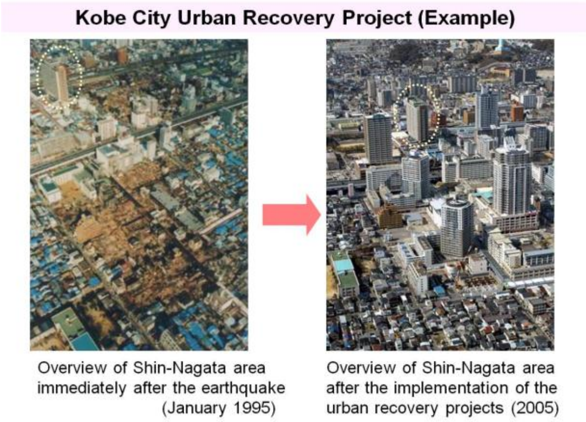
The responsibility of the recovery projects was given to damaged local governments. Though in usual public projects, financial assistance is limited to 50% of the project cost, with the application of the Severe Damage Disaster Law, areas recognized to be heavily damaged by the disaster were granted more than 90% support for the recovery of public works. In the case of Kobe city’s recovery, 86% of the total costs were covered by the central government. In the case of the Great Kanto Earthquake in1923, central government has covered 90% of the costs.[vi]

4) Disaster Area Urban Recovery Special Measures Law

The assistance target area was expanded in the disaster urban recovery implementation area. The restrictions for land readjustment project areas were also deregulated (from minimum 5 hectares to more than 2 hectares), as well as that for road width in urban planning (from minimum 12 meters to 8 meters).

5) Decision on the Earthquake Recovery Project

The target area was announced on January 31st, 1995. These were disaster damaged areas that covered more than 5 hectares and more than two-thirds of the structures were completely collapsed. The new Special Measures Law was established on February 17th. The Recovery Urban Plan was announced on February 21st. The law was enacted on February 26th. March 17th was the deadline of 2 months’ construction limitation set forth by the Article 84 of the Building Standards Law and the City Planning Law. By the urban planning decision of the project areas, a new construction limitation was applied to the project areas.



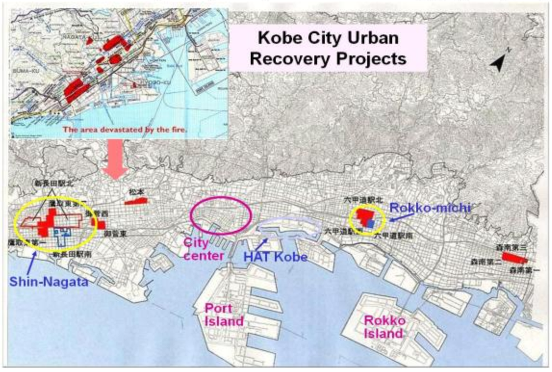




**Figure 9**: One of the Recovery Projects in Kobe City (up)
**Figure 10**: Reconstruction Projects in Kobe City (1995-2010) (down)

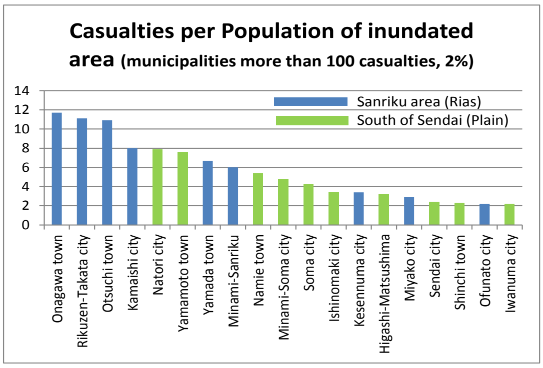
6) Collaborative Community Development

Initially, in response to the plan from March 17th, there was big opposition from the media and disaster victim residents. However, there was demand from the disaster-struck residents to also avoid the regeneration of densely built-up areas and to construct anti-seismic houses and parks. For this, the residents are also required to take on some of the burden.

Finally, reconstruction projects in Kobe city applying land readjustment projects and urban renewal projects were conducted by the Kobe city as shown in the Map 3.[vii]

## 4. THE GREAT EAST JAPAN EARTHQUKAKE

Firstly, the damage of the Great East Japan Earthquake on March 11, 2011 is analyzed in this section to verify the current policy measures of building regulation against tsunami disasters. Fig 2 shows the ratio of casualties per population in the inundated area by affected municipality including dead and unknown (missing) persons as of 30 Dec., 2011 reported by the National Police Agency. Blue columns of in the figure indicate Sanriku area where main geographical condition is “rias” coast that was suffered from severe damages, while green columns imply plain area in Sendai and southern regions.



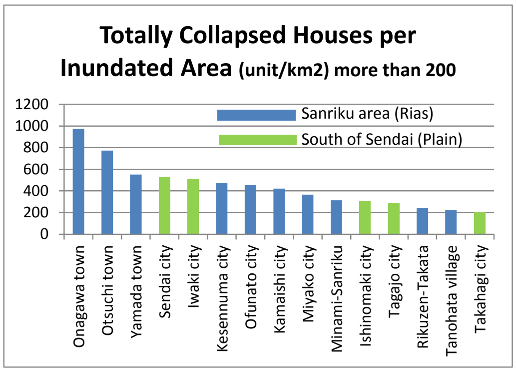
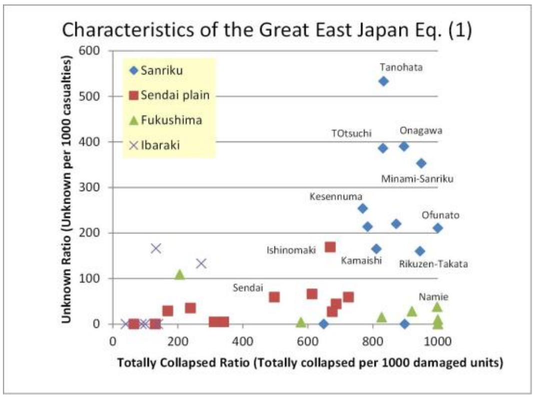




**Figure 11**: Ratio of Casualties by Municipality (left)
**Figure 12**: Totally Collapsed Houses per Inundation Area (right)

## 4.1 Characteristics of Damage by Tsunami

(1) The maximum ratio of human damage (casualties including death and unknown) per population of the inundated areas in a municipality is recorded as 12 % in Onagawa town. Otsuchi town and Rikuzen Tkata city claimed the following large ratio of human damage per population in the inundated areas that were almost 11 %.
(2) Since no damage by tsunami can be observed outside of inundated areas, Fig 11 and Fig 12 represent human damage and physical damage per inundated area respectively. The density of human and physical damages in Otsuchi town and Onagawa town are the severest. The third concentrated damage was seen in Yamada town. Kesennuma city and Kamaishi city follow them as the areas of collective and massive damages both in human and physical aspects.
(3) The gravity of physical damage can be measured by the totally collapsed ratio. The density of houses and population in the inundation area of these cities was lower than in Onagawa and Otsuchi town. If the ratio of unknown (missing) per human damage will represent severity of human damage, Onagawa town reached 39 % as the highest ratio and Otsuchi town, Minami Sanriku town follow the high ratio. They are the municipalities that are ranked in Fig 12 as the heavily damaged areas.
(4) Fig 13 and Fig 14 show the severity of damage by municipality, classifying the characteristics of regions. The indicator of Fig 16 may represent characteristics of damage and will help to compare with other disasters. The proposed indicator is calculated as “number of human damage (as a sum of death and missing) per 100 totally collapsed houses” in each affected municipality. Coburn, Spence and Pomonis defined similar ratio as “Lethality Ratio” in 1992.
(5) The ratio varies almost 100 times under this indicator. Rikuzen-Takata city recorded more than 50 persons’ human damage per 100 totally collapsed houses, while Sendai city’s indicator shows around 2 persons. Fig 5 tries to classify the damages however there was not so clear characteristics from above mentioned data. Analysis on other big disasters in the world is conducted utilizing the same indicator (casualty ratio: number of casualties per 100 totally collapsed houses) in the latter section.



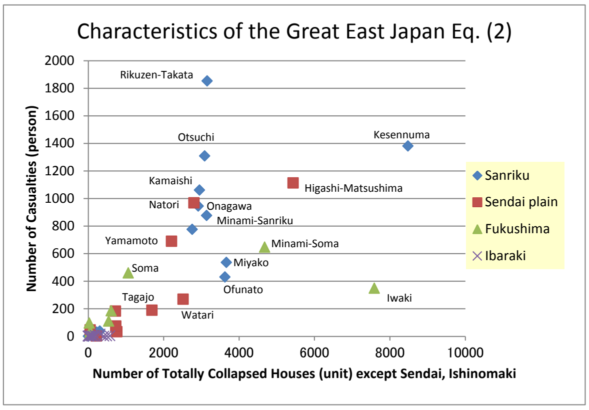
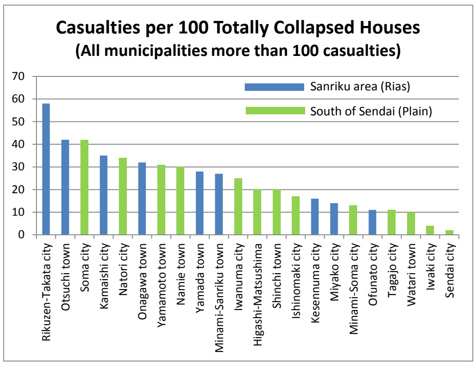




**Figure 13**: Missing / Totally Collapsed Ratio (left)
**Figure 14**: Totally collapsed houses and Casualties (right)

The Fig 15 and Fig 16 show the comparison of disasters in different areas using a proposed indicator. From the indicator that sets forth number of casualties per 100 totally collapsed houses, the range of numbers varies from 60 to 2 or 1 in both figures that Fig 15 shows difference among municipalities in the Great East Japan Earthquake affected areas. Fig. 16 indicates difference of recent huge disasters.



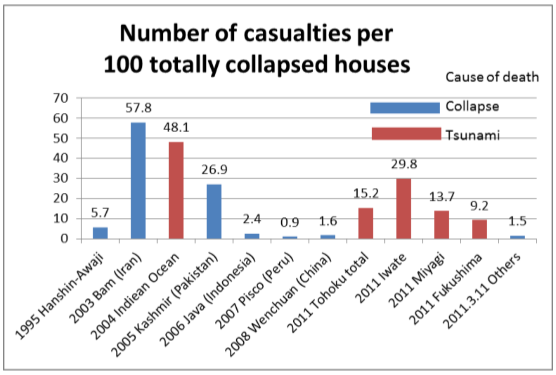




**Figure 15:** Casualties/ collapsed houses (left)
**Figure 16:** (recent world) Number of casualties per 100 totally collapsed houses (right)

### 4.2 Relation between Physical and Human Damages

(1) Number of Fig 15 represents the "inclination" of Fig 16. Although there may exist slight difference of judgment and definition of a "totally collapsed house" among municipalities, large difference of value cannot be explained. It is not so clear the difference of each municipality. The difference of prefectures may be analyzed.
(2) Figure shows lower "casualty (mortality) ratio" in Ofunato city even though it is located in Sanriku. The reasons why the ratio in Soma city, Natori city and some other plain areas resulted in higher ratio compared with average of Iwate or Sanriku region may also provide social or historical reasons of the damages. Since this paper focuses on institutional aspect, further research is executed.
(3) Figure indicates also the wide range of difference of casualty ratio in the recent huge disasters. In general, tsunami disasters claimed rather higher ratio than the other cases. One of the reasons may be the frequency of a disaster (Huge tsunamis occur every thousand years while huge earthquakes can be experienced once per several hundred years, as it is said "disaster comes when it is forgotten").
(4) Figure also suggests that the large difference of casualty ratio between the higher cases such as Iran and Pakistan (and in the case of Haiti, the casualty ratio became over 100 persons by official statistics) and lower cases in China 2008, Peru 2007 and Java 2006. The case of Kobe in 1995 set forth the middle level of casualty ratio.

**Figure 17**: Tsunami damage of Onagawa Town, Miyagi pref., Japan (April 2011)
**Figure 18**: Recovery situation of Onagawa Town, same place as Fig. 17 (September 2011)

## 5. ANALYSIS OF DISASTERS AND POSSIBLE MEASURES

In each on-site observation, the collapse of buildings caused major damages in the earthquake related disasters. In order to achieve resilient social infrastructures including earthquake resistant buildings, cooperation of engineers and governments is essential. Damages to buildings and built environment from earthquakes in different parts of the world indicate the fact that earthquake risk mitigation is one of the most essential tasks for sustainable development of a city and region. Natural hazards such as earthquakes and typhoons occur every time. However, human society faces at the following disaster risks. The following key issues are also analysed and identified as general reasons why disasters occur frequently in the world.

1) Rapid increase of population and urbanization;
2) Effects of poverty in least developing countries;
3) Delay of preparedness by governments / citizen;
4) Effects of eco-system degradation / global climate.

In particular, earthquakes affect not only lower society but also middle income people. The middle society covers most of the population and influences a deep impact on the national level economic activities. For instance in Indonesia, middle class people often live in a vulnerable house that was constructed without proper knowledge on brick structure, while the poorest group live in the bamboo-mat houses that are not affected by earthquakes. The damages shown in the former sections suggest the needs for capacity building of recovery experts who work on-site after a disaster, community workers who directly motivate people, local governmental staff who implement key policies, and policy makers at national level and so on. Limited loss of lives from earthquakes can be observed in the United States, Japan and other developed countries that have long history of implementation of building safety compared to loss of lives in developing countries where building safety measures are not properly regulated. It is an indicator of how the earthquake risk can be reduced in cities. However, even in the countries with long history of building safety measures, inadequacies in the performance of building are often evident. Cautionary assessments after the 1994 Northridge earthquake found that "there would have been far less damage if building codes were rigorously enforced." Similar evaluation has been made after the 1995 Kobe earthquake in Japan which resulted in extensive loss of lives and properties despite of the fact that Japan has long history of practicing building safety regulations.

Most of the earthquake prone countries in the world have already established building codes and many countries have also enacted the seismic codes. However, lack of institutional mechanism, lack of complimentary implementation tools and lack of awareness about earthquake risk reduction among governmental agency, designers, builders and general public have contributed to the poor enforcement of the building code. Observation of damages from the past earthquakes have pointed out the fact that buildings perform the way it is constructed in the field and not the way it is designed. In order to mitigate earthquake risk, all stages of building construction, from planning to construction and maintenance, are important. Properly designed buildings may not perform the way they are supposed if constructed improperly. Awareness creation is instrumental in building culture of safety and resilient communities and also in creating demands for intervention in disaster mitigation. The demands ultimately help in creating conducive environment for policy intervention, in realizing institutional mechanism of code enforcement for the municipal authorities and creating demand for competent professionals. For instance in Japan, demands for seismic assessment and retrofit of houses that follow the old seismic building code before 1981, could be realized mainly by raising awareness of people.

## 6. CONCLUSIONS

In order to achieve earthquake-safe and tsunami-safe buildings and cities, it is the most important task along with capacity development and policy tools. Compliance and control have an inter-linkage and they compliment each other. Compliance can be increased and made effective by indirect control tools such as housing loans and insurance; whereas, effectiveness of control relies heavily on compliance.

Despite of existence of building codes and serious intention for its effective implementation, realization of safe buildings in the field requires quality material, good workmanship and awareness in masons, builders and house owners. One sided control mechanism for implementation of building cannot solve the problem and has to be integrated with socio-economic, institutional, technical and other tools at the same time in order to achieve safety of buildings and built environment against the earthquakes and the tsunamis.

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Note:

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i 2005-2010 Housing Earthquake Safety Initiative (HESI).

ii Japan International Cooperation Agency (JICA), 2007-2010

iii Teddy Boen, 2009, "Constructing Seismic Resistant Masonry Houses" Indonesia.

iv UN Centre for Regional Development (UNCRD) 2009, and Building Research Institute, (BRI) No.118, 2008.

v Specialized Law on Reconstruction of the Great East Japan Earthquake was established on 29 April 2011 to allow the extension of original two-month's deadline to maximum six months more (plus maximum two months, in total eight months) in the heavily affected areas by the Great East Japan Earthquake.

vi In the case of the Great East Japan Earthquake in 2011, central government announced almost of all recovery cost will be covered by the national budget, even if the municipalities or prefectural government may need issue their bond to promote reconstruction, the bond will be reimbursed by the national budget.

vii In the Map 3, red areas were implemented by applying land readjustment projects while urban renewal projects were utilized in blue areas; "Earthquake Recovery in Kobe City and the Roles of Local Government and Residents" Seminar convened on August 8th, 2008, Venue: UNCRD, Lecturer: H. Nakayama