STRATEGIC APPROACH TO MITIGATE HUMAN CASUALTIES CAUSED BY LARGE SCALE EARTHQUAKES
<Engineering for Safer Non-engineered Houses>

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ABSTRACT :

Every large scale earthquake causes tragic damages to human societies especially human casualties. Sichuan Earthquake 2008 reminded us the fact again. Main cause of the human casualties is collapse of usual people's houses, which are often called "Non-engineered" as they have no or little intervention of engineers. In spite of this crucial situation, only a few researchers and engineers pay attention to non-engineered houses. Following statement by UNISDR (United Nations International Strategy for Disaster Reduction) in their report "Living with Risk: 2004 version" clearly describe the situation.
"It remains something of a paradox that the failures of non-engineered buildings that kill most people in earthquakes attract the least attention from the engineering profession."
Under this circumstance, Building Research Institute (BRI) launched a research and development project focusing on non-engineered structures in 2006 on net work of researchers and practitioners in Japan, Indonesia, Nepal, Pakistan, Turkey and Peru.
This paper presents outline of our major activities such as full scale shaking table experiments on brick masonry structures, shaking table experiments on simple and affordable seismic isolation, monitoring activities on construction practices on construction sites and pilot projects for disseminating technologies to people/communities. Based on the collaborative activities and discussion with our partners, we propose three approaches listed below to realize mitigation of disasters in actual situation.
- to develop feasible and affordable seismic technologies acceptable for people/communities
- to prepare effective approaches to deliver the technologies to people/communities
- to encourage more researchers and practitioners to work on non-engineered structures

KEYWORDS: non-engineered, earthquake disasters, feasible, affordable, acceptable, dissemination

1. Background

Every large scale earthquake causes tragic damages to human societies especially human casualties. Sichuan Earthquake 2008 reminded us the fact again. Main cause of the human casualties is collapse of usual people's houses, which are often called "Non-engineered" as they have no or little intervention of engineers. In spite of this crucial situation, only a few researchers and engineers pay attention to those houses. Following statement by UNISDR (United Nations International Strategy for Disaster Reduction) in their report "Living with Risk: 2004 version" clearly describe the situation. "It remains something of a paradox that the failures of non-engineered buildings that kill most people in earthquakes attract the least attention from the engineering profession."
In order to mitigate the disasters by earthquakes, encouraging and involving researchers, engineers and practitioners of engineering professions is essential. We believe that only people in each area/country could realize mitigation and people outside could not be main stakeholders, only could be supporters. Therefore collaboration of experts of each target country, who are responsible for disaster mitigation and know actual situation of communities/society, and those of industrialized countries with technical knowledge, is importannt.

2. Experiences and Lessons from Recent Earthquakes

We have suffered from serious damages by earthquakes almost every year. I review recent two large scale earthquakes for basic inputs.

2.1 Central Java Earthquake in Indonesia 2006

Central Java Earthquake on May 27, 2006 (M=6.3) caused serious damages to Indonesian society as 5,778 peoples killed, 139,859 houses destroyed, 190,023 houses severely damaged. I conducted field survey of affected area nine days after the seismic event. Major findings are as follows.

- structure types

Usual structure types of the affected area are brick masonry and confined brick masonry. There are some traditional wood structure houses. Most of them are constructed by non/semi skilled workers and can be categorized into non-engineered structure.

- vulnerability

It seems that the intensity of shaking motion by the earthquake was not so strong even in the area most heavily damaged, judging from conditions that almost all of furniture remained standing and TV sets or clocks did not fall dawn as you see in Photo 1 and 2. It means houses were quite vulnerable against earthquakes.

Figure1 Furniture remained standing even the building completely collapsed (Bantol in Indonesia)

Figure2 Cupboard did not fall down in Bantol (same site as Figure1)

2.2.Psico Earthquake in Peru 2007

Pisco Earthquake on August 15, 2007 (M=8.0) destroyed 52,887 houses and damaged 22,939. The number of fatalities is 519. I also conduct field survey about one month later. Major finding s are as follows.

- structure type

Most popular house in the affected area is adobe (sun-dried brick) and the next majority is confined brick masonry. Damaged confined masonry houses are limited to the area where soil is soft and near the epicenter. Whereas damaged areas of adobe reached as far as 250 km from the epicenter or more.

- Reinforced adobe houses

Several reinforced adobe houses (Figure5) constructed by a pilot project(1) by JICA (Japan International Cooperation Agency) located in affected area and showed enough strength as Figure3 and 4.

- Behavior of people

Even the houses were destroyed, most of the people could escape from their houses before collapse as there were about forty seconds between the two peaks of strong motion (Fogure7), which is back up by statements of interviewees during my filed survey in heavily damaged areas such as San Jose de Los Molinos (Figure6).

2.3.Lessons from the two earthquakes

In both of the two earthquakes mentioned above, it is clear that non-engineered structures are quite vulnerable.

Those could be reinforced with materials locally available to considerable level of strength like an example of Peru. We could reduce casualties only if we could make houses remain standing for a few more seconds.

Figure3 Model House in Zuniga in Peru
No structural damage by Pisco Earthquake

Figure4 Central part of Zuniga in Peru
Many adobe houses collapsed

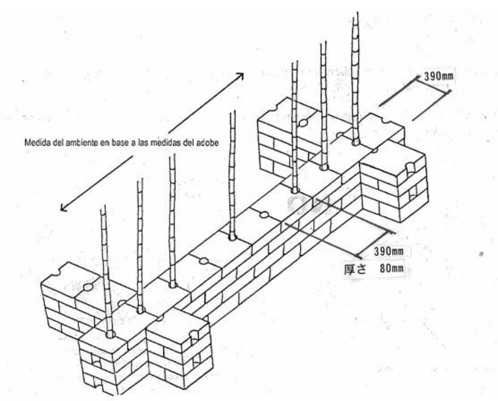

Figure5 Reinforcement of adobe houses

Figure6 San Jose de Los Molinos in Peru
Almost all adobe houses were destroyed

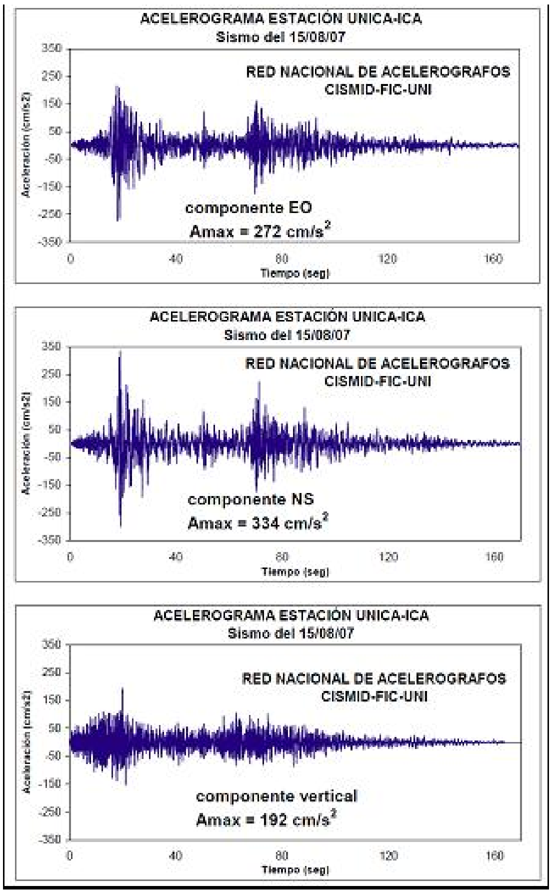

Figure7 Acceleration data of Pisco Earthquake 2007
Strong motion with two peaks

3. Outline of Research and Development Project

3.1.Objectives and the framework of the Research and Development Project

Building Research Institute and partner institutes started a research and development project focusing on mitigation of disasters of non-engineered structure. The objectives of the project is to enhance capacity of research

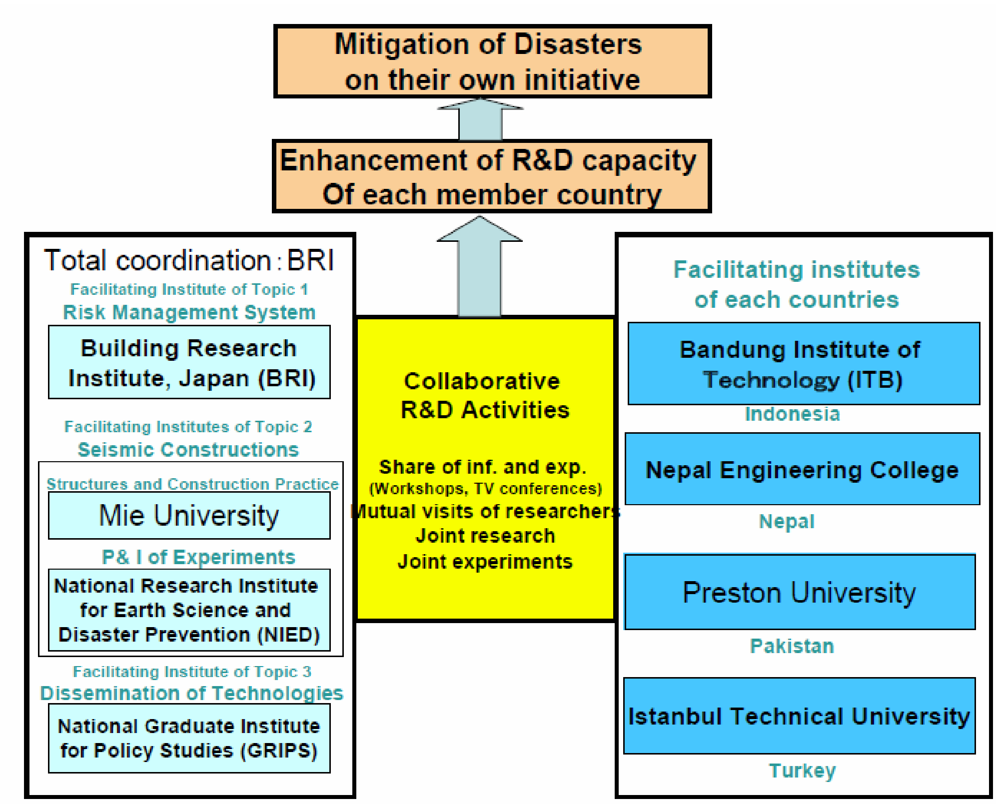

Figure8 Structure of "Collaborative R&D `Project on Network of Research Institutes"

and development capacity of each of countries in earthquake prone area, which is expected to be basis for development of strategies and policies on their own initiatives. We choose three research topics essential for mitigation of disasters of non-engineered structures.

The first one is "Feasible and affordable seismic constructions", technical solution, which local people and workers could understand and accept. The second one is "Strategies for dissemination of technologies to communities". As in most of the affected countries, social infrastructures to disseminate technologies on non-engineered structures such as technical guidelines diffusion through professional institutions or effective enforcement of building codes are not available. We also choose "system for estimation and management of seismic risks of buildings" as a basis of activities.

Each of the countries is responsible for its people to provide safe constructions and need to develop their own basis of strategies and policies. In this context, we propose to conduct collaborative research and development project with researchers in Indonesia, Nepal, Pakistan, Turkey and Peru. The structure of the project is shown in Figure8.

3.2.Basic Scheme of the Research and Development Project

The activities of the project can be categorized into 1)Platform of R&D project and 2)R&D activities program (Components).

- Platform of R&D project

Mutual visits, events for sharing information and discussion, communication by IT tools like video conference system and internet(2)

- R&D activities program (Components)

We have a policy that any people/institute is welcome to propose and participate components. All the participants are requested to contribute to R&D activities in any possible ways. The achievement will be shared through the Platform mentioned above and other channels. After a series of active and constructive discussion, we choose seven components.

4. Summary of Each of Research and Development Activities (Components)

4.1.Component 1-1: Contrivance for Seismic Risk Recognition by Communities

Estimation and perception of risks is the first step of risk management. We find difficulties when we try to estimate earthquake risks because necessary data/information is often not available especially date on each of houses. In order to manage this kind of situation, this component is to develop effective tools to support to grasp earthquake risks of each community with participation/contribution of residents in collecting information on their own community and houses (Figure9).

The tools consist of following items.

* Software to prepare mapping base with full utilization of free satellite image or aero photos
*software for recording data on site by residents with cheap devices

Residents are encouraged to participate risk assessment survey and evaluate their own houses by simple criteria on earthquake safety. The participation procedures are expected to let the residents more aware of earthquake risks and more prepared to future earthquakes.

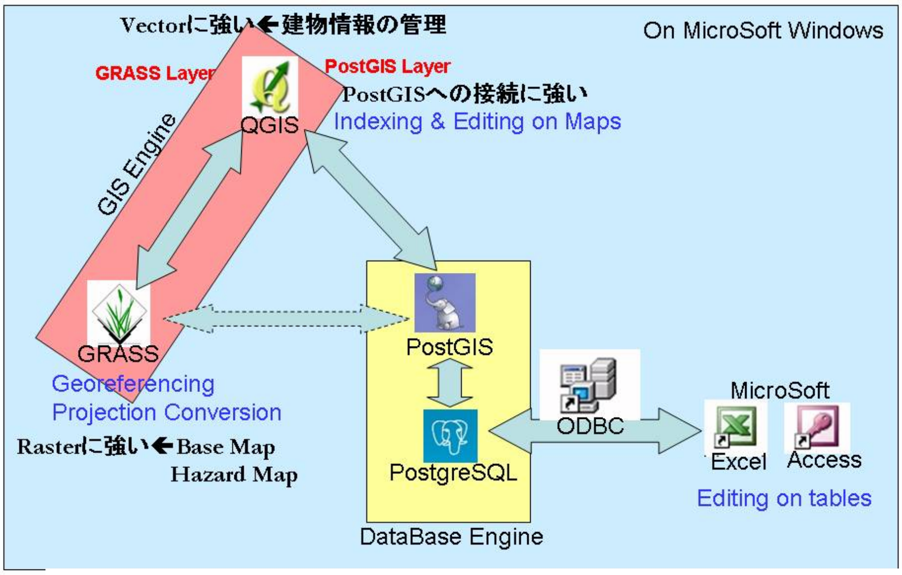

Figure9 Outline of Component 1-1
Contrivance for Seismic Risk Recognition by Communities

4.2.Component 1-2: Compilation of Available Information/Data on Seismic Risks

This component is to collect data/information regarding to earthquake risks such as seismic zone map for building codes, reports of survey on risks in specific areas and others for basic inventory.

4.3.Component 2-1: Research on Feasible and Affordable Seismic Constructions with Full Scale Model Experiments

Although we have several analysis of structural behavior of non-engineered structures based of observation of collapsed houses after large scale earthquakes, precise procedures of failures are still not clarified. Therefore we conduct shaking table experiments of full scale specimen of non-engineered houses to grasp the actual behavior (Figure10,11). We also try to develop numerical model of Finite Element Method (FEM), Distinct Element Method (DEM), and Frame Analysis Method based on measurement data of the experiments for analysis of different design model and evaluation of effects of reinforcement elements. Furthermore we plan to verify the reinforcing effects by several proposed designs by full scale specimens for final stage of this component in December 2008.

4.4.Component 2-2: Bridge between Engineering and Construction Practice

We observe a huge gap between engineering and construction practices in construction sites of non-engineered

Figure10 Shaking table experiment on December 27, 2007

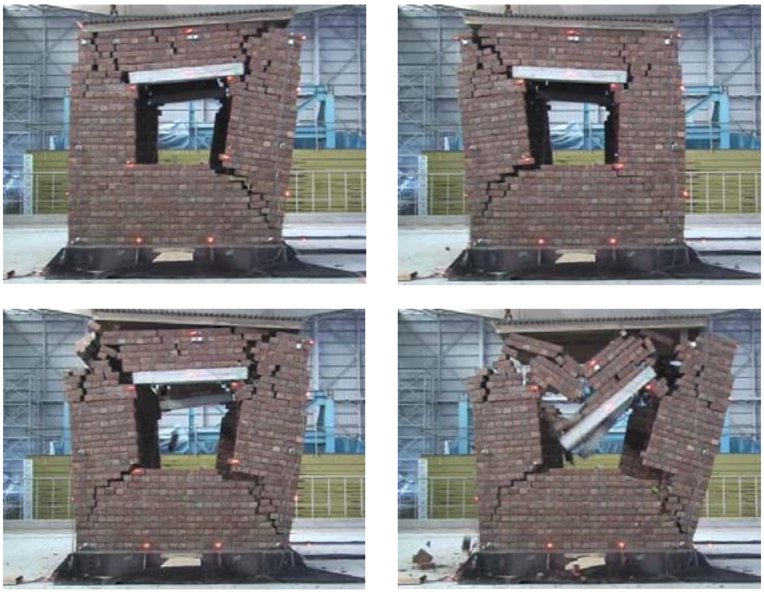

Figure11 Collapsing Procedures of brick masonry structure in the experiment of Figure10 (right)

houses. This component is to try to propose feasible and acceptable technical solution (reinforcing designs) to local workers. For the purpose we implement monitoring construction procedures to grasp actual situation such as construction works, procedures, materials, tools/facilities and labor forces (Figure12,13,14,15) Based on the monitoring results we propose several designs which could be accepted and applied in actual situation by local workers. In order to verify the effect of reinforcement or others, we conduct experiments of structural members.

Figure12 Bending works with simple tool

Figure13 Placing of fabricate rebar

Figure14 Poor connection of rebar of RC framed

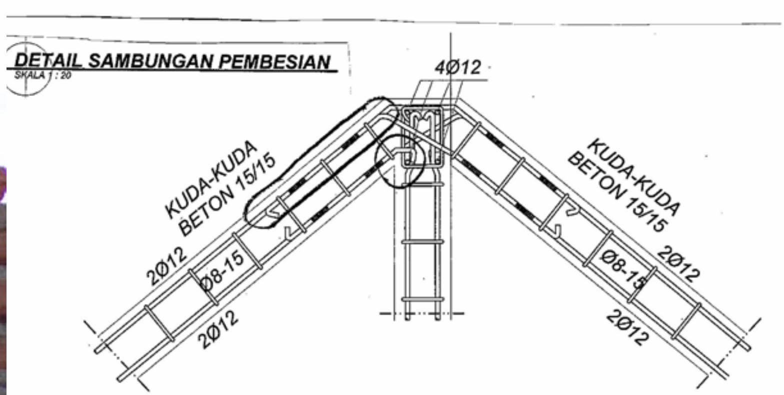

Figure15 Required connection of rebar in design

4.5.Component 2-3: Development of Simple and Affordable Seismic Isolation

Seismic isolation is one of very effective technologies to mitigate damages caused by big earthquakes. However application is still limited to specific buildings because of sophisticated design/construction works and high cost. This component is to develop simple and affordable seismic isolation technologies applicable to developing countries. We have conducted cyclic loading and shaking table experiments on several possible simple and affordable seismic isolation devices as follows (Figure16,17).

*simple sliding devices with low cost materials such as stone plain, metal plate
*low cost rolling devices with usual steel materials such as steel bar and steel plate
*laminated scrap tire pads (STP)

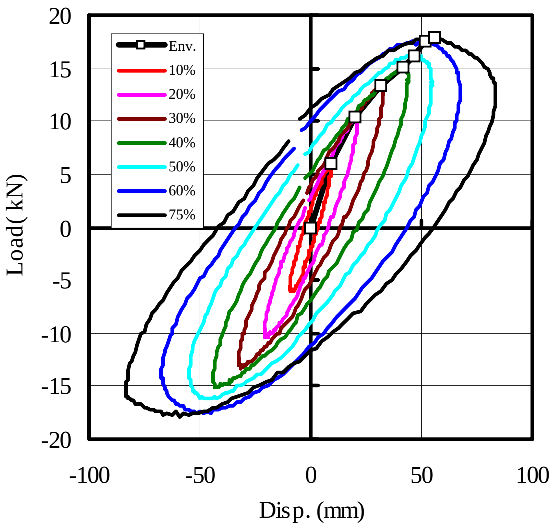

Figure16 Load-displacement curve of STP

Figure17 Specimen of seismic isolation device of STP

4.6.Component 3-1: Strategies for Dissemination of Technologies to Communities

Dissemination of technologies to communities is very keen issue in developing countries as social infrastructures for dissemination such as institutional scheme for technical guidelines, effective enforcement of building codes, established training programs for construction workers and designers in are not available. We have to explore every possibilities for dissemination both formal approach and informal approach like demonstration directly addressed to people such as Figure18 and 19. This component takes comprehensive approach including followings.

Figure18 Demonstration with simple shaking table

Figure19 Active participation of audience

*collecting and analyzing good practices
*interview survey on risk perception of relevant stakeholders such as home owners/residents, construction workers, local government officials
*survey on policies of local governments and central government on disaster mitigation
*pilot projects in each participating countries with several approach

4.7.Component 3-2: Compilation of Manuals/Guidelines/Brochures for Safer Housing

Easy and user friendly manuals/guidelines are effective tools for safer non-engineered houses. We find several good examples for the purpose. The component is to collect and inventory them for reference.

5. Conclusion

In order to realize mitigation in actual situation, we should make efforts to encourage people in engineering/technical fields to come into non-engineered fields. Still we suffer from shortage of researchers and practitioners. We need wider experts in wider fields such as structural engineering, construction engineering, material engineering for technical solution, sociology, social sciences, economics, community development studies, policy studies for dissemination of technologies, and seismology for assessment of earthquake risks. In this context we propose to organize a international study group on non-engineered construction in CIB, International Council for Building, an established international community of researchers and practitioners in building fields. We also proposed to revise the world famous guideline on non-engineered construction published by IAEE, International Association for Earthquake Engineering in 1986.

REFERENCES

UNISDR (United Nations International Strategy for Disaster Reduction), 2004, Living with Risk, UN (United Nations)
IAEE Committee on Non-engineered Construction, 1986, Guidelines for Earthquake Resistant Non-engineered Construction, IAEE
Tatsuo Narafu, Mizuo Inukai, (2006) Proposal for Safer Buildings and Housing against Earthquakes in Developing Countries <Learning from Northern Pakistan Earthquake 2005>, Proceedings of First European Conference on Earthquake Engineering and Seismology
Kenji Okazaki, Tatsuo Narafu (2007) Housing Reconstruction Practices in Aceh, Indonesia, Journal fo Architecture and Planning (Transaction of AIJ), Architectural Institute of Japan (AIJ)

ANNOTATION

(1) The structural design was prepared by Catholic University of Peru (PUCP). The pilot project was conducted in cooperation with CIDAP, Peruvian NGO, and SENCICO, a governmental organization of Peru.
(2) We have been organizing international workshops on video conference system. The proceedings are available on the web site of Building Research Institute (BRI) at following addresses.
http://www.kenken.go.jp./english/information/information/event/ws2007/index.htm
http://www.kenken.go.jp./english/information/information/event/nepal-ws/index.htm
http://www.kenken.go.jp./english/information/information/event/tokyo-2007/index.htm
http://www.kenken.go.jp./english/information/information/event/tokyo-2006/index.htm
http://www.kenken.go.jp./english/information/information/event/shaeic/index.htm