Innovation to Indonesian Earthquake Resistant Structures

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Executive Summary

Most of the territory of Indonesia is prone to earthquake shaking. Structures may be classified in two extreme groups, engineered and non-engineered ones. The Islamic University of Indonesia (UII) in collaboration with CEEDEDS International have set up field investigation teams to the earthquake damaged areas in Indonesia for the last 10 years. Close looking in the recent damaging earthquakes in Indonesia, non-engineered house using masonry walls (NEHMW) were popular but always suffered most and caused most loss of life and loss of properties. If such structures are not constructed properly, in the future they are still potential to become terrible killers. This leads to focus this paper on this kind of structure.

During the field investigations, the teams not only investigated the damaged structures but also interacted with local people and institutions. Those experiences are very beneficial in (1) understanding the dynamic performance of non-engineered structures that apply local technology, (2) portraying the society condition and their real needs in short and long terms after the jolts, including their needs in affording earthquake-resistant houses, and consequently, (3) inspiring the demand in innovation of earthquake resistant NEHMW.

This paper briefly reviews the lessons learnt from those field investigations, and consequently, the need for response actions in the innovation of NEHMW to reduce the effects of future earthquake disasters in Indonesia.

1. CASE STUDIES

1. 1. Backgrounds

Based on the seismic history and analysing the geologic condition, most of the Indonesian territory is earthquake shaking prone areas (Erickson, 1988; Fauzi, 2001; Kertapati, 2000; Naryanto and Tejakusuma, 1999; Irsyam et. al., 2007; Natawidjaja, 2007). This condition should need special attention, since most of those areas are densely populated. In the islands of Java and Sumatera, even, such areas are extremely populated.

Structures may be classified in two extreme groups, engineered and non-engineered ones. The engineered structures are the structures designed, built, and supervised using engineering approach by participation of professional engineers. Vise-a-versa, the non-engineered structures are structures that are built by local builders and/or structure owners using traditional approach.

In the range of the two extreme groups, apparent in Indonesia, there are structures that can be classified as semi-engineered ones. However, people usually include semi-engineered structures in the class of non-engineered ones. Therefore, non-engineered structures mentioned in this paper are the structures beyond engineered ones, which are the combination of non-engineered and semi-engineered structures. Most of such structures apply local technology.

The Islamic University of Indonesia (UII) Yogyakarta in collaboration with other parties, such as CEEDEDS, formed field investigation teams to visit several areas damaged by strong earthquakes shortly after the jolts. Those investigated areas were strongly shaken by the 1998 Blitar, 2000 Banggai, 2000 Bengkulu, 2000 Sukabumi, 2000 Banjarnegara, 2000 Pandeglang, 2001 Yogyakarta, 2001 Majalengka, 2003 Pacitan, 2004 Bali-Lombok, 2004 Aceh, 2005 Garut, 2006 Yogyakarta, and 2007 Bengkulu - Padang earthquakes (Adenan and Sarwidi, 2007; CEEDEDS, 2007). Close looking to those investigation results, non-engineered houses using masonry walls (NEHMW) were popular but always suffered most, although there were different portion in each damaged areas. In general, NEHMW has caused most loss of life and loss of properties due to those earthquakes.

For many reasons, the popularity of NEHWM is going to rise. If they are not constructed properly, they are potential to become terrible killers whenever a strong earthquake occurs. This leads to focus this paper on this kind of structure. According to interviewed local people in the damaged areas, low-engineering-knowledge local builders, called mandors, lead the building of most of the failure structures. During the building process, the builders were usually strongly influenced by the owner ideas due to limited budget of the owners. Therefore, reducing casualties due to collapse non-engineered structures should involve both builders and owners.

This paper summarizes the lessons learnt from those field investigations, and consequently, the need for response actions in the innovation of NEHMW to reduce the effects of future earthquake disasters in Indonesia.

1.2. Matters and Issues to Innovate

It is not easy to evaluate the dynamic performance of non-engineered structures, including NEHWM, using mathematical approach because of the wide range in the real structural element properties and in the real structural shape variations. However, field investigations to the performance of structures (failure and withstand structures) in damaged areas due to earthquakes are possible and give beneficial experiences. One of the reasons of the importance of such work is that there is always new lesson in every damaging earthquake, especially in line with the dynamic of socio-economic condition.

Any structure will better withstand to earthquake shaking if the structure is as light, ductile, simple, and strong as possible (CEEDEDS, 2004; CEEDEDS, 2007; Chopra, 1995; Sarwidi, 2006; Wiegel, 1970). But, the structural characteristics will be brought to the practice by the people with many considerations, such as engineering capability, as well as social and economic condition (Bappenas, 2006; Carter, 1991; CEEDEDS, 2007; Musyafa, 2000; Sarwidi, 2007).

There have been innovations in the field of earthquake resistant structures, especially for houses since many years ago (e.g. Boen, 1978). The structural materials of the houses are wood, bamboo, masonry, concrete, and their combination. Most of the design is based on the state of the art. IAEE (1986) enrich the innovation by introducing wide broad of similar innovation in other countries. Innovation has also applied by many parties in Indonesia in the area of introducing new materials, new component forms, and new construction methods, but relatively sluggish to be applied by the society due to many reasons (CEEDEDS, 2007; Musyafa, 2000).

Based on the study of various references and lessons that have been obtained from earthquake damaged areas in Indonesia, the author formulate an innovation on a NEHMW model, called BARRATAGA, which is especially appropriate to earthquake prone areas. Therefore, BARRATAGA is an earthquake resistant NEHMW. The innovation is in the completeness of simple anchored concrete frames and specific reinforcement joint connectors as well as setting up sufficient sand layers beneath foundations to reduce horizontal vibration from the base soil. The basic model of BARRATAGA can be seen in Figure 1.

The innovation is also in the dissemination method of the BARRATAGA concept to the specific target that is foremen or mandors. In the construction of an NEHWM (non-engineered houses using masonry walls), a mandor usually play important role, since a mandor has loyal construction workers under his coordination, and a mandor usually has full authorisation from the house owner in manage the design and construction.

In the dissemination, a target group of mandors are trained with brief theory and much practice. The trainings use various demonstration tools that make them easier to grasp the training content, such as seen in Figure 2. To accelerate in spreading the concept, many parties from society and government have collaborated in the dissemination, such as Islamic University of Indonesia, Peace Winds Japan, CEEDEDS International, the Government of Japan, GTZ-Germany, and Gap Inc. USA. From the first training in 2004, trained mandors have applied the BARRATAGA concept to the field for the Indonesian society. Two examples of their good practices in the application of the concept in the field prior to the 2006 Yogyakarta-Central Java earthquake can be apparently observed in Figure 3.

However, in the consideration of structure price, most people still give up to the higher cost of earthquake resistant structures comparing with regular structures. Although standing on earthquake prone areas, the people tend to build regular structures with the priority in building nice-looking. Therefore, this condition leads to increasing number of failure structure due to earthquake shaking.

In the consideration of construction time, people naturally rush to have permanent structures in order to recover the condition as faster as possible immediately during post earthquake disaster. This situation steers to uncontrollable construction cost. In the issue of job opportunity, however, construction growth allows unemployment people find jobs. In the issue of security, people need to protect their life and properties from the crime in their home. All of those facts and issues guide to innovation necessity.

1.3. Efficiencies and Results by Innovation

The following brief description is efficiency and results by recent innovation in the field of earthquake resistant non-engineered structures.

In the long term, applying BARRATAGA and other similar recent innovations to increase structural resistance to damaging earthquake is much more efficient than applying only regular structures in the earthquake risk areas. However, most people still reluctant to apply, especially in the regions that do not experience strong earthquake jolts for long time. One of the causes is the cost of steel reinforcement for the frames beyond people afford. The use of bamboo or timber reinforcement in replace of steel can answer part of the problem, since most people feel that bamboo or timber strength can not surpass the steel one. Therefore, innovation in the reinforcement materials to reduce the cost is required.

Innovation to lighter and more ductile construction materials and components, such as tile, roof structures, and partition walls, escort to decrease the loads that are beared by the structure during earthquake shaking. This can reduce the size of the structural components, and consequently, shrink the price of houses that can make such structures more affordable to the people. In the short term after experiencing damaging earthquake, innovation by fabricating structural components can guide to shorten construction time.

1.4. Limitations and constraints of innovation

Whenever having unclear direction and becoming uncontrollable, innovation could create problems, such as in the case of fabrication of components of houses. The fabrication helps to make reconstruction phase faster, but it could create more number of unemployment in normal condition, especially in the developing countries. This fact should become limitation in order innovation yields benefits to the society.

The following paragraphs briefly mention the constraint of recent innovation. The collaboration among construction stake holders seems loose. In addition, the similar condition applies to the relationship between construction society and common society as construction users. Those gaps as well as the quantitative and qualitative shortage of construction experts leave away to optimum innovation.

Many people tend to be difficult to change their detriment custom, for example there are very slowly to change the people for using concrete block masonry instead of clay brick masonry. Continuously using clay bricks can lead to environmental destruction. Another example, many people prefer to use very heavy tiles for their house prestige, although lighter roofs are available.

In addition to be potential to create unemployment, the fabrication of structure components could not run freely, since most Indonesian people prefer variation than uniform for their house components.

1. 5. Lessons learnt

There is different characteristic of society in each region. People live close kingdoms, such as in Central and East Java usually have high spirit in working voluntarily together (*gotong royong*), while in other regions, people generally tend to be individualistic. Innovation is commonly faster to be created and adapted in the socialistic society rather than in the individualistic society. Therefore, selection or introduction of innovation should be appropriate for different groups of society. The steel reinforcement for the NEHWM frames is considered by most people to elevate the cost.

2. FUTURE DEVELOPMENTS

2.1. Socio-Economic and Political Constraints

There are socio-economic constraints in conducting innovation, such as follows. Most people live in rural areas. The education level of most construction agents and economic level of most people lead to insufficient participation in innovation. Creation and application of innovations should be selective in order not to increase the number of unemployment.

Examples of   political constraints can be mentioned as follows. Since bureaucrats commonly have to face many social problems to solve in priority, their remains energy is not sufficient to withstand their political will in boosting up innovation. Some parties in the society and in governmental entity prefer to dominate rather than to share their roles or authorization. This can reduce the beneficial environment for innovation.

2. 2. Suggestions from Industry

Close communication and sharing the roles or authorization among bureaucrats, construction agents, research and education institutions, as well as construction users and construction industries are necessary to create. This condition encourages innovation, since creating and applying innovation is going to be effortless.

2.3. Regulation and Institutional Frameworks

The regulation enforcement in urban and neighbourhood areas is less problematic comparing with rural areas. In rural areas, it seems to be more effective using persuasive approach using local wisdom rather than using strict way.

The existent authorised institutions related to the innovation in the field of construction should be strengthened by offering as many interested individuals or institutions as possible to participate and by urging them to close collaborate. In addition, the extensive publication of recent innovation by the authorised institutions is going to encourage other innovation and to diversify them.

CONCLUSIONS

The following general conclusions are drawn from the series of field investigations to the earthquake damaged areas.

1. NEHMW becoming more popular, because such buildings increase the social status of the building owners. However, major cause of casualties and damage to property in the investigated areas was the failure of such structures. In order to become earthquake resistant structures, such building should be properly constructed and reinforced with good quality material. This provides the space for innovation on strength of material and structure.
2. Most of local builders in the investigated areas stated their need in having sufficient knowledge in making earthquake-resistant structures, but most building owners were attracted in having economic structures. The steel reinforcement for the NEHWM frames is considered by most people to elevate the cost. This also offers the space for innovation in cost-effective earthquake resistant NEHMW.
3. The training of the earthquake resistant non-engineered houses to the grassroots construction worker supervisors (mandors) shall be intensive and extensive, because the target group is one of the key roles in constructing non-engineered houses in Indonesia. This also leaves the space for innovation in the means of dissemination including in the tools for demonstrations.

RECOMMENDATION

The following general recommendations, based on the conclusions, are measures to reduce casualties due to collapsing non-engineered structures for future earthquakes in the earthquake prone areas.

1. A lot of expectations to work on, however, the innovation on NEHWM to be resisted to earthquake shaking and to be affordable to the people should become priority.
2. The space of such NEHWM and non-NEHWM is still widely opened for innovation, either in the material, component, or method of construction. Close collaboration of construction stake holders should be created to optimize the innovation.

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Figure 1: Basic model of BARRATAGA (Sarwidi et. al., 2007)

Figure 2: Training mandors (foremen) watch the different behaviour of non earthquake resistant NEHWM and earthquake resistant NEHWM using various simple demonstration tolls, such as small scaled houses on SIMUTAGA SWD-1BM (a simple shaking table) (Sarwidi et. al., 2007)

Figure 3: Two examples of the application of BARRATAGA concept by trained mandors. The two houses have stood completely with very light cracks surrounded by heavy damaged and collapsed regular houses due to the 2006 Yogyakarta-Central Java earthquake (Sarwidi et. al., 2007)