The 14th World Conference on Earthquake Engineering
October 12-17, 2008, Beijing, China

BASIC STUDY FOR BRIDGE BETWEEN ENGINEERING AND CONSTRUCTION PRACICE OF NON-ENGINEERED HOUSES

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ABSTRACT :

Non-engineered houses are constructed with no or little technical intervention and need more to be safer against earthquakes. There are several guidelines, recommendations, manuals or others on seismic designs for non-engineered houses in several countries, which are claimed to be feasible and acceptable for local construction workers. However we still find big gap between engineering and construction practice in construction sites. Some of the causes of the gap are that local workers do not understand or ignore the technical issues. But we also found some of them are caused by the designs, which require construction works which could not implemented with simple and cheap tool on site, detailing which are too complicated, or materials which are not available in local markets. In order to improve seismic safety of non-engineered houses, we need a bridge over this gap.
This is a basic study to construct a bridge between engineering and construction practice of non-engineered houses. We implemented monitoring of construction procedures of confined masonry houses with brick walls in Lima in Peru and Yogyakarta in Indonesia to grasp actual situation of construction works and profile of workers for the basic information/data. Based on them we elaborate recommendations through discussion with researchers of each country and neighboring countries. We conclude we should identify most critical issues among various kinds of aspects for safer structures because smaller number of issues is the very basic condition for non skilled or semi skilled local workers to understand and accept. We tentatively propose that bending works of rebar of reinforced columns and beams and anchorage of brick walls to RC members are most critical issues for safer confined masonry houses and also present several alternatives of designs and detailing.

KEYWORDS: non-engineered, seismic design, construction practice, monitoring, acceptable technologies

1. Background

Large scale earthquakes cause tragic damages to human societies. Sichuan Earthquake 2008 reminded us the fact again. Developing countries are more vulnerable because they have less capacity to be prepared in every aspect like technical, financial, or social aspects. Low income people suffer more especially in human casualties. 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.
I joined field surveys organized immediately after the seismic events of Northern Pakistan Earthquake 2005, Central Java Earthquake 2006 and Pisco Earthquake 2007. In each of the survey I found devastating damages of non-engineered houses and far less attention of engineers, government officials or policy makers than larger buildings and infrastructures such as bridges or high ways. Most of the engineers think non-engineered houses are out of their responsibility. Some say "engineers do not have knowledge on non-engineered structures because there is no engineering knowledge on those structures as their name 'non-engineered' shows" and others say "those are sub standard houses of low income people. When we become rich enough, those would disappear. It is not worth survey/research". In every country I always found a huge gap.

2. Proposal of Study for Bridge between Engineering and Construction Practices of Non-engineered Structures

2.1 A Typical Example of the Gap

When I joined the first field survey in affected area by Northern Pakistan Earthquake 2005, I found collapsed houses/buildings with RC members which are not usually observed in Japan. Most of them got broken at connection of structural members and often got flattened as seen in Figure1 and 2 and all the reinforcing steel bars were not broken, but seemed like to come off, judging from the fact that all the ends of rebar did not have signs of yielding. I asked the reason to engineers of Pakistan and got answer that construction workers are non-skilled and do not have knowledge or are totally negligent and never follow the correct way. Since then I always check ends of rebar of broken houses in every survey area and found no case of broken/yielded rebar. Answers of engineers of each country are also same as in Pakistan.

Afterwards I had several opportunities to conduct field survey on construction practices on construction sites. I investigated how coming off of rebar occurs. Figure3 is a drawing of bending works of rebar prepared by consultants of an Aceh reconstruction project. We can see the consultant required lapped splices to prevent coming off of rebar. Whereas the construction practice on sites are shown in Figure4 as rebar are assembled on the ground (Figure5) and assembled rebar is just placed like Figure6. Tools for bending work are usually timber bending bed with nails and steel bar with hook. It is impossible to implement bending works required by the drawing with usual tools by usual construction way. I interviewed several consultants on the matter. Their explanations are as follows; they draw the bending drawings according to the guidelines/recommendations they learn at schools, training programs or others, most of which are direct quotation from those of developed countries. Regarding construction practice on site, some actually do not know the situation because they have completely no interest in them. And some believe their job is limited to design and drawings. Even though they know it is impossible for workers to follow the drawings, they claim that it is responsibility of workers to follow as they exactly follow the way they learned.

This experience made me recognize there is a huge gap between engineering and construction practices on site. The engineers follow what they learned in their professional education/training. Most of them are direct import from developed countries and do not reflect conditions of construction site of developing countries. The workers conduct construction works as they learn from their experience of construction works or advice from master builders or senior colleagues, who have little opportunity to learn engineering. Furthermore there is usually no dialogue/discussion between engineers and workers. The example I explained so far is only a single issue but a proof evident enough to show that there exists a huge gap between engineering and construction practices.

Figure1 Collapsed buildings by Northern Pakistan Earthquake 2005 in Balakot

Figure2 Failures often occurred in connections of structural members

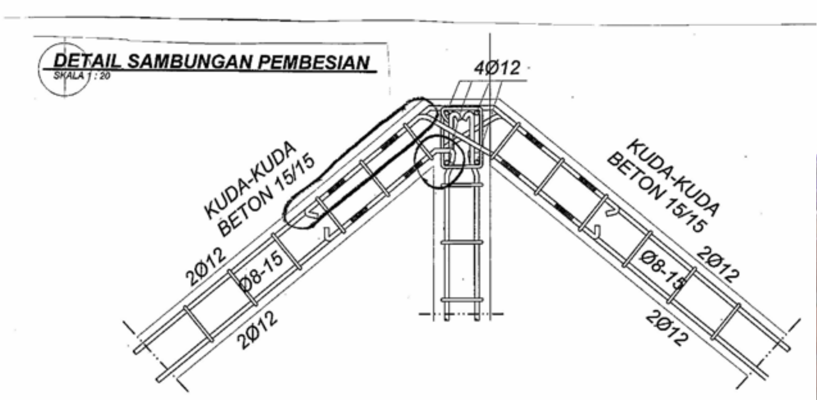

Figure3 Drawings of bending works for reconstruction houses in Banda Aceh, Indonesia

Figure4 Construction practice on site Insufficient connection of longitudinal rebar

Figure5 Bending works on site with simple tools Fabrication of rebar is also conducted on ground

Figure6 Placing rebar of a roof beam fabricated on ground

2.2.Characteristics of Non-engineered Construction

Non-engineered construction can be characterized as Table1. It is much different from engineered construction in all the significant aspects as we see in Table1. As we can naturally imagine from the name of "non-engineered", it is out of scope of most of engineers and researchers in construction engineering. The owners and customers of these houses are mostly low income people. They can not afford to pay for technical services by professional experts like structure engineers, architects, or examiners. Therefore experts have rarely have opportunities to get to know actual situation of non-engineered constructions. In most of countries non-engineered construction attracts least attention of people in engineering profession just like the statement in a report, Living with Risk 2004 version, by UNISDR (United Nations International Strategy for Disaster Reduction).

Table1 Comparison of engineered and non-engineered construction

aspects	Engineered construction	Non-engineered construction
Materials	Mainly quality-controlled materials	Mainly local material without quality control
Workers	Skilled, full-time	Semi/non skilled, sometimes residents themselves
Technical intervention	Design, supervision and others	Almost none
Owners/dwellers	Middle or high income	Low income

2.3.Proposal of study for bridge between engineering and construction practice

As we see so far, there is big difference between engineered and non-engineered in every aspects and non-engineered has little/no technical intervention. Furthermore we even do not have information regarding to non-engineered construction and do not know the actual situation. These facts lead us to recognize that basic studies on construction practice and actual situation is essential as a basis of study for mitigation of earthquake disasters on non-engineered construction.

3. Monitoring of Construction Procedures on Sites

3.1.Outline of Monitoring Activities

As the first step of study to bridge engineering and construction practice, we implement monitoring construction procedures as follows. We choose construction type of confined brick masonry structure, in which brick walls are confined around by small section of RC members (beams and columns), because we find similar type of buildings/houses almost everywhere in the world. We also find it often suffered from earthquakes. Selected construction sites for monitoring are usual and typical in each area.

1) Monitoring activities in Peru
- period: October 9 to November 28, 2007
- area: Caral, Distrital de Supe, Provincia de Barranca, Departamento de Lima, Peru
  Distrital de Villa Salvador, Provincia de Lima, Peru
- monitor: Shizuko Matsuzaki

2) Monitoring activities in Indonesia
- period: October 29 to November 12, 2007, December 12, 2007 to January 1, 2008, February 27 to March 1, 2008
- area: Desa Sidomulyo, Kecamatan Bambang Lipro, Kabpaten Bantul, Propinsi Daerah Istimewa Yogyakarta
  Kr. Takun Imogiri, Kecamatan Imogiri, Kabpaten Bantul, Propinsi Daerah Istimewa Yogyakarta
  Desa Wonokromo, Kecamatan Prelet, Kabpaten Bantul, Propinsi Daerah Istimewa Yogyakarta
- monitor: Keiko Sakoda

3.2.Construction Practice in Lima, Peru

- Concrete mixing: Cement, sand and aggregate are mixed directly on ground (figure7). Those are batched by volume with barrow.
- Excavating and foundation: Excavating depth is around 50cm. Foundation is about 40cm in width and about 40cm high above ground level. (Figure8)
- Brick laying: Brick laying is conducted neatly and accurately with taut line and plumb bob (Figure9).
- Bending work of rebar: Lapped splices are not long enough as rebar is fabricated with hoops on ground, placed and no bending works on the spot (Figure10).
- Forms for concrete placing: Forms are made of timber. Packing of small piece of cement bags to fill crevices is usually found (Figure11).
- Concrete placing: Compaction is not enough. Honey comb and exposure of rebar is often found (Figure12).

Figure7 Concrete mixing on ground on site
Mixing is carried out without sheets or others tools

Figure8 Excavation works for foundation

Figure9 Laying work of bricks with plumb bob
Taut line is usually used

Figure10 Corner of beams and column
Length of lapped splices is limited to the dimension of RC members' section size because of fabrication method

Figure11 Form works
Packing of small piece of cement bags is usually observed

Figure12 Honey comb in beam
Some of rebar is exposed to air

3.3. Construction Practice in Central. Java, Indonesia

The monitored houses are those constructed for reconstruction from Central Java Earthquake 2006 with financial and technical support of JRF (Java Reconstruction Fund: Multi donor fund by European Commission, European countries and others). JRF provide technical support by printed guidelines and periodical supervision of technical staff.

- Concrete mixing: Cement, sand and aggregate are mixed directly on ground (figure13). Those are batched by volume with barrow just same as in Peru.
- Excavating and foundation: Excavating depth is around 80cm. Foundation is about 40cm in width and about 15cm high above ground level. (Figure14)
- Brick laying: Brick laying is conducted neatly and accurately with taut line (Figure18) and plumb bob.
- Bending work of rebar: Rebar is fabricated with hoops on ground with simple tools such as steel bars with hook (Fugure15). We found improvement of several aspects recommended by JRF such as continuous rebar in beams at corners (Figure16) and anchorage between walls and columns (Figure17). Each of them seems effective to improve seismic performance but needs further improvement from view point of efficiency of construction works because they required complicated and time consuming works.
- Forms for concrete placing: Forms are made of timber. Packing of small piece of cement bags to fill crevices is usually found.
- Concrete placing: Compaction is not enough. Honey comb and exposure of rebar is often found.

Figure13 Concrete mixing on ground on site
Mixing is carried out without sheets or other tools

Figure14 Excavation works for foundation

Figure15 Bending works of rebar on ground with simple tools without machines

Figure16 Connection of RC members
Horizontal rebar is not connected at the corner, but using continuous rebar

Figure17 Anchorage of walls to column

Figure18 Laying work of bricks with taut line

3.4. Improvement of Construction Practice by Technical Intervention (an example in Central Java, Indonesia)

We observe impacts by Central Java Earthquake, which increase seismic safety. Before the earthquake, majority of structure type is un-reinforced brick masonry (55.9%) and only 28.4% is confined masonry (Figure19). In reconstruction projects almost all the houses are confined masonry. Regarding mortar for brick laying, cement

mortar is just 25.9% before the earthquake (Figure9) and it becomes to be almost 100% after the earthquake. As we stated in 3.3 with Figure16 and 17, there is significant improvement in construction works. These prove that appropriate technical intervention could be accepted by people and enhance seismic safety. However those technical interventions still need betterment especially from the view point of efficiency/ease of construction work.
On the other hand, we also found serious defects in construction. Figure21 and 22 show an example of concrete placing. Insufficient compaction with simple tools like steel bars (not effective ones like vibrators) and congested rebar within small section of RC elements are the most probable reasons.

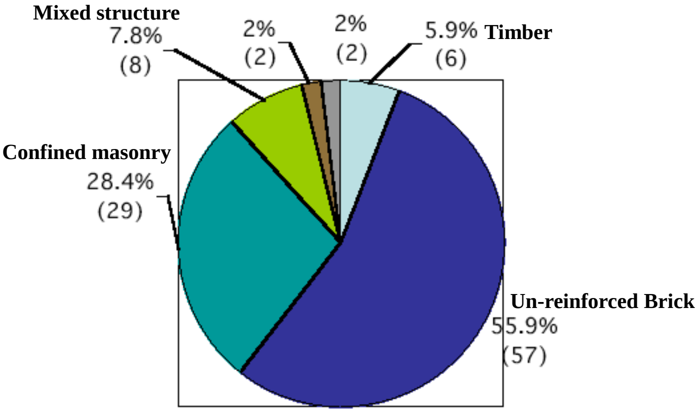

Figure19 Structure type of houses before the earthquake

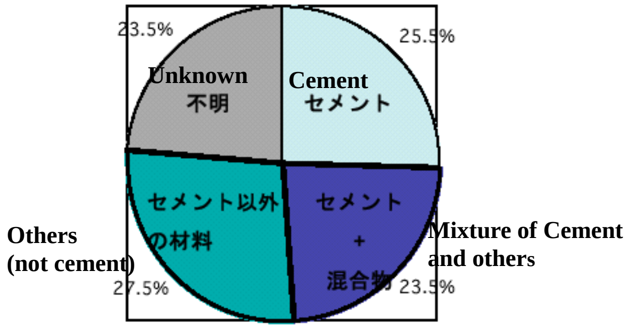

Figure20 Type of mortar for brick wall before the earthquake

Figure21 Poor concrete placing work with a lot of honey comb and void

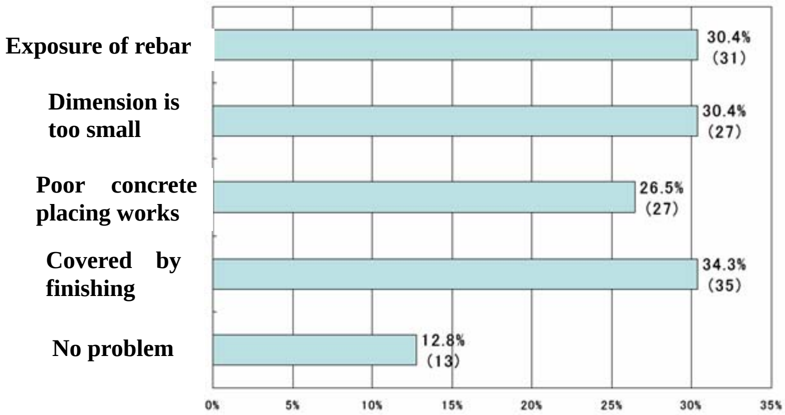

Figure22 Ratio of improper concrete placing work (multiple choice)

4. Tentative Proposal of "Practical Technology"

Non-engineered houses are constructed by low income people with construction works of semi/non-skilled labors. Therefore we have to propose practical technology. In this context, practical means affordable for owners/residents, feasible for local workers and acceptable for all the relevant stakeholders. We are elaborating several proposal of "practical technology". Figure23 is one example of them. We propose to make dimension of RC members at intersection larger for better concrete placement and to add additional rebar for connecting longitudinal rebar to avoid difficult works like bending at the point. We assume this detailing could be followed with a little addition of cost and labor.
We will discuss on our proposal of several aspects with our partner researchers and practitioners in Indonesia, Nepal, Pakistan, Turkey and Peru, partners of "Collaborative Research and Development Project on Network of Research Institutes" (2006-2008) supported by Ministry of Education, Culture, Sports and Science (MEXT), Japanese Government. We are also planning to conduct physical experiments to verify the effect.

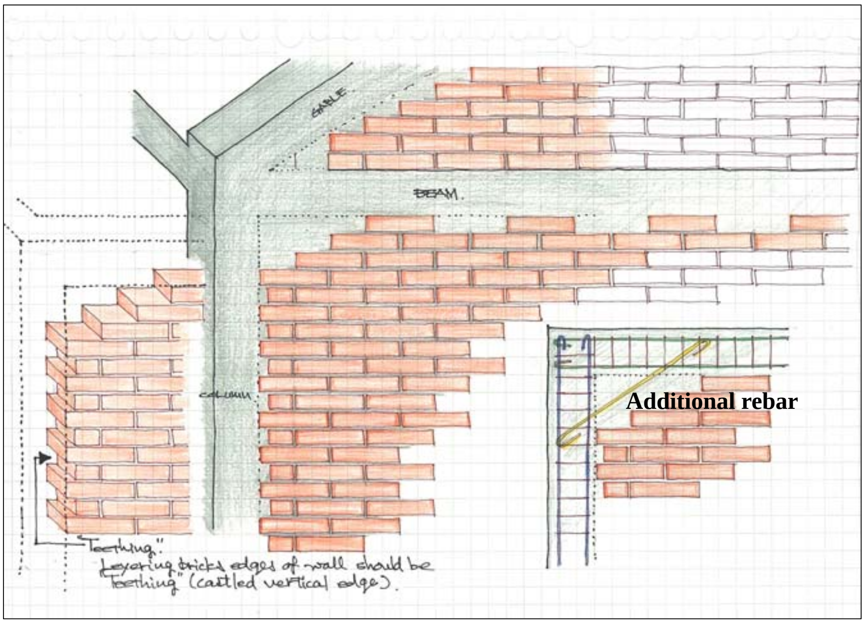

Figure23 A proposal of detailing of connection of RC members
Additional rebar (yellow) and larger dimension at intersections

5. Conclusion

Non-engineered construction should be safer as it is the main cause of human casualties. For the purpose, “practical technology” is essential, which is affordable for owners/residents, feasible to local workers and acceptable for all relevant stakeholders. We started to work on this issue in cooperation of researchers/practitioners in relevant expertise in many countries. We could just work on several types and limited aspects of construction so far. There still remain vast fields which need appropriate technical intervention. We expect more people of technical knowledge to work on this crucial issue of non-engineered constructions.

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