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# Evaluation of the Policies for Seismic Retrofit of Buildings

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**Abstract:** The Japanese government has established a law to promote seismic retrofitting of buildings immediately after the Great Hanshin-Awaji Earthquake in 1995. This paper evaluates the effectiveness, efficiency, administrative feasibility and technological incentives of the policies related to the law. The data shows that the policy target of seismic safety of existing buildings will be achieved in 2018 if the current trends of improvement will be continued. In the field of school buildings, national government supports the school retrofit works that are carried out by the local governments, using the guideline for school retrofit. However, there are still significant issues to make all buildings safe. One of the key challenges is how to persuade the elderly who would not invest their money to improve their old houses. Another challenge is to make owners understand the importance and have priority in improving the seismic safety of buildings. Currently many efforts are taken by the local governments, such as holding seminars for local communities, preparing financial support schemes, providing consultancy for seismic assessment and making earthquake hazard maps. This paper also provides comments on the improvement of the current policies for promoting seismic retrofit based on some international experiences in retrofit of buildings.

**Key words:** ?

## 1. Introduction

After the Great Hanshin-Awaji Earthquake in 1995, the Japanese government has established around 20 legal systems including the “Act for Promotion of the Earthquake Proof Retrofit of Buildings” (Retrofit Promotion Act) that has been established in 1995 as one of new legal systems. Moreover, many Japanese local governments become to provide various support systems in order to promote seismic retrofit conducted by owners and the private sector. The national government also provides new subsidy systems such as the regional housing grants and the community renovation grants based on the Retrofit Promotion Act. Furthermore a tax reduction system of loans for seismic retrofitting has started from the fiscal year 2006.

Why so many public assistance systems for housing seismic retrofitting exist, though houses are private assets? Originally, this argument arose immediately after the Great Hanshin-Awaji Earthquake. Has the government decided not to appropriate tax revenue (public assistance) for the reconstruction of individual houses, then?

One of the reasons why such a policy change has made, may result from the establishment of the “Act concerning Support for Reconstructing Livelihoods of Disaster Victims” in 1998 and its revision in 2004. This Act is legislation at the instance of house members on the basis of several disasters after the Great Hanshin-Awaji Earthquake. According to this Act, in case of completely or partially destroyed houses, a certain amount of public assistance can be provided to owners of such private assets. For instance, the owner of a completely destroyed house can allow one million yen for purchasing household effects and two million yen for reconstruction of the house, i.e., in total three million yen will be granted.

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In addition, collapse of houses often causes streets blockade and this may bring about crucial obstacles to escape, fire fighting and/or relief activities, when an urban fire occurs as the experience at the Great Kanto Earthquake in 1923 and in Nagata ward of Kobe city at the Great Hanshin-Awaji Earthquake. Namely, seismic retrofitting of buildings including house, is indispensable in order to secure entire urban safety. Therefore, public assistance can be provided, even though houses are private assets.

Taking a view of the estimated tolls by the Tokai Earthquake published by the Cabinet Secretary in 2005 as a reference, the maximum number of death toll will reach to approximately 9,200 persons by the assumed ocean-type Tokai Earthquake. And around 85% of death toll, i.e., approximately 7,900 dead persons will be due to the collapse of buildings and like. At the same time, the Japanese Cabinet Secretary announced a target to reduce those tolls by half in the “Earthquake Disaster Mitigation Strategy” for Tokai Earthquake. For that purpose, a detailed target to improve housing seismic retrofitting ratio was set up from current 75% to 90% within 10 years (till 2015). The “Earthquake Disaster Mitigation Strategy” was also created for coming Tohnankai and Nankai (South-east Ocean and South Ocean) Earthquake in 2005 and the main targets consist of housing seismic retrofit and tsunami disaster prevention measures.

These are the backgrounds of movement that many actors established new supporting measures for housing seismic retrofit in all parts of Japan from the establishment of the Strategy in 2005 till now.

## 2. Retrofit Systems in Japan

### 2.1 Technical Background

“The 1995 Great Hanshin-Awaji Earthquake disaster revealed the weakness of reinforced concrete (RC) structures that were designed in accordance with the pre-1981 design code. Failure of RC columns was primarily in the lack of lateral reinforcement. Larger deformation capacity may be attained by enhancing the capacity by

(a) Jacketing RC columns with steel plates and

(b) Wrapping RC columns with fiber reinforced plastics (FRP).

The use of FRP sheets has merit of easy construction work and of light material weight. Placement of bracing structures (structural walls or steel braces) is effective limiting the response deformation of the structure, thus avoiding the failure of brittle members.

The occupancy of a building during the retrofit work should be considered in selecting retrofit works. For example, the strengthening work of RC columns normally requires the removal of mortar and other finishing materials (tiles) from the concrete surface. The noise, vibration and dust during the retrofit work will not allow occupants to stay in the building.

If advanced technology is affordable, especially in hospitals for post-earthquake medical treatment of the injured, the earthquake induced forces may be reduced by placing isolation devices at the base. The response of a structure may be reduced by installing dampers or energy dissipating devices are available. The failure of foundation piles was reported after the 1995 Kobe earthquake disaster. In some structures, the failure of pile foundation is said to reduce the earthquake ground motion input to the structure and limit the damage in the super-structure. However, the cost of damage investigation of foundation as well as the repair work of damaged foundation is expensive. It is normally desired to provide the foundation structure with higher resistance”. [1]

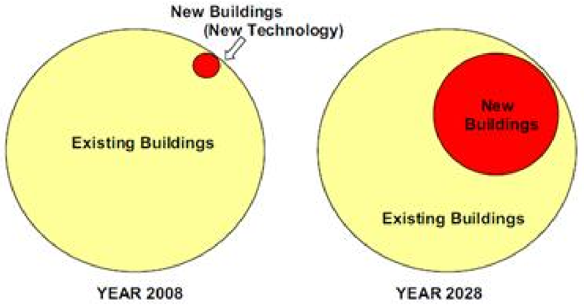

**Fig. 1 Relation of Design Code for New Construction [2].**

### *2.2 Retrofit Promotion Act and Its Support Systems*

The Retrofit Promotion Act was enforced in 1995 immediately after the Great Hanshin-Awaji Earthquake in January 1995, since the lessons learnt from the devastated disaster urged quick response of the government and policy makers to secure the safety of urban built-environment that are mainly consisted of houses and buildings. Key components of the new Act are:

- Obligation of owners to make best efforts to assess and retrofit the buildings that are utilized many people;
- Exemption of retroactive application of building code except for seismic related code to approved retrofit works;
- Guidance, advices and instructions from the responsible governmental agency.

With regard to new obligation for the owners of building that is utilized by many people, such building is defined as, more than 3 stories and more than 1,000 m2 of floor area and its use is in line with designated one such as school, hospital, department store, office, shop, hotel, care facility for the elderly and so on.

When the Retrofit Promotion Act was established, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) surveyed the conditions of houses and buildings in terms of applicability to seismic code (in 1981, the current level of seismic safety). The updated result of the survey is indicated in the Table 1. The target of applicable level of seismic code is also shown in the Fig. 2.

The Act was established to introduce retrofit of houses and buildings. Therefore, in addition to regulatory measures some economic measures have been prepared at the same time by the national government. Those economic measures are available only in the local government that established "Plan for Retrofit Promotion". Table 2 shows the number and ratio of the local governments that have established the Plan for Retrofit Promotion. Table 3 shows the number and percentage of the municipalities that have prepared the subsidy systems for seismic assessment and retrofitting.

Those tables show the fact that even in 2009, one quarter (25%) of municipalities have prepared the subsidy system for condominium to assess/evaluate the vulnerability to earthquake. In case of detached houses, almost 2/3 of municipalities have established subsidy system by 2009 for assessment and almost half of them have prepared financial support for retrofitting of houses. Figures of the Table 3 in the entre- parenthesis

**Table 1 Numbers of buildings under (1981) seismic code level.**

| **Houses** | |
|---|---|
| | Total houses in Japan |
| Total numbers of houses | 47 million units |
| Under seismic code units | 11.5 million units |
| (percentage of under level) | Around 25% |
| Estimated based on the data in 2003 | |
| **Non-residential Building** | |
| Total number | 3.4 million buildings |
| Under seismic code units | 1.2 million buildings |
| (Percentage of under level) | Around 35% |
| Estimated by the Ministry of Land, Infrastructure, Transport and Tourism in 2002. | |

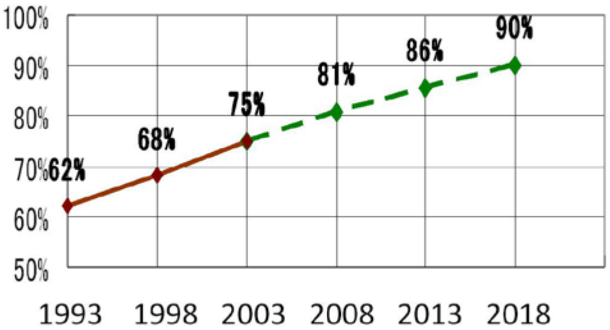

**Fig. 2 Trend estimation of safe houses (seismic code) (Estimated by the Ministry of Land, Infrastructure, Transport and Tourism in 2003).**

**Table 2 Number of Local Governments that have retrofit promotion plans (as of 1 April 2009).**

| | Have plans | -2009.9 | -2010.3 | -2010.4 |
|---|---|---|---|---|
| Prefecture | 47 | | | |
| Total (%) | 47 | | | |
| | 100.0% | | | |
| Municipality | 1.193 | 50 | 185 | 70 |
| Toal (%) | 1.193 | 1.243 | 1.428 | 1.428 |
| | 66.3% | 69.1% | 79.3% | 83.2% |

**Table 3 Subsidy system for seismic assessment and retrofit (as of April 2009, Japan).**

| Building type | Project type | Applicable local Govt. for reftrofit subsidy | |
|---|---|---|---|
| | | Number of local Govt. | Ratio: Applicable Govt. |
| Detached house | Assessment | 1,227 | 68.2% (62.7%) |
| | Retrofitting | 857 | 47.6% (37.2%) |
| Condominium | Assessmen | 450 | 25.0% (19.0%) |
| | Retrofitting | 321 | 17.8% (12.1%) |
| Non-residential | Assessmen | 310 | 17.2% (13.2) |
| | Retrofitting | 154 | 8.6% (5.9%) |

indicate the number of percentage of the April 2008. Within only one year, the percentage has been significantly improved because of the following policy measures, while a limit of financial support to the retrofit can be observed especially in the field of condominium and non- residential buildings.

The following policies are described as the MLIT has reported as below;

(1) Formulation of municipal Retrofit Promotion Plans;

(2) Establishment of prefectural/municipal subsidy system;

(3) Promotion of retrofitting of public buildings;

(4)Securing engineers who manage assessment/ retrofit;

(5) Utilization of tax incentives for business use buildings;

(6) Preparation of seismic hazard mapping;

(7) Best practices for seismic assessment/retrofit;

(8) Model projects on seismic safety houses and buildings.

Those measures are comprehensive. Socio-economic measures, information measures, technical measures, and institutional measures are included to promote the policy for seismic assessment and retrofit of buildings. [3]

### *2.3 Retrofit of Schools in Japan*

"Because of the Great Hanshin-Awaji Earthquake in 1995, school buildings were also severely damaged by the shake." [4] According to a report provided by the Ministry of Education, Culture, Sports, Science & Technology (MEXT), approximately 4,500 educational facilities were structurally or non-structurally damaged, though there were fortunately no death tolls resulted from damaged schools since the Great Hanshin-Awaji Earthquake occurred in early morning at 5:46 a.m.. After the strike of the Earthquake, 390 schools took the role for evacuation shelter and these schools accommodated approximately 180,000 evacuated people.

Furthermore, at the time of recent major earthquakes such as Niigata-Chuetsu Earthquake in October 2004 and Iwate-Miyagi Nairiku Earthquake in June 2008, while many school buildings were damaged, non-damaged schools accommodated many evacuated people. On the basis of these experiences, it is critical to ensure that school students are safe and school facilities are fit to serve as evacuation shelters for local populations. MEXT's policies on structural and nonstructural retrofitting of school buildings are introduced. Since school buildings have the following crucial roles, it is indispensable to assure the safety of school buildings against earthquakes.

(1) Place for educating children: school buildings are the place where many children study and live most part of their days. It is, therefore, vital to keep school buildings in safer and healthier environment.

(2) Place for cultural and sporting activities: school is a well-known building to the people who live near the school. School buildings are, therefore, often utilized for the cultural and sporting events for the local population.

(3) Place for evacuation: school often becomes an evacuation shelter when a major natural disaster occurs. To this end, it is important that school buildings accommodate necessary functions for evacuation shelter.

The Building Standard Law of Japan was revised in 1981 and new seismic resistant design methods were adopted. According to the revised law, the buildings constructed based on the new design would have no damage in the case of middle class earthquakes (about

JMA 5 upper scale). Moreover, there would be no casualties in these buildings and no severe collapse of these buildings even in the case of major earthquakes (about JMA 6 upper) (Table 4).

In order to evaluate the seismic capacity of an existing school building, the seismic capacity index of structure (Is) is used in Japan based on the regulation of the Retrofit Promotion Act. The law regulates that a building has low risk of collapsing if the "Is" of the building is more than 0.6. However, in consideration of the importance of school building, MEXT recommends that the "Is" of school building should surpass 0.7 after retrofitting.

**Is (Seismic Capacity Index of Structure)** (Table 5): An index to define the seismic capacity of an existing reinforced concrete building

$$Is = Eo \times S \times T$$

**Eo**: A basic structural seismic capacity index calculated by the elements of Strength index (C), Ductility index (F) and Story Index (St)

$$Eo = C \times F \times St$$

**S**: A reduction factor to modify **Eo** index, which is based on the structural balance in both plan and elevation.

**T**: A reduction factor to modify **Eo** index, which is graded by time-dependent deterioration.

A survey carried out by MEXT in April 2002 showed that public school buildings had not been satisfactorily retrofitted. It emerged from the 2002 survey that seismic assessment/diagnosis was carried out on only 30% of buildings built based on the pre-1981 Old Seismic Resistant Design, and only about 45% of public primary and junior high school buildings had been retrofitted.

**Table 4 Difference between new and old seismic resistant design.**

| Type of earthquake (JMA scale) | Medium scale earthquake (about 5 upper) | Larger scale earthquake (over 6 upper) |
|---|---|---|
| Old seismic resistant design (until 1981) | No major damage | Not verified |
| New seismic | No major damage | Will not collapse |

JMA Scale: Scale indicating the strength of seismic motion, which was formed by JMA (Japan Meteorology Agency);

5 Upper: Many people are considerably frightened and find it difficult to move;

6 Upper: Impossible to keep standing and to move without crawling.

**Table 5 Seismic capacity index of structure (Is).**

| | |
|---|---|
| Is < 0.3 | There is high risk of collapsing |
| 0.3 < Is < 0.6 | There is risk of collapsing |
| 0.6 < Is | There is low risk of collapsing |

In this connection, a council called "Co-operators' Meeting for the Survey and Study of the Promotion of Earthquake-Resistant School Buildings" was established by MEXT in October 2002. The outcomes of the council's discussions were submitted to MEXT in April 2003 in a report entitled the "Promotion of Earthquake-Resistant School Buildings". Based on this report, the "Guidelines for the Promotion of Earthquake-Resistant School Buildings" was stipulated by MEXT in July 2003.

Chapter 1 of this guideline describes the basic concept of the "earthquake-resistant school building" and Chapter 2 outlines the methods for devising earthquake-resistant promotion plans, the points to bear in mind, and the suggested methods for determining the urgency of earthquake resistance projects.

The basic principles pointed out in this guideline are: (1) to prioritize earthquake resistant measures for school buildings at high risk of collapse or severe damage; (2) to implement seismic resistant capacity evaluation promptly; (3) to develop a plan for promoting earthquake resistance promptly; (4) to disclose the results of the seismic resistant capacity evaluation and the plans for promoting earthquake resistance; and (5) to check and take measures for the earthquake resistance of non-structural elements. [5]

MEXT has been urging municipal governments, which are responsible for school buildings, to promote school building's retrofitting based on the above-mentioned guideline. In addition, as the following figure shows, MEXT has a subsidy system regarding public school buildings (Table 2). In line with the Sichuan Earthquake in China in May 2008, MEXT has raised the subsidy rate for vulnerable school buildings (Is < 0.3) from a half to two thirds in June 2008.

By utilizing the above-mentioned subsidy system, the retrofitting of school buildings has been implemented in Japan. The data shows the status of earthquake resistance on elementary and lower secondary public schools in Japan as of April 1, 2008. Approximately 48,000 of school buildings, or 38% of school buildings were found lacking needed earthquake resistance or needed further assessment. Above all, 10,000 of these buildings were estimated to be at high risk of collapse in expected large scale earthquakes. A commitment was made to reinforce all of these buildings at high risk within 5 years. In addition, as mentioned, the subsidy rate for vulnerable school buildings has been raised in June 2008. Moreover, in order to accelerate the 5 years retrofitting program into 4 years, MEXT has added an additional national fund (114 billion JPY) to the regular budget of fiscal 2008 (115 billion JPY, total 229 billion JPY) in the supplementary budget of fiscal 2008 of Japanese government in October 2008.

Even though structural parts of school buildings such as columns, beams and walls are enough retrofitted, if non-structural members such as ceiling materials, various fixtures and furniture are not sufficiently retrofitted, these non-structural members may fall or topple when a major earthquake occurs. Children and evacuated local people can be killed or injured by these vulnerable non-structural members. Therefore, the retrofitting of non-structural members of school building is extremely important.

**Table 6 Subsidy rate for public school building.**

| Type of construction | Subsidy rate from MEXT |
|---|---|
| New construction | 1/2 |
| Reconstruction | 1/3. 1/2 (Is < 0.3) |
| Renovation | 1/3 |
| Seismic rehabilitation | 1/3, 1/2 (Is < 0.3) |

Budget of fiscial 2008:229 billion JPY.

In order to urge municipalities to implement non-structural seismic retrofitting of school buildings, the National Institute for Educational Policy Research of Japan (NIER) published a reference book on non-structural seismic retrofitting of school building in December 2005.

The following case is an example in this reference book. [6]

## 3. Issues of Retrofit Works

### *3.1 Technical Issues [7]*

It should be noted that these countermeasures may not be the same from a country to another because the expected performance (minimum required strength and acceptable damage) of buildings varies from a country to another. Each country has different levels of

(a) Seismic risk,
(b) Hazard tolerance,
(c) Economic background, and
(d) Technical development (construction practices).

Most building codes in the world explicitly or implicitly accept structural damage to occur in a building during strong earthquakes as long as the hazard to life is prevented. Indeed, many earthquakes caused such damage in the past. Then, what percentage of buildings suffered heavy damage in major earthquakes. The Architectural Institute of Japan (AIJ) collected damage statistics in Mexico City and Lazaro Cardenas after the 1985 Mexico Earthquake, Baguio after the 1990 Luzon, Philippines Earthquake, Erzincan after the 1992 Turkey Earthquake, and Kobe after the Hyogo-ken Nambu 1995 (Great Hanshin-Awaji) Earthquake. A heavily damaged area was first identified in each city, and the damage level of all buildings in the identified area was assessed by structural engineers and researchers.

From damage statistics (Table 7 and Fig. 3), the importance of identifying the small percentage of those buildings possibly vulnerable in future earthquakes can be easily realized. Therefore a simple procedure is desirable to examine the vulnerability of all existing buildings in a region, spending a few hours at most for a building, and "screen out" the majority of safe buildings. A more detailed and sophisticated procedure, spending a few weeks, may be utilized to those buildings identified as vulnerable by the simple procedure.

In a screening procedure, for example, dimensions of columns and structural walls per floor areas may be used to roughly estimate lateral load resistance. The lateral load strength is not a single index to represent the safety of a building, but gives some idea if the structure has a sufficient capacity to resist earthquake motions by strength. Those buildings, identified as questionable by the simple procedure, must be analyzed by more sophisticated procedure

The following development and application of technology are needed to mitigate earthquake disaster from construction point of view: i.e.:

(a) Effective earthquake resistant building codes for new construction,

(b) Earthquake vulnerability assessment methods for existing buildings,

(c) Seismic strengthening technology for vulnerable buildings,

(d) Seismic damage evaluation methods for damaged buildings after an earthquake,

(e) Technology to repair damage for immediate occupancy, and

(f) Technology to rehabilitate damaged buildings for permanent use.

**Table 7 Damage Statistics from Major Earthquakes [8].**

| City, year of earthquake | Operational damage | Heavy damage | Collapse | Total |
|---|---|---|---|---|
| Mexico City, 1985 | 4251 (93.8%) | 194 (4.3%) | 87 (1.9%) | 4.532 |
| Lazaro Cardenas, Mexico, 1985 | 137 (83.5%) | 25 (15.2%) | 2 (1.2%) | 164 |
| Baguio City, Phillippines, 1990 | 138 (76.2%) | 34 (18.8%) | 9 (5.0%) | 181 |
| Erzincan City, Turkey, 1992 | 328 (77.4%) | 68 (16.8%) | 28 (6.6%) | 424 |
| Kobe (pre-1981 construction), 1995 | 1186 (79.4%) | 149 (10.0%) | 158 (10.6%) | 1493 |
| Kobe (post-1982 construction), 1995 | 1733 (94.0%) | 73 (4.0%) | 38 (2.1%) | 1844 |

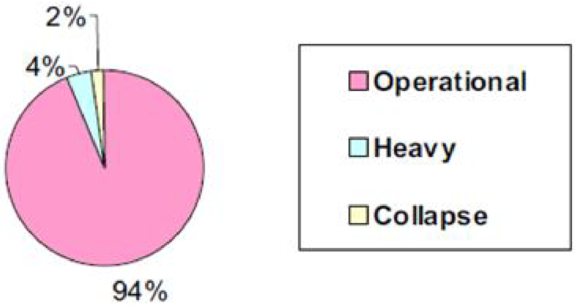

**Fig. 3 Damage distribution of Mexico City.**

### *3.2 Socio-Economic Issues*

An examination of allocation of government resources, in terms of financial and human, for pre-disaster and post-disaster disaster programs reveals that more resources are devoted recovery than to disaster prevention. They commit a large amount of financial and human support after a disaster. This is particularly true for the international community. Disaster prevention programs attract little attention. However, because emergency operations take place after a disaster when many lives have already been lost, only few lives can be saved. In contrast, the implementation of disaster preventative measures can potentially save many more lives.

Hence, we must shift our done on seismic resistance and isolation technologies of high rise buildings, but little research is done on conventional houses. But over 80% of total stock in the world is non-engineered. Because these unsafe buildings are occupied by humans, we cannot reduce disaster losses unless we improve the safety of non-engineered buildings (in case of Japan, wooden houses). However, they attract little attention and research funds. Similarly, when spending habits for new and existing houses are compared, people tend to spend generously for new houses but not as much for the maintenance. However, many more lives can be saved by improving the safety of existing houses.

Another essential aspect is cost reduction. There are several ways to achieve this, for instance, technological development and government subsidies. It is also necessary to train masons and carpenters on available techniques.

The political commitment is also crucial. The rea1493son is that many individual house owners would pay to reinforce their houses if they understand the need; but not all house owners would. Everybody dies eventually. Considering this, the probability of death from an earthquake, which chance of occurrence is 40 percent in every 30 years, might seem negligible. Just like the fact that many smokers wouldn't stop smoking even if they are told to do so, not all individual house owners would reinforce their houses. [9]

One of the key challenges is how to persuade the elderly who would not invest their money to improve their old houses. Another challenge is to make the housewives understand the importance and have priority in improving the seismic safety of houses.

## 4. Retrofit Examples in the World

This section shows four retrofitting examples in the world. In addition to the cases in Japan, the author had relation with some retrofitting cases in Nepal, Indonesia, Uzbekistan and China through projects at the UNCRD Hyogo Office and the Building Research Institute (BRI).

### *4.1 Example 1 (Houses in Nepal)*

Nepal faces a variety of disaster risks owning both to its natural characteristics and human induced factors. Nepal has experienced several major earthquakes: The Bihar Earthquake in 1934 which measured 8.3 on the Richter scale killed 4,300 people, and destroyed 20% of all structures (Earthquake and Megacities Initiatives, 2005). Three earthquakes of similar size occurred in Kathmandu Valley in the 19th century: in 1810, 1833, and 1866. In 1988, there was another earthquake, which caused to loss of 709 lives (The National Society for Earthquake Technology NSET- Nepal).

United Nations Centre for Regional Development (UNCRD) has carried out a training project in Nepal in 2007. The training was organized with technical support from NSET to train practical measures that can be applied at the house level. 20 female members from target communities participated in the training. In the workshop, they learnt the basic science of earthquakes, importance of disaster risk reduction, and how to apply non-structural risk mitigation measures in their homes. For example, they visited several houses to learn practical ways of securing refrigerators and shelves by using brackets and props.

After the initial training, follow-up evaluation meetings were held with the participants. 19 participants reported that they have applied non-structural measurements in their homes within one or two weeks after the training by themselves (13 people) and/or with male members in the family (16 people), while there was one person who hired a handyman. 17 participants reported having talked about the training with relatives and/or friends, and 15 participants had showed their relatives and/or friends what they had done in their homes to secure their furniture.

Furthermore, 14 participants answered that they know relatives/friends who have implemented such non-structural risk reduction measures in their homes after observing their examples. The result showed that there was a strong potential for using women's network and communication to disseminate disaster risk reduction strategy. [10]

**Fig. 4 Household assessment of non-structural part (NSET).**

**Fig. 5 A trainer of NSET secures furniture using anchors in a community participant's home in Kathmandu (by UNCRD).**

Though the project has not aimed at retrofitting itself, fixture of nonstructural part of a house is recognized as the first step to raise awareness of community people, especially for housewives who must play an important role as decision makers for house maintenance. And this case study shows the communication network among housewives effectively works to disseminate the seismic measures for houses like fixture of furniture.

### *4.2 Example 2 (Schools of Indonesia)*

Earthquakes in the past have exposed that vulnerability of school buildings is disproportionately high compared to the other infrastructures. For instance, in the 1999 Chi-Chi Earthquake, Taiwan 43 schools in Nantou and Taichung area were completely destroyed and a total of 700 schools nationwide were damaged to different extent. The 2001 Gujarat Earthquake in India caused damages to over 11,600 schools. The 2005 Kashmir earthquake resulted in collapse of 6,700 schools in North-West Frontier Province and 1,300 in Pakistan-administered Kashmir.[11] Recently in May 2008, Wenchuan Earthquake in China killed about 7,000 students trapped in damaged school buildings. When an earthquake hit Spitak area of Northern Armenia during school hours in 1988, many children lost their lives due to collapse of school buildings. For example, 285 children out of 302 in total died at one school. This resulted in almost 2/3 of total deaths of 25,000 were children and adolescents.

UNCRD and the Center for Disaster Mitigation (CDM) of the Institute of Technology Bandung (ITB) conducted a collaborative project to reduce the vulnerability of existing school buildings in the corridor of the School Earthquake Safety Initiative (SESI) project. Two school buildings, SD Cirateun Kulon II and SD Padasuka II both in Bandung County, were selected for this project due to the dire needs of improvement and severe deficiencies of earthquake resistant systems. The project included retrofitting and strengthening of school buildings, and other activities to improve school community preparedness regarding earthquake.

Prior to conducting any physical work to the structure, the locations and building layouts were checked to ensure that the buildings could be retrofitted. The existing structures were investigated to determine the type and quality of materials used, as well as the existing lateral resisting system. Then, the retrofitting was designed based on the structural deficiencies/weak parts and their accessibilities, weighing in retrofit factors on buildings' life time, earthquake resistance capacity, their function, and appropriate retrofit strategy/ techniques. The design of retrofit strategy also considered factors of continuation of normal function, availability of materials and skilled construction workers, needs of upgrades for non structural components, and total costs.

**Fig. 6 Retrofit work of School Building I (ITB ).**

The retrofitting project was first conducted at the school SD Cirateun Kulon II. The school buildings consisted of two buildings made of RC frames and masonry walls. Each building has four rooms. Based on results from survey and tests, structural analyses were performed on the existing structures using the actual material and structural components. Earthquake risks were introduced to the buildings by applying loads based on potential seismic risks and local soil conditions. The analysis showed that both buildings were considered likely to behave poorly under seismic loadings, thus required retrofitting. The physical works were then conducted to improve the structural quality and reduce the earthquake vulnerability.

Building I which was considered to have lower quality was retrofitted by adding adequate RC frames with mat footings. Anchorage was provided to connect walls with columns and beams. Building II which was in better condition was retrofitted using wire mesh for strengthening wall elements. Double tie beams were added adjacent to the existing one for better foundation system. For both structures, proper detailing was applied to roof truss systems, and repair was carried out for nonstructural elements such as doors/windows and ceilings. Finishing/cosmetic repair and improvement of sanitary facilities were also conducted for both structures.

### *4.3 Example 3 (Schools of Uzbekistan)*

In Tashkent city, there are more than 360 schools. Nearly 20% of school buildings have had deficiencies of different level at present. Preliminary analysis of seismic risk for Tashkent city showed that more than 25% of school buildings may be completely destroyed and 30% may be heavily damaged in case of design earthquake.

The buildings of schools in Tashkent are represented mainly by two construction systems: bricks and RC frame-panel consisting major portion of school building stock and a few buildings made up of from adobe bricks. Nearly 35% of school buildings were constructed before Tashkent earthquake of 1966 for design intensity 7 by MSK scale. Since 1966, half of school buildings were constructed using assembled RC frames of IIS-04, which are inherently weak in seismic resistance. The weakness of this construction type was revealed Spitak (1988), Kairakkum earthquakes (1985) and also confirmed by through the engineering analysis of earthquake consequences.

Many school buildings in Tashkent are located in the zone with slumping soils, and as a result many buildings, both brick walled and frame panel type are likely to be damaged. The survey showed that typical structures used for school building in Tashkent basically consist of brick works up to 4 stories in old construction, and reinforced concrete frame-panel for the more recent buildings. Recurrent structure typologies for school buildings are categorized in the following three groups:

(1) Mixed type of brickwork and reinforced concrete or wood reinforcing frame - year of construction ’40s;

(2) Brickwork structures, frequent typology used until 60s;

(3) Frame-panel, widely used in the modern construction.

In order to establish an effective and recognizable linkage to the local professional practice in the Central Asian region, and to follow the standard analysis procedure, it is ensured that the characterization is in compliance with the previous study on the Risk Assessment of Tashkent city in the framework of IDNDR RADIUS project in 1990’s. [12]

**Fig. 7 Retrofit of RC panel school in Tashkent (UNCRD).**

### *4.4 Example 4 (Buildings of China)*

Ministry of Housing and Urban-Rural Development of People's Republic of China (MOHURD) has held several investigations on the disaster after the Wenchuan Earthquake. Upon the analysis and research, MOHURD has constituted "Technical Guide for Appraiser and Strengthening of Earthquake Affected Buildings" on July 23rd, 2008, and promptly issued "Seismic Technical Specification for Building Construction in Town and Village" on June 13th, 2008, and implemented on October 1st, 2008.

The Chinese "Standard for Classification of Seismic Protection of Building Constructions" GB50223-2008 has been enacted on July 30th, 2008. It has been partially amended on the original "Standard for Classification of Seismic Protection of Building Constructions" GB50223-2004. In addition, "Code for Seismic Design of Buildings" GB50011-2008 (enacted on July 30th, 2008) has been amended on the original "Code for Seismic Design of Buildings" GB50011-2001.

Wenchuan earthquake provided abundant experiences for seismic project constructions. In order to improve the capability of disaster area's reconstruction and Chinese project construction disaster-prevention, MOHURD and experts from relevant departments have researched and analyzed earthquake experiences, and have summed up the seismic engineering research results.

On the above amendments, MOHURD has adjusted some seismic standard, especially enhancing the public building seismic standard on secondary & primary schools and hospitals, extending the seismic prevention scope of public seismic buildings including retrofitting works. Besides, MOHURD has also amended the design code and criteria from the aspects of specific technologies.

To learn from Japan's accumulated seismic building technology and further promote the application of seismic technology, to improve the capability of earthquake and hazardous prevention, and to increase the technical level in China, Financing & Foreign Affairs Dept. of MOHURD and Japan International Cooperation Agency (JICA) has reached an agreement on the "China-Japan Seismic Training Program" on May 12th, 2009. This program will last 3 years and be fully supported by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan.

The International Institute of Seismology and Earthquake Engineering (IISEE) of the Building Research Institute (BRI), Tsukuba, Japan is the implementing agency of the training on assessment, retrofit and design for seismic building since 2009.

## 5. Conclusions

The Japanese government has established a law to promote seismic retrofitting of buildings immediately after the Great Hanshin-Awaji Earthquake in 1995. This paper evaluates the policies related to the Retrofit Promotion Act. The data shows that the policy target of seismic safety of buildings (90% of buildings follow the 1981 seismic code) will be achieved in 2015–2018 if the current trends of improvement will be continued. In the field of school buildings, national government supports the school retrofit works that are carried out by the local governments, using the guideline for school retrofit.

However, there are still significant issues to make all houses safe. One of the key challenges is how to persuade the elderly who would not invest their money to improve their old houses. Another challenge is to make the housewives understand the importance and have priority in improving the seismic safety of houses.

Currently many efforts are taken by the Japanese local governments, such as holding seminars for communities, preparing financial support schemes, providing consultancy for seismic assessment and making earthquake hazard maps. This paper also provides comments on the improvement of the current policies for promoting seismic retrofit based on some international experiences of house and building retrofit. Some international cases will help to develop an effective Japanese policy for promoting retrofit, such as the case of Nepal shows the role of females to disseminate the seismic safety of non-structural part of houses.

The Japanese experiences on seismic retrofit will be able to contribute to the disaster risk reduction in the other seismic-prone countries in the world. The lessons from Kobe and lessons from all over the world should be disseminated to find solutions towards challenges to promote policies and actions of seismic assessment and retrofitting.

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