16th World Conference on Earthquake, 16WCEE 2017
Santiago Chile, January 9th to 13th 2017
Paper N°1407
Registration Code: S-X1463031950

A Study on Approach for Risk Reduction of Non-engineered Houses in Japan through Building Regulation System

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Abstract

Every earth quake causes serious damage to human society, especially to non-engineered structures like adobe, non-reinforced masonry of stone, brick or concrete block because of its vulnerability in many countries. However, formal legal frameworks in many countries do not recognize non-engineered buildings in its code and building regulation system, and the performance improvement has been lagging in large scale. Taking an example of traditional wooden houses in Japan as non-engineered structure, we had analyzed historical integration process of non-engineered structures into formal legislative framework to improve its performance in scalable manner. In conclusion, it suggests lessons learned for developing countries based on the experience in Japan.

Keywords: non-engineered, housing, formal approach, building code, Japan, performance, legal framework

1. Introduction

In recent earthquake in Nepal reminded us the vulnerability and existing high risk of non-engineered houses. A Post Disaster Needs Assessment, damage and loss assessment exercise led by the Government of Nepal, estimated the total disaster effect as about 7 billion, in which the housing sector accounted for about its half. Majority of the houses were analyzed as non-engineered houses with stone or brick masonry using mud mortar, widely spread in the rural area. These non-engineered houses are often built without engagements of professional designers, engineers and contractor. Besides, formal building regulatory system in many countries does not recognize locally wide practiced construction methods, non-engineered structures in another words, to regulate the performance of those in formal building regulation system. This paper shares example of Japan which utilized formal building regulatory system to improve the resilience of non-engineered houses, and distill relevant lessons learned for countries tackling similar challenges.

2. Historical improvement of non-engineered housing performance in Japan

1) Objective and Target

This study aim to distill lessons learned for developing countries to improve resilience of non-engineered houses, based on the experience in Japan. Therefore, this paper look back the historical process of performance evolvement in Japan, particularly after the World War II when the large scale housing supply happened. It targets wooden structure focusing on housing purpose building only. This excludes other wooden structures such as school and shrines, and engineered wooden structure with 2x4 or prefabrication methods.

2) Overview of Traditional Wooden Structures

In Japan, all type of buildings should be constructed in accordance with relevant law including Building Standards Act and Architect Law. As earthquake prone-country, wooden houses have historically proven its seismic resistance through its flexible joints, and 89% of detached houses is still with wood (conventional type: 74%), as of 2014.

3) History of Building Regulation and Key Triggers for improvements

3-1) Development of Earthquake Resistance Building Standards

The Great Kanto Earthquake 1923 killed more than 100,000 people and area of 3,465ha (45% of Tokyo) was destructed by fire. (See Fig.1)

souse: www.bunpodo.co.jp

Fig.1 Tokyo after the Great Kanto Earthquake 1923

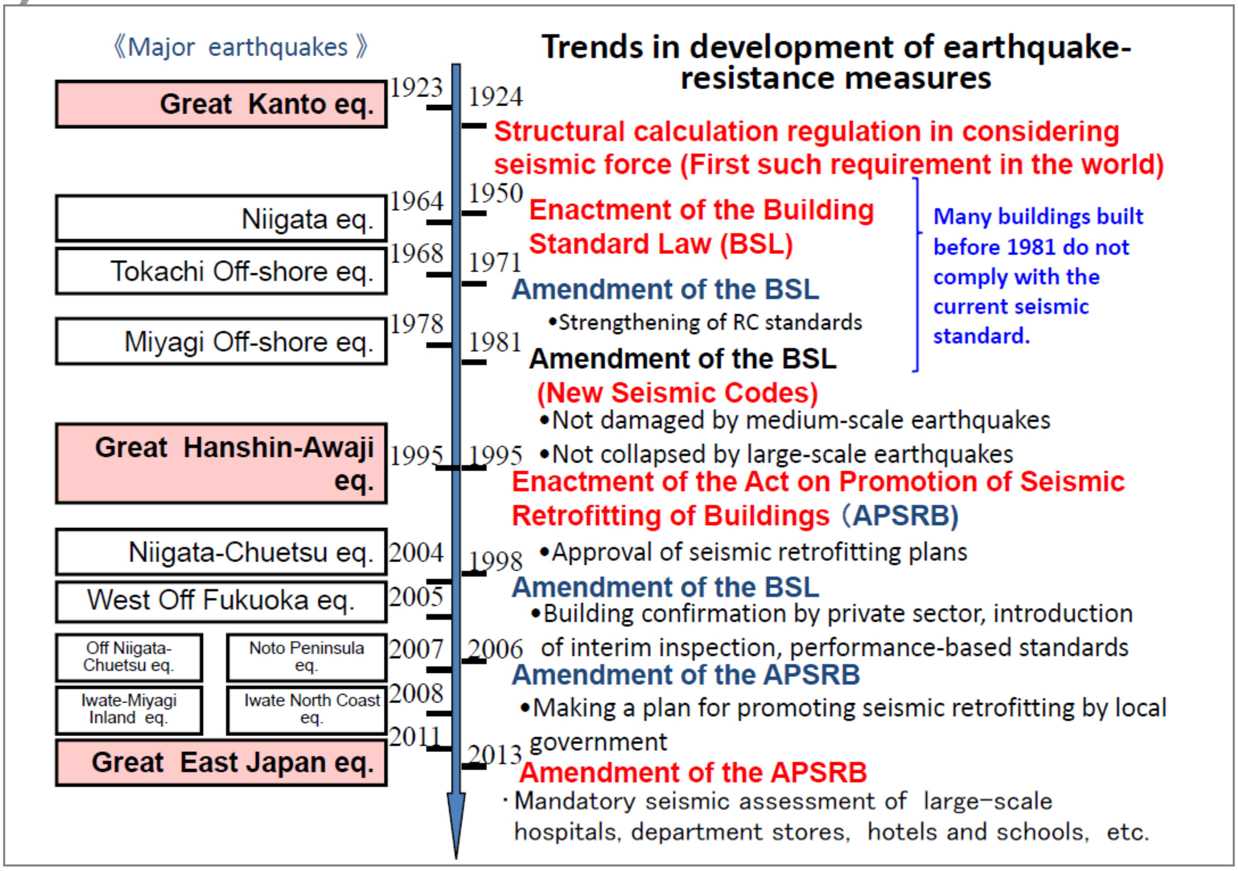
The following year in 1924, Earthquake resistant construction regulations were introduced. The seismic requirement that horizontal seismic coefficient factor 0.1 was added to the Urban Building Law (UBL). This was the first seismic code in the world to introduce seismic coefficient. The 1924 UBL also included provisions for wooden building. However, these rules only applied in urban areas. Figure 2 shows Development of Seismic Resistant Building Code in Japan.

After the 1948 Fukui earthquake which had a magnitude of 7.1, the introduction of the Building Standards and what is now known as "kyu-taishin" and this earthquake resistant design was enforced nationwide and no longer limited to just urban area in 1950.

In 1971, Amendments to the Standards for shearing reinforcement and reinforced concrete foundations. Wooden structure should have reinforced concrete foundations.

Damage from the 1968 Tokachi off-shore earthquake with a magnitude of 7.9 and the 1978 Miyagi earthquake with a magnitude of 7.4 led to this new revision. The New Earthquake Resistance Standards Amendment what is known as "shin-taishin" in 1981.

The 1995 Great Hanshin Awaji Earthquake caused extensive damage, it was 6,460 deaths, 40,000 injuries and more than 240,000 total and partial collapse of buildings. Those most damaged building was built before 1980 as following kyu-taishin. There were very few of the shin-taishin buildings suffered serious damage. Therefore, it might be say that the effectives of amendment has been verified. Figure 3 shows Damage situation of wooden houses after 1995 Great Hanshin Awaji Earthquake.



source: from MLIT data

Fig.2 Development of Seismic Resistant Building Code

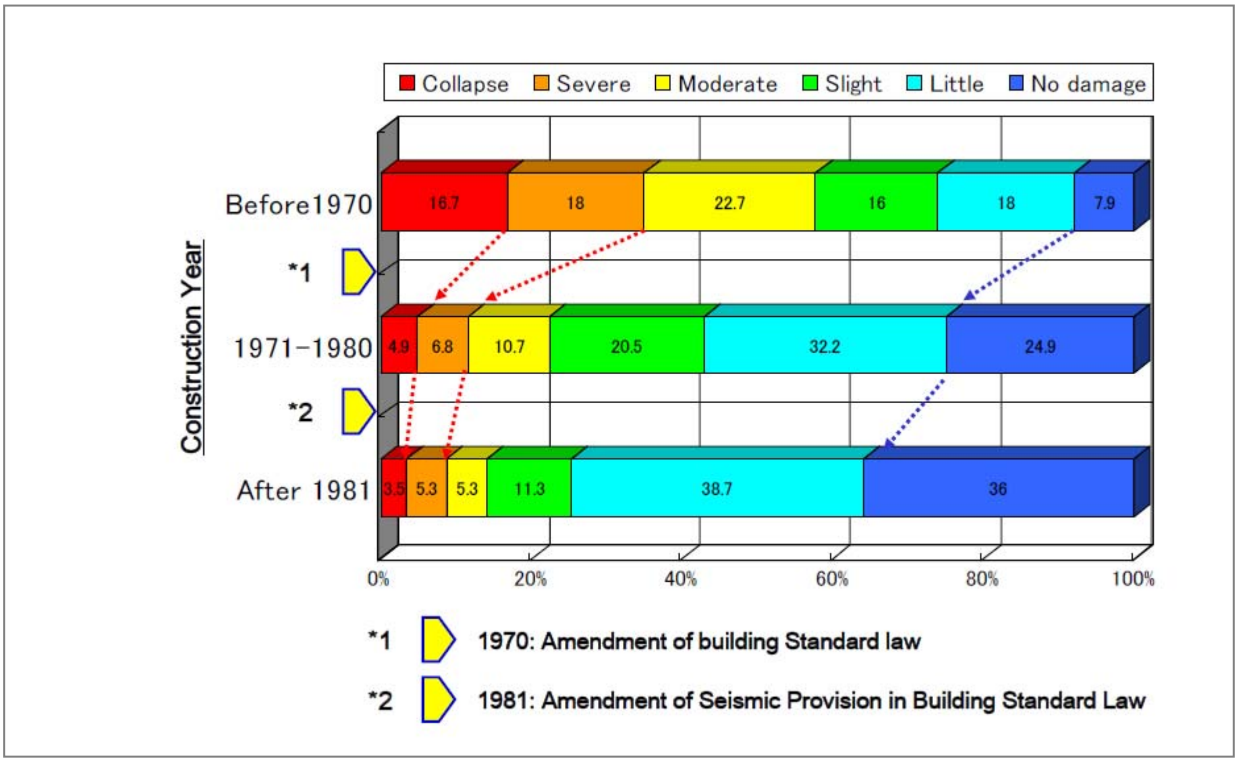


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Fig.3 Damage situation of wooden houses after 1995 Great Hanshin Awaji Earthquake

3-2) System of Qualified Architect (“*Kenchikushi*” in Japanese)

Kenchikushi is a national qualification under the *Kenchikushi* Law which was promulgated and came into effect in 1950, and has been revised several times since then.

The holder of the *Kenchikushi* qualification, referred to as a “*Kenchikushi*,” is licensed to provide services such as design and construction administration of buildings, and plays the dual role of an architect and a building engineer. Those who intend to become *Kenchikushi* must pass the qualifying examination for *Kenchikushi* and obtain the license through the registration procedure.

There are three types of *Kenchikushi* licenses (1st-class *Kenchikushi*, 2nd-class *Kenchikushi*, and *Mokuzo Kenchikushi*), which restrict the use, scale and structure of buildings for which the *Kenchikushi* is qualified to offer a professional service. (See Fig.4)

- 1st class *Kenchikushi* can design buildings and superintend construction work covering all buildings. Under this category, 1st class Kenchikushi for Structure and 1st class Kenchikushi for appliances have been added recently
- 2nd class *Kenchikushi* can design and superintend construction work mainly for small buildings.
- *Mokuzo Kenchikushi* can design and superintend construction work of only small wooden buildings.

Total floor area (S: m2) / Height and structure		height of building ≦ 13 m and Height of eave ≦ 9 m					Height of building＞13 m, or Height of eave ＞9 m
		wooden			Non-wooden		
		1 story	2 story	3 story	Up to 2 stories	3 stories or more	
S ≦ 30		Anyone can engage in this.			Anyone		
30 ＜ S ≦100							
100 ＜ S ≦ 300		1st, 2nd, or *Mokuzo* can engage in this.					
300 ＜ S ≦ 500							
500 ＜S ≦ 1,000	General-purpose buildings	Only 1st–class or 2nd-class can engage in this area.					
	Special-purpose buildings						
1,000 ＜ S	General-purpose buildings	1st, 2nd			Only 1st-class can engage in this area.		
	Special-purpose buildings						

source: from 2014 MLIT data

Fig.4 Scope of Activity by Type of “*Kenchikushi*”

3-3) Development of new construction methods and materials for wooden structures

In the early 1990s, the wave of wood substitution began, and was characterized by a substitution by type of wood products being demanded in the building industry. Traditionally, most wood house construction in Japan had been column and beam as frame structure. The connection of structural member were cut and notched on site for immediate assembly by skilled master carpenters. Very few metal connectors were used. However, a shortage of skilled carpenters and high labor cost, coupled with a general willingness to lower the cost of a built house, meant that things had to change. This led to a number of dramatic shifts, all of which affected the types of wood products demands in Japan in the 1990s. Each is introduced in turn below.

- Pre-cut component manufactures (See Fig.5)

The growth of pre-cutting connection manufactured in factory-automated environments has been impressive. The number of pre-cut plants is Japan increased from 181 in 1986 to 890 in 1998.

➢ Metal connectors (See Fig.6)

The use of metal connectors and hangers to complement or even replace traditional joinery.

source: http://www.yumehouse-sagamihara.com/

source: http://house-aa.jp/kouhou/88.html

Fig. 5 Pre-cut notched joints

source: Building Research Institute

source: http://mirai-wood-archi.at.webry.info/

Fig.6 Metal connectors

3-4) Industry-wide capacity building

In the wooden house, house owner arranges material and carpenter provides technical work in the past. Then, the transition into a form that turnkey job as entire construction work was proceeded. The government has been implementing a variety of support measures because to order the contract requires a financial power for the construction company. The supporting range is a wide variety, such as improvement of technology including the design, improvement of productivity, streamlining of procurement, improved capacity building, modernization of management, etc. Also training of engineers who will lead the construction business was conducted.

3-5) Approach housing market

The support to development of quality housing stock formation and improvement local housing industry. For examples, there is collaborated housing project of government and private builder. Mass housing project planned by local government, then construct and carry out the sale by local builder. In this case, the main assistance, support for buyers of these house, for example, Government Housing Loan was carried out with preferential treatment.

3-6) Low interest housing loan and technical assistance

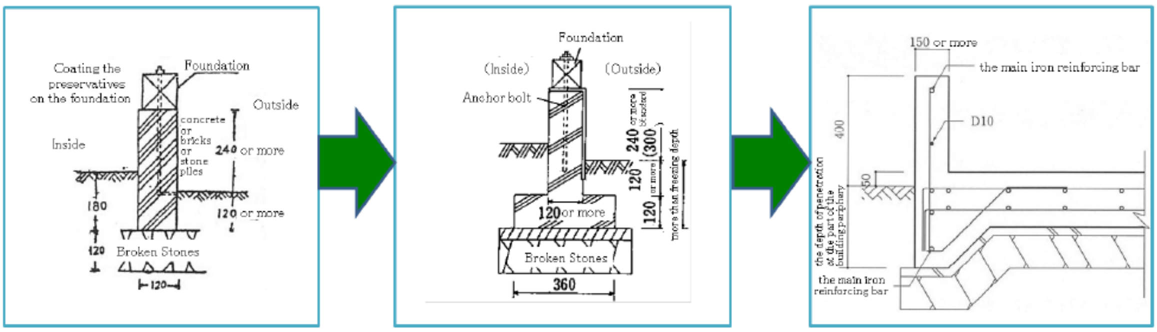
Government Housing Loan Corporation (GHLC) was established in 1950. GHLC did an important role in the housing policy in Japan after the World War Ⅱ. From 1950 to 2007 when GHLC was abolished, there were 63 million housing units constructed in Japan, of which 19 million, or 30%, were financed by GHLC.

What was unique with GHLC was that it was committed to enhance the quality of houses in Japan as an implementing agency under government. GHLC set technical criteria for the architects and carpenters to comply with clear understanding. Shown in Figure 7.

In order to receive housing loan from GHLC, the house owner had to undergo the process of checking of drawings as well as on-site inspection. GHLC disburse our fund only after the certificate of compliance to GHLC standard is submitted.

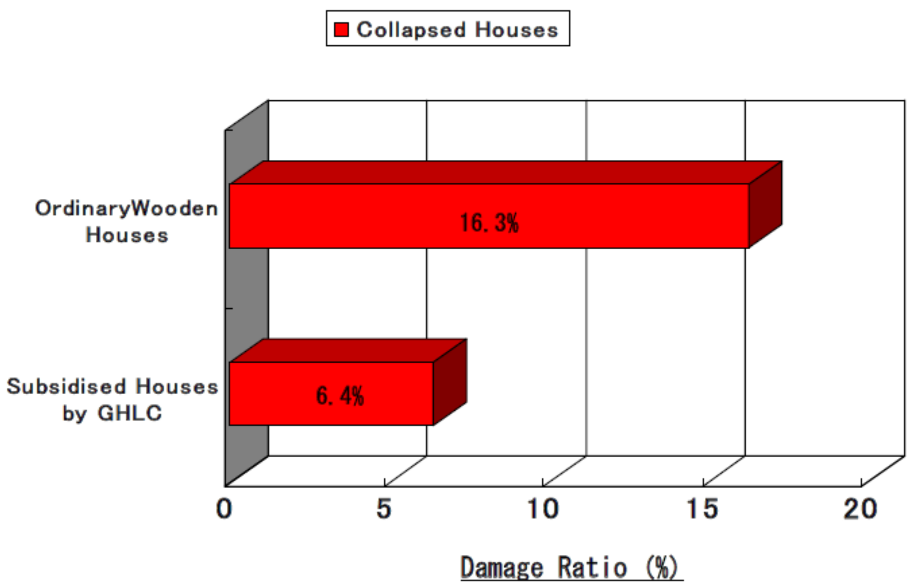
In 1995, Great Hanshin-Awaji Earthquake occurredand many houses were destroyed. It is difficult to measure the damages exactly, but our survey shows that more GHLC financed houses survived than privately financed housesby 2.5 times margin. Shown in Figure 8.

We understand that the difference of the damages came from thefact that GHLC financed houses underwent due process of design supervision and construction supervision on site, which contributed to saving lives of many people.



source: GHLC report

Fig.7 Transition of the drawings of the GHLC specification

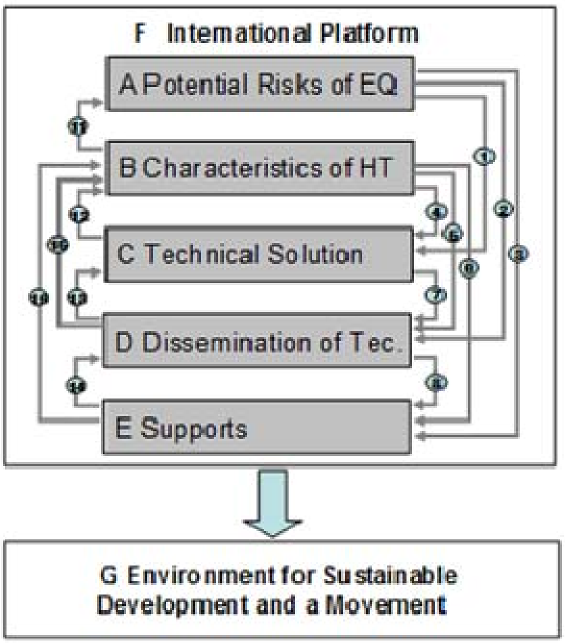


source: GHLC report

Fig.8 Ratio of house destroy or heavily damaged by Great Hanshin-Awaji earthquake 1995

4) Proposed Framework for Comprehensive Approach on Performance Improvement

Discussion of key issues and lessons from our experience suggests that a comprehensive approach extending beyond key issues to wider socio-economic realities is needed in order to realize a reduction in earthquake damage in practice. A perspective of relevant issues and relations among them is shown in Figure 9. Each of the relevant items is discussed individually below and details like sub items, and actions and expertise needed is shown in Table 1.



Inputs for other items	
①	Anticipated risks of earthquakes
②	Inputs for enhancing risk recognition
③	Inputs for enhancing risk recognition
④	Technical information for research
⑤	Technical information for dissemination activities
⑥	Technical information for designing encouragement
⑦	Technical contents to be disseminated
⑧	Inputs for designing encouragement
⑪	Information of vulnerability of each house type
⑫	Feedback for verification of technical solution
⑬	Feedback for verification of dissemination methods
⑭	Feedback for verification of encouragement
⑮	Feedback for verification of dissemination methods
⑯	Feedback for verification of encouragement

Fig.9 Relations between relevant items for safer house construction

Table 1 shows framework which we proposed for safer house construction.

In this section, comparative study of the framework which table 1 with respect to Japanese experience was carried out.

3-3 (Development of new construction methods and materials for wooden structures) is related appropriate construction technologies (C1) cover structural engineering, structural design, and construction methods. In addition to such expertises, we must pay attention to materials and components (C2) and to improving on-site construction practices (C3).

3-2 (System of Qualified Architect) is based on dissemination of technologies for industries, engineers/workers and administration as supply side (D1).

3-4 (Industry-wide capacity building) and 3-5(Approach housing market) are related some items in supports for building (E). It classify into economic support (E1) and social supports (E2).

3-6 (Low interest housing loan and technical assistance), at first, it involve to Technical solution for safer house (C), then there was a significant effect on certainly tell that the technology to construction companies is related dissemination of technologies (D). And Aspects of cooperation with other measures, collaborate with initiative targeting low and middle income groups (E3) is also covered.

Table 1 framework for safer house construction

Items		Sub items		Action	Expertise/Fields
A	Potential risks in case of earthquakes	1	Potential of earthquake occurrence	Anticipate future earthquakes with the magnitudes and return period	Seismology, Geology
		2	Seismic ground motion	Determine propagation and amplification of vibration and anticipate ground motion	Seismology, Geology, Soil Dynamics, Earthquake Engineering
		3	Potential risks of building damages	Estimate damages of buildings by anticipated ground motion	Earthquake Engineering, Structural Engineering
B	Characteristics of targeted housing types	1	Structures	Determine characteristics that influence earthquake damages, such as materials, supporting members against lateral forces (walls, reinforcing, etc), number of stories, etc.	Structural Engineering
		2	Materials and components	Specify physical characteristics of structural materials and components such as compression/tensile strength, ductility and their dispersion	Engineering on Building Materials
		3	Construction technologies	Specify characteristics of construction methods/procedures and tools/facilities of construction works	Construction Engineering
		4	Skills of workers	Determine skills of workers who build targeted housing type	Construction Management
C	Technical solution for safer houses	1	Appropriate construction technologies	Promote structural engineering, structural designs, construction method, appropriate for each housing type for earthquake safety	Structural Engineering, Construction Engineering, Construction Management
		2	Appropriate materials and components	Improve materials and components or introduce new ones to promote earthquake safety	Engineering on Building Materials, Construction Engineering, Construction Management
		3	Improvement of on-site practices	Improve or introduce tools/facilities and construction methods/procedures for earthquake safety	Construction Engineering, Construction Management
D	Dissemination of technologies	1	Industries, engineers/workers and administration (supply side)	Disseminate technical information/recommendation to relevant groups such as construction workers , manufacturers of materials and components and government officials	Engineering Education, Dissemination of Technologies, Training of Engineers and Workers, R&D on Materials and Components, Circulation of Materials and Components, Policy for Building Industry, Building Permit
		2	People and community (demand side)	Educate and motivate users/dwellers and their family members, community members (neighbors etc.) and their supporters like housing facilitators and volunteers	Disaster Education, Community Based Disaster Reduction
E	Supports for building users/dwellers and community	1	Economic support	Provide subsidies, loans, donation of materials etc. to encourage investment in earthquake safety	Community Development, Policies and Strategies for Poor Groups
		2	Social supports	Support users'/residents' access to economic support and administrative procedures, such as building permits and settling of legal issues like land tenure, migration control	Community Development, Policies and Strategies for Poor Groups
		3	Collaboration	Collaborate with initiatives targeting low- and middle-income groups, such as public health, improvement of living condition, and community development projects	Community Development, Policies and Strategies for Poor Groups, Development Aid
		4	Collaborative platform for all stakeholders (governments, donors, NGOs and international organizations)	Establish a platform to support collaboration by stakeholders involved in activities E1, E2, and E3	Development Aid, International Cooperation, NGO Activities
F	International platform for exchange of information, lessons, and good practices			Establish an international platform to enhance the human resources devoted to reducing earthquake damage	All the relevant fields and sectors above
G	Environment for sustainable development and a movement for safer houses			Prepare an environment to facilitate sustainable development that requires less financial and human resources through the activation of local economies and community development	Community Development, Development Aid, International Cooperation

3. Lessons learned for developing countries

Based on the experience in Japan, the following four key lessons could be relevant to developing countries today.

1) Establishing robust building regulatory system and Proactive enforcement support

Building code and regulatory system are known as key tools for improving building performance. For instance, when Hanshin-Awaji (Kobe) earthquake hit in 1995, 97% of collapsed buildings had been built under old building codes, while those that followed the most updated building code accounted for only 3% of the total number of collapsed buildings. Therefore, recognizing all type of major construction including non-engineered in the building code and regulatory system is important. Particularly for non-engineered structure, proactive supports by the public entities to enforce the building code and technical standards are critical, given the fact that major players are non-professional local residents.

2) Securing open process engaging multi-sector players

Evolvement of engineering and science knowledge can help improve construction methods, materials and human capacity. In Japan, these knowledge helped transform non-engineered structures to engineered. It is important to draw attention of, for instance, leading academic and researchers into non-engineered structures, although the formal education system normally shed very little light on this issue. Establishing open process for the evolvement is a key to accommodate expertise from various sectors and promote comprehensive regulatory process that can strengthen non-engineered houses.

3) Leveraging relevant policies for scaling-up impacts

Clustering this agenda with prioritized policy actions is an efficient approach. In the case of Japan, non-engineered related policies were implemented under the piggyback of other prioritized policies such as post-World War II housing supply in large scale; small and medium enterprise development; local business enhancement and etc. In developing countries today, non-engineered housing improvement could have strong link with community development; rural development; poverty eradication and small scale livelihood projects.

4) Identifying co-benefitting partners to stimulate market mechanism

Improving performance of non-engineered houses can be further accelerated with other co-benefitting partners, such as government-led housing financing agency in the case of Japan. Housing financing agency is mandated to develop a sustainable financing mechanism ensuring quality of housing that leads to smooth repayment of housing loans and sustainability of the agency itself. This clearly has good reasoned synergy with performance improvement of locally wide-spread construction practices. Similar approaches are observed in the construction material industry. For example, some material companies provide manual for safer construction using their own products. The collaborative approach should be accelerated among co-benefitting partners with technical and financial capabilities.

4. Acknowledgement

All those who supported this study is gratefully acknowledged.

5. Reference

[1] Tatsuo Narafu et al., Basic study on Strategies for Earthquake Disaster Mitigation on Buildings in Developing Countries –Lessons from Experience of Non-engineered Houses in Japan-. Institute of Social Safety Science (ISSS), No.37, 2015.11