LEARNING FROM RECENT INDONESIAN EARTHQUAKES: AN OVERVIEW TO IMPROVE STRUCTURAL PERFORMANCE

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ABSTRACT :

In the last four years, Indonesia has experienced numerous major earthquakes, from the 2004 Aceh, 2005 Nias, 2006 Pangandaran and Yogyakarta, and lastly 2007 Bengkulu and West Sumatra earthquakes. The number of casualties and economic loss due to these earthquakes were very high, mostly due to damage and collapse of buildings and infrastructures. The paper presents an overview of structural damage found in recent Indonesian earthquakes. Most of the structural problems found were related to minimum reference to standards/codes. In the case of newly reconstructed structures, with the high demand of structures and the limited time frame, replacement structures are being built in a short time using any available resources. As a result, the reconstruction efforts can be easily shifted towards the quantity of structures, making the aimed quality in buildings and infrastructures sometimes overlooked. Considering the future seismic risk in the region, it is necessary to ensure the structural quality and earthquake resistance of both existing and newly reconstructed structures in Indonesia. Therefore, several applicable solutions to improve the structural quality and reduce earthquake vulnerability are presented in this article. It should be understood that efforts to improve structural quality and reduce earthquake vulnerability of structures involve all parties in the area, from government, society, experts, as well as construction professionals and workers. To minimize losses, efforts should be done to raise earthquake awareness in the communities. Improvement of earthquake risk perception for all parties in building construction, including government officers, is necessary for earthquake mitigation efforts.

KEYWORDS: Indonesia, structural damage, lessons learned

1. INTRODUCTION

Indonesia is located in one of the most active seismic zone in the world. Geologically lies on five active tectonic plates, earthquakes occurred daily in the region, with a magnitude of 5 in Richter scale or larger happened weekly. As an illustration, Figure 1 shows the epicenters of recorded earthquakes in Indonesia during the period of 1992 – 2000.

Several major earthquakes that occurred recently in the region, such as the 2004 Aceh, 2005 Nias, 2006 Yogyakarta, West Java, and West Sumatra, and lastly 2007 Bengkulu and West Sumatra earthquakes, some followed by large tsunamis, claimed lives of hundreds of thousands people and damaging half a million structures in total. The effects of these earthquakes on social and economic aspects are tremendous.

The government and the community are trying to cope with the recovery efforts, while bracing for the next hazard. Various reconstruction and rehabilitation efforts in the affected regions are in place and efforts related to repair, rehabilitate, and rebuild housings, schools, and other infrastructures are underway, in recognition to the extensive supports from many local/national and international donors. In the Aceh region, the government formed the Rehabilitation and Reconstruction Agency (BRR, Badan Rekonstruksi dan Rehabilitasi NAD-Nias) to manage the recovery efforts for the much devastated region. Physical efforts in building structures and infrastructures are also accompanied with many disaster mitigation activities, targeting in raising earthquake risk awareness in the society. Combining efforts from the government, the people, and various local as well as international institutions are designed to make the region safer in terms of earthquake hazards.

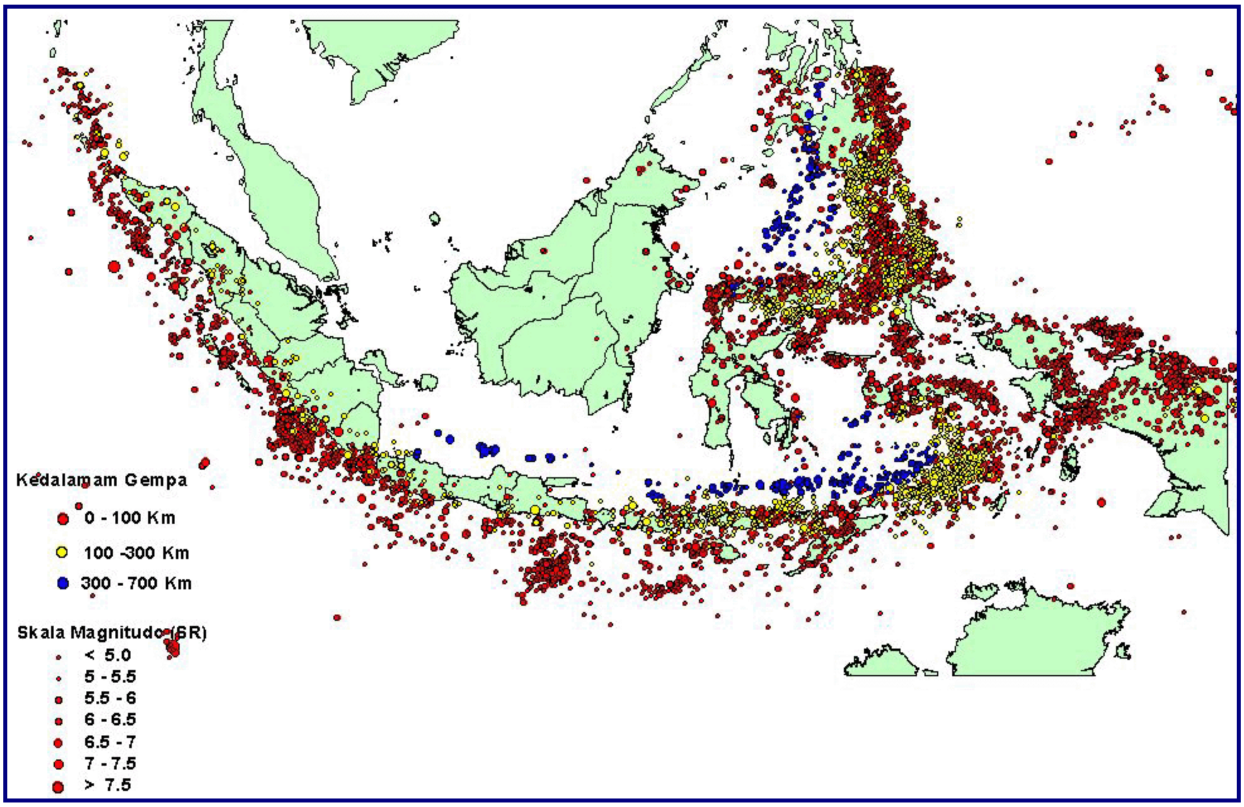

Figure 1 Recorded earthquake in Indonesia during 1992 – 2000. (Source: Indonesian Geophysics and Meteorological Institution, http://www.bmg.go.id).

Experience shows that most of the casualties and economic losses in the earthquake are due to damages of both engineered and non-engineered structures. Considering the geological and seismological conditions of Indonesia as one of the most prone areas to earthquake, it is very important to ensure that all buildings, existing and newly reconstructed, performs well under earthquake loads. The disaster presents opportunities to learn from previous mistakes and to rebuild a safer community against earthquake hazard. Therefore, the quality of the structures should be taken as a serious issue. The existing structures should be evaluated and ensured that they can perform satisfactorily during earthquakes. The recovery and reconstruction process gives a second chance to build structures with higher seismic performance, and to be able to fulfill their social and economical objectives.

2. TYPICAL BUILDING DAMAGES

There were several types of damage commonly found on buildings in Indonesia, i.e. soft story, failed elements and connections, regardless of the types of the buildings. The deficiencies or weaknesses in the structural system and/or components resulted in minor damage up to partial or total collapse of the structures, as uncovered from recent earthquakes.

Figure 2 shows examples of buildings having soft first story which were completely collapse during Yogyakarta earthquake. This type of damage was quite common in structures subjected to earthquake excitation. Other common damages are due to poor connections and improper detailing, as shown in Figures 3 and 4.

Figure 2. Soft story and weak story effects causing total collapse of structures

Figure 3. Failed elements and connections.

Figure 4. Failed elements and connections.

Figure 5 shows damages occurred on non-engineered structures. These damages usually caused by improper detailing and lack of structural integrity of various components in the building. These problems created separations of structural elements and partial collapse, or total collapse. Most damage occurred on the walls, as these elements were often left unconnected to beams and columns.

Figure 5. Damages in non-engineered buildings

3. BUILDING EARTHQUAKE VULNERABILITY

From damages shown above, the problems can be analyzed from several aspects. First, the design of buildings often caused problems for the structure to perform satisfactory under earthquake loading. Conformity to building codes remains a critical issue in ensuring the structural performance. Improper detailing and structural configuration often become major causes in poor performance of structures. Moreover, the detailing in the structural drawing and building specifications sometimes were unclear, leaving the construction workers to improvise the parts. It is common to find buildings designed with structural irregularities, thus resulting in force concentrations and disruptions in load transfer elements. The lack of concern for the placement of openings and non structural elements also caused problems, as in the case of soft story effect and short column behavior.

Non-engineered structures face many problems during earthquake in Indonesia. Many of these structures have been evolving from vernacular buildings, which used to have good performance in earthquake, toward more common masonry structures such as those found in urban areas. These structures often do not follow minimum requirements for a good confined masonry building, and many of them use locally available materials to give a "masonry-like" features, which are in fact very vulnerable to ground shaking (Boen and Pribadi, 2007). Typical non engineered structures in Indonesia using different types of materials are shown in Figure 6. The picture on the far right shows non engineered structure with good feature of confined masonry.

Figure 6 Non-engineered ordinary houses in Indonesia.

It is interesting to also note that efforts to imitate the concept of traditional houses in terms of building shapes and ornaments can also create unnecessary loads for roof systems, and combined with minimum vertical elements in non-engineered houses, leading to more vulnerable structures. Falling front canopies in the Aceh region are examples of this problem. In the old days, the canopies were built using timber for roof and façade supported by wood columns, while newer structures have these canopies made of bricks and concrete supported by small columns that could not resist lateral loads (Figure 7).

Figure 7 Good masonry houses with heavy canopy.

Construction materials may contribute to the vulnerability of the structures. From the procurement aspect, the lack of availability of qualified construction materials sometimes leads to substitution using any available resources. In the case of Aceh, poorly graded sand and gravels coming directly from the river are often used as concrete aggregates. The use of plain rebars for longitudinal and transversal reinforcement are common, whereas Indonesian seismic code clearly states that plain rebars can only be used for spirals and tendons. The size of rebars used is also a typical problem. Although minimum dia. 12 mm of deformed bar for column longitudinal reinforcements, dia. 10 mm of deformed bar for beam longitudinal reinforcements, and dia. 8 mm plain bar for stirrups are specified in the Indonesian concrete code, smaller diameter bars are often found in practice. Non standardized brick size and quality add problem to the vulnerability of masonry buildings (see Figure 8).

Figure 8 Different types of local bricks

Construction methods and practices may increase the vulnerability of the structures. Construction workers usually learn from previous generations on how to build structures, and very few training were held to improve their skills. As a result, most of the workers simply did what they thought as the easiest way for building construction with little concern about the quality because they were not equipped with knowledge of proper construction methods nor basic concepts of quality in structures. In non-engineered structures, this problem is apparent, since the process is more autonomous than in engineered structures, and many works were done manually. Most non-engineered structures in Indonesia were built using the conventional building technology for confined masonry with reinforced concrete frames, and no special equipments or tools are needed.

The results from problems discussed above are structures that are vulnerable to earthquakes. These structures usually lack in structural integrity, since they have insufficient connections and anchorage between each structural components. For example, beam-column connection did not comply with the requirements in the codes, no seismic hook supposed to be provided by a 135 degrees bending was used in the stirrups, and no anchorage was provided from walls to columns and ring beams, leading to collapse of walls during earthquakes.

4. RECONSTRUCTION EFFORT

After earthquakes, recovery efforts were flourishing in the affected regions by the government, communities, and various donors from local and international institutions. The rehabilitation and the reconstruction projects often target a large number of structures to be built in a limited time frame. With the limited resources of materials and construction workers, the quality of structures sometimes was overlooked in the efforts to get the target completed in time. Therefore, the problems for building earthquake resistant structure as presented before are more common in the earthquake affected area, resulting in more earthquake vulnerable structures after the disaster.

The recovery efforts usually involve several parties, i.e. government, donors, communities, contractors, workers, inspectors, and owners. With a large number of projects going on at the same time, the quality control became difficult, since there were not enough qualified building inspectors to go around and ensure the quality of the structures. The scarcity of qualified workers and masons also forced anybody who is willing to work in the construction field to join the process without proper training. Again, these workers tried to get everything done in the easiest way, and they were able to do that with minimum inspection, thus placing the quality of the structure in question.

The problems were magnified since very few guidelines and regulations were available for proper earthquake resistant structures that people could follow. A number of institutions tried to fill the gap by producing manuals and guidelines for earthquake resistant structures. However, these guidelines and manuals are often tailored to specific projects and very little efforts have been done to standardize these manuals. At the end, the community was left with many unofficial guidelines from different institutions or donors, and no knowledge of official guidelines and regulations from the government.

A study on post reconstruction buildings in Aceh revealed that some newly reconstructed structures are vulnerable to earthquake hazards. This is a very unfortunate situation, since the disaster actually offers an opportunity to build a proper structure that is better in terms of earthquake resistant system. (BRI and GRIPS, 2006)

In the post recovery efforts, the problems in material aspects are related to the high demand and short supply situation. For instance, 'half-baked' bricks were found to be used in the construction in Aceh. These bricks were poorly built and fell below the minimum strength level of bricks, showed by their inability to be tested for their strength and 'melt' if soaked with water (Figure 9). Another typical problem found was the quality of the concrete mixture. The gradation of aggregates did not comply with the standard material gradation used for concrete mixture. Large aggregates were found in the mixture. Sand was not washed thus silt or clay could be mixed with it, leading to a very poor mixture. Moreover, excessive amount of water also used in the concrete mixture for higher workability, which leads to high water content and low strength concrete.

Figure 9. Poor material quality and workmanship, variation of brick quality found in Aceh reconstruction.

Efforts have been made by various institutions to rectify these problems. For example, trainings were conducted in Aceh for construction workers and masons to equip them with the necessary skills. These trainings usually include hands on practice works so that the workers had an experience of working with proper materials and tools/equipment for producing qualified structures. The dissemination of construction of earthquake resistant structures were also conducted with training participants including local government officers, building inspectors, and house owners. In Yogyakarta, a local university produced a manual of BARRATAGA (earthquake resistant people house) and disseminated this manual to the communities, conducted training for masons and built model houses (Sarwidi, 2007). The trained masons were then served as trainers for other masons, thus the concept and knowledge of earthquake resistant structure can be widely spread among the workers.

Figure 10. BARRATAGA model houses with adequate structural components and proper brick layering.

5. QUALITY ASSURANCE IN REHABILITATION AND RECONSTRUCTION

Post-earthquake rehabilitation and reconstruction efforts should consider several objectives to ensure a safer community towards earthquake hazards. Existing buildings need to be retrofitted or strengthened when the structural quality and seismic performance are below the requirements, based on thorough vulnerability assessment process. For new structures, a quality control should be well established to guarantee that these buildings are built in compliance with the building codes.

The first step in ensuring the quality of the structures is to make available manuals and guidelines for earthquake resistant structures and to disseminate these manuals to those who are involved in the rehabilitation and reconstruction process of housing and buildings. Therefore, design of newly reconstructed structures should be compliant to the building codes. The dissemination should also promote community awareness and risk perceptions of the people towards earthquake hazards. If the community understands the risks involved, they would be more willing to participate in reducing the risk.

More efforts should be implemented in ensuring proper materials used for constructions. National standards of materials should be introduced during reconstruction process to prevent large variation in the building materials quality. Research and development need to be conducted to better understand different materials and their effects in building constructions, so they can be modeled accurately in the structural analysis. Appropriate building technology can also be used to reduce earthquake vulnerability of structures, such as the use of wire mesh-mortar combination for strengthening non-engineered masonry structures and the use of energy dissipation devices, such as dampers and base isolation for important facilities.

Logistic problems related to the supply of materials and equipment due to extreme increase of demand during post-disaster recovery period may affect the construction quality, thus it should be well addressed in the planning of reconstruction program. Proper construction and material needs, as well as possible changes in the local supply chain system in the post-disaster areas, must be well assessed and understood in order to deal with the logistic problem.

In terms of construction human resource, capacity building becomes a necessity. Massive training for masons and craftsmen as well as construction personnel and supervisors should be planned and implemented in the beginning and it should be an integrated part of the whole post-disaster reconstruction plan, to anticipate the increasing demand surge of skilled construction personnel. Governance related to the building approval process need also to be established as part of the program, which address the review, approval and issuance of building permit to ensure that building codes, regulation and proper construction methods are enforced in order to produce structures with better performance, right from the first time.

Regarding the needs to identify, assess and monitor disaster risks as one of the priorities for action for building the resilience of nations and communities to disasters as stipulated by the Hyogo Framework for Action adopted in the 2005 World Conference on Disaster Reduction, improvement of risk perception of the actors within various institutions and communities supposed to be involved in earthquake disaster risk reduction is very important. For government officials, both at national as well as local level, earthquake risk should be realized as an important issue and major actions are needed to mitigate it (Pribadi, et.al., 2008).

6. CONCLUDING REMARKS

Recent earthquakes show that many casualties and economic losses can be avoided if the structures are built properly to resist earthquakes. Damages found on buildings reveal that problems stemmed from minimum compliance to the regulations and building codes. From the design and planning aspect, the conformity to building codes and standard is a must to ensure the first step in creating a less vulnerable structure towards earthquake. Then, the design has to be implemented in clear drawings and specifications for easier construction. Next, in the construction stage, the quality of materials should be controlled. The construction workers should be equipped with basic skills and knowledge of proper construction methods. Inspections and quality controls should also be conducted throughout the construction stage to guarantee that the structure will be built according to the design. Finally, the maintenance of the buildings have to be done properly so that the buildings can perform satisfactorily during their life times.

The dissemination of building codes and regulations is important in improving knowledge of earthquake resistant structures. Capacity building for all parties in the construction works on national level can also have significant impact in building better structures. Earthquake risk perception should be enhanced so that mitigation efforts can be conducted on both national and local levels. Combined efforts and coordinations of government and research agencies, construction developers, construction personnel (contractors, technicians, masons and crafts) and the community are necessary in improving building performance towards future earthquakes.

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