Challenges and Potentials of Retrofitting Masonry Non-Engineered Construction in Indonesia

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Executive Summary

Indonesian non-engineered construction mostly consists of masonry structures confined and / or unconfined. The construction of masonry buildings are not too complicated, therefore, it is widely used all over Indonesia. It is also known that masonry is brittle and unless provided with reinforcement, or other suitable materials, such buildings are weak against earthquakes.

With the extreme pressures of a great demand for new masonry houses together with a limitation on the resources available, including finance, skills, and building materials, resulting in poor workmanship and poor quality of construction. The general tendency has been for the standards to fall year by year. World experience in damaging earthquakes has shown that these types of construction are dangerous to human life, often in a relatively small earthquake. It is quite apparent that it will be difficult to do away with this kind of construction in seismic areas, particularly in developing countries, because brick is relatively cheap, easy to produce and to transport, and masonry construction is relatively easy to construct. Those factors have made masonry very suitable as a construction material, and therefore, the trend to build more and more masonry buildings is obvious.

The objective of the study is to find some means and methods to improve the present construction and the related materials using available materials with local labor under minimal supervision and most suitable to the local culture, particularly in Indonesia. The main aim is to save human life; therefore, structures might be damaged when shaken by earthquakes, but does not collapse and kill people.

In general, this dissertation can be divided into three main parts.

The first part of the dissertation contains explanation why Indonesia continuously still experiences damages of non-engineered construction in spite of the fact that considerable research and available guidelines regarding non-engineered construction were available since 35 years ago. Almost every year earthquake disaster occurs in many places in different parts of Indonesia and causes damage and destruction to non-engineered constructions. Despite of the many human casualties and the severe impact on the regional economy and development, it seems that relatively little is being done to prepare, prevent or mitigate the effects of future earthquakes. The earthquakes are repetitions of all past occurrences and are demonstrations that not much has been done with regard to non-engineered constructions. With the re-occurrence of the same mistakes until today, "the earthquake problem in Indonesia" should be reviewed so that the necessary action can be taken to prevent damage and casualties in future earthquakes. Two major issues related to non-engineered construction in Indonesia will be discussed: the unsafe non-engineered construction stock in Indonesia; and ineffectiveness of disaster risk reduction. It is evident that the number of non-engineered constructions in Indonesia that are not earthquake resistant is increasing year by year and the understanding and realization of

disaster risk reduction in Indonesia is limited if not none. This is the real Indonesian earthquake problem that must be resolved using simple and affordable methods.

The second part describes the non-engineered construction in Indonesia, the damages of non-engineered constructions from the past 40-years earthquakes, the causes of damages, the problems encountered in implementing the earthquake resistant non-engineered constructions, and design basis of non-engineered constructions. The methodology used is observation survey.

Typical Indonesian non-engineered construction consists of unconfined and confined masonry. The unconfined masonry buildings were introduced by the Dutch when Indonesia was a colony of the Dutch hundreds of years ago. This type of masonry buildings is copied from Europe and consists of one brick thick walls, using brick pilasters without any reinforced concrete columns and beams as confinement. Trass lime blocks, concrete hollow blocks were introduced in the 60's.

After Indonesia becomes an independent nation, the demand for masonry buildings / houses is substantial and due to the increase in cost, people started building half-brick masonry houses. In the very beginning, those half-brick masonry buildings / houses were built without any reinforcement, the so called Unreinforced Masonry (URM). However, from documenting earthquake damages in various areas in Indonesia over the past 40 years, it is evident that in almost all rural as well as urban areas all over Indonesia, a good earthquake resistant design feature can be identified, namely almost all half-brick-thick masonry buildings are built with reinforced concrete framing, consisting of the so called "practical columns and beams" (Boen, Yogya Earthquake 27 May 2006, Structural Damage Report, 2006), forming confined masonry walls. In some places in Indonesia, timber is also used as framing to confine the masonry walls. In addition, it is also found the use of bamboo as replacement of reinforcing bars in "practical columns and beams".

The confined masonry construction using reinforced concrete framing has become a new culture all over Indonesia and from past earthquakes it is evident that provided they are built with good quality materials and good workmanship, they can survive the most probable strongest earthquake in accordance with the Indonesian seismic hazard map (Boen, Earthquake Resistant Design of Non-Engineered Buildings in Indonesia, 2003; Boen, Yogya Earthquake 27 May 2006, Structural Damage Report, 2006; Boen, Bengkulu & West Sumatra Earthquakes, September 12, 2007, Structural Damage Report, 2007; Boen, West Sumatra Earthquake, 6 March 2007, Structural Damage Report, 2007). Shaking table tests that were performed in Japan showed good results. However, due to poor quality of materials and poor workmanship, resulting in, among others poor detailing, poor mortar quality, poor concrete quality, and poor brick-laying, this masonry construction became not resistant to earthquakes and could be damaged and even collapsed when shaken even by minor earthquakes. In general, the quality of workmanship for the newly constructed houses in Indonesia is below average and in many cases poor. This is clearly demonstrated in the reconstruction of Aceh, after the 2004 tsunami (Boen, Building A Safer Aceh, Reconstruction of Houses, One Year After The Dec. 26, 2004 Tsunami, 2006). Poor quality materials (such as bricks, sand, and timber) combined with poor workmanship (Boen, Building A Safer Aceh, Reconstruction of Houses, One Year After The Dec. 26, 2004 Tsunami, 2006; Boen & Priyono, Reconstruction of Houses in Aceh Post the Dec 26, 2004 Tsunami Catastophe - Six Years After, 2011) and non-compliance with the Indonesian seismic guidelines resulted in many houses reconstructed so far are below standard. In many instances, the "quality" is enhanced a bit due to the widely use of Portland Cement mortar.

Surveys and tests of building materials were conducted in recent years by Universities, and foreign government agencies in several places in Indonesia. The objective of these surveys is to know the quality of local building materials as well as workmanship. The survey and test results showed that there are many variations of brick dimensions. The qualities of brick-works also vary, from good enough until poor brick-work. From site observations, it was also evident that many of the masons as well as carpenters are "instant" masons and carpenters and lack the necessary skills and apply incorrect mixing of mortar as well as concrete. This can be observed from the results of their works. Reconstruction of 127,400 houses in Aceh is evidence that in general, the quality of workmanship is below average and in many cases poor (Boen, Building A Safer Aceh, Reconstruction of Houses, One Year After The Dec. 26, 2004 Tsunami, 2006).

Learning from past earthquake damages, typical damages of non-engineered constructions can be identified. With the increased computing power and speed of desktop / laptop computers and also the availability of softwares, particularly in the last 15 years, static and dynamic analysis of structures can be quickly and efficiently performed by the engineers (Boen, Earthquake Resistant Design of Non-Engineered Buildings In Indonesia, 2001; Boen, Earthquake Resistant Design of Non-Engineered Buildings in Indonesia, 2003; Boen, Engineering Non-Engineered Buildings, from Non-Engineered to 3D Non-Linear Analysis, Performance Based Design, 2007). The purpose of the analysis is not to simulate the actual behavior, but to get reliable information that there is a correlation between the observed damages and the results of the analysis. The correlation is not perfect, but is good enough to get a good idea to build appropriate non-engineered constructions that can withstand earthquakes (Powell, 2013).

The third part of the dissertation contains the proposed retrofitting method that is simple, affordable and replicable, for existing non-engineered constructions in Indonesia. **The method proposed is not scientific brain teasing research stuff, but an engineering design utilizing all existing references on the subject, meaning not "re-inventing the wheel". The methodology used is taken from literature study and make use of existing theories regarding the proposed method of retrofitting.** Besides literature study, shaking table test was performed in Japan, for Indonesian types of non-engineered constructions retrofitted with wire mesh.

As mentioned in part one, **millions of non-engineered constructions in Indonesia are vulnerable and a simple, affordable and replicable method to strengthen the existing non-engineered construction in Indonesia is introduced.**

The principle of sandwich structures will be introduced because the same principle of sandwich structures can be applied to strengthen unreinforced masonry walls, i.e. brick wall as core and ferrocement as skin facings. The analysis and design will be explained and subsequently an example of the analysis and design utilizing existing commercial software will be performed.

There are few researchers that mentioned one of the retrofitting methods of walls using ferrocement using welded mesh located at the center of the ferrocement layer. However all papers (ElGawady, Lestuzzi, & Badoux, 2004; Muntean, Muntean, & Onet, 2010) were mostly laboratory tests and did not explain in detail how to implement it. Apart from that, those papers also did not explain how to analyze the wall and DID NOT CORELATE IT as a sandwich structure, in which brick-walls act as a core and ferrocement on both sides of the walls act as skin facings (ElGawady, Lestuzzi, & Badoux, 2004). Another paper deals with similar strengthening URM, also using ferrocement, however, sandwich analogy was not applied (Muntean, Muntean, & Onet, 2010).

In 2012 a full-scale shaking table test was conducted in Japan. The results of the test will be highlighted to confirm the soundness of the proposed retrofitting method. The methodology used is experimental and verified by analysis.

The closing chapter will explain the way forward how to improve disaster risk reduction in Indonesia and the applicability of the proposed retrofitting method for other countries that have similar masonry construction.