RECONSTRUCTION PRACTICES IN ACEH AFTER 2004 TSUNAIMI DISASTER

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ABSTRACT :

This study was conducted to investigate and assess the current house building practices of various actors in the ongoing reconstruction process in Aceh, Indonesia, where the 2004 tsunami and earthquake killed many people and destroyed many houses and buildings. A field survey, laboratory tests of building materials, structural analysis, and a one-day workshop were conducted. The study produced the following findings. Planning and design should be improved so that the needs of the communities match with the reconstruction efforts. Proper seismic design should be ensured to avoid severe damage from future earthquakes. Building materials should be improved to meet minimum qualifications. The quality of workmanship should be improved. Good project management and supervision should be introduced to improve structural quality. Unless such improvements are achieved, unsafe houses and buildings will be reproduced in a large numbers through the reconstruction process, making it impossible to “rebuild a safer Aceh against earthquakes.”

KEYWORDS: Aceh (Indonesia), reconstruction, houses, seismic safety

1. INTRODUCTION

The 2004 Indian Ocean earthquake followed by the tsunami waves caused enormous losses in the surrounding region. In particular, Aceh Province (NAD) in Indonesia suffered from the huge loss of human lives and housing, and the destruction of economic and social infrastructure. The report from Satkorlak Banda Aceh on 2 March 2005 shows that in Aceh Province alone, approximately 125,000 people were killed, 95,000 were reported missing, and more than 600,000 were displaced from their homes. According to a six-month information sheet published by the Rehabilitation and Reconstruction Agency (BRR), 116,880 housing units were destroyed, out of a total of 820,000. Further, about 152,000 housing units suffered damage estimated at over a half of their value. The damage was concentrated within a 3–6 kilometer zone along the coast, affecting 80% of the housing stock in Kota Banda Aceh, Aceh Jaya, Aceh Besar, Kota Sabang, and Aceh Jaya. Education facilities also experienced extensive losses, with 2,135 schools partially or totally damaged and about 2,500 teaching and non-teaching staff killed by the tsunami. As a result, about 150,000 students lost their education facilities.

More than one year after the disaster, progress had been achieved in the reconstruction projects, albeit slower than expected. Out of about 26,000 houses planned to be built, about 7,000 houses (27%) were completed by February 2006. School buildings were also reconstructed at a rate almost identical to that of houses. However, in the effort to achieve reconstruction at the expected pace and produce the targeted number of buildings, it seems that the quality control for the newly constructed houses and buildings is being overlooked. In the ongoing reconstruction process, the quality of the structures should be taken as a serious issue, in addition to the issue of the large quantity of structures to be built in the region. Recognizing the geological and seismological conditions of Aceh Province as one of Indonesia’s most earthquake-prone areas, “rebuilding a safer Aceh” is a goal that should be pursued. To improve the safety of Aceh’s communities, it is very important to ensure that building regulations are implemented to minimize the earthquake vulnerability of the newly reconstructed buildings.

This research was organized to investigate current building capacity and practices and analyze the quality of the buildings. The research was conducted jointly by the National Graduate Institute for Policy Studies (GRIPS), the Building Research Institute (BRI), and the Bandung Institute of Technology (ITB)1). The objectives are as follows:
(1) To investigate and assess the current capacity and building practices of various actors in the ongoing reconstruction process, focusing on the vulnerability of houses, and
(2) To develop recommendations for technological interventions to prevent unsafe practices in building construction.

2. METHODOLOGY

2.1 Outline of survey

The field survey was conducted among various reconstruction projects in Banda Aceh and Aceh Besar from January to February of 2006. Due to the limited time frame and the vastness of reconstruction activities in the area, the survey was limited to several selected samples of housings, school buildings, and small scale public buildings. The buildings were randomly selected, and included those constructed by the communities, local government, and donors (NGOs). In addition to buildings that were in the construction stage, several pre- and post-rehabilitated buildings were also observed to better understand the building capacity and common practices in building construction in Aceh. In total, 53 buildings were visited for the field survey as shown in Table 1.

The survey intended to obtain general pictures of ongoing reconstruction projects and their actual building practices. Therefore, field testing for building materials and interviews with various parties involved in the reconstruction process were conducted. Documentations including structural drawings, specifications, pictures, and notes were also obtained in the survey. A few samples of building materials were collected to be analyzed in the laboratory. Local actors - consisting of workers, contractors, related local government agencies, NGOs, and local community groups - were interviewed to obtain information concerning building technology capacity as well as the building procurement process and mechanisms. Input from the owners or future occupants of the buildings as well as other interested parties was also collected.

Table 1 Types and numbers of buildings surveyed

Type of Building	**Number of Buildings**
Housing	34
School	12
Mosque	2
Other	5
Total	**53**

2.2 Assessment of quality of structures

The assessment examined several aspects of building practices: structural design, project management, materials, workmanship, infrastructure and supporting facilities, and policies. The quality of structural design in terms of earthquake resistant design was analyzed based on the buildings' documentation. The structural drawings and specifications were reviewed to ensure that the original documents endorse seismic building design. The project management aspect, which includes construction technology, procurement process, and tools used, was reviewed to assess the efficiency of the project. These assessments were followed by the analysis of the quality of the materials used in the structures. In addition to the results from the field testing, several material samples were tested in the laboratory to determine their properties and structural qualities. The quality of workers was analyzed to observe the adequacy of workmanship.

In addition to the buildings, the environment required for conducting a reconstruction project was also reviewed. We investigated the infrastructure and other supporting facilities such as roads, electricity, and drainage, necessary to ensure the smoothness of the reconstruction projects and to support the communities after the completion of the projects were investigated. Local/national codes and other policies used for the reconstruction projects were also studied to determine the adequacy of regulations for these projects.

Based on the results from the field survey and laboratory tests of materials, an analytical study was conducted to examine the structural performance of the buildings. We selected a few buildings from the reconstruction projects to examine their weaknesses and to find ways to improve the quality of the structures. Structural analysis was conducted and the building performances were analyzed based on the calculated force/stress and displacement responses.

From the field observation and structural analysis, an appropriate technological intervention was developed to reduce the vulnerability of the buildings. This intervention is based on the available capacity, culture, local materials and tools, and also the supporting environment. A workshop was then conducted in Banda Aceh on 22 February 2006 to share the findings from the survey and analytical results. The goal of this workshop was to obtain input from local actors (related local government agencies, NGOs and local community groups, contractors, consultants, universities, and other related parties) as to how to overcome the problems in reconstruction projects.

3. SURVEY FINDINGS

3.1 Current construction practices in Aceh

From an engineering perspective, about two thirds of the buildings in Aceh are non-engineered buildings, meaning that they were built traditionally with very little or no assistance from qualified engineers. Most masonry houses fall into this category. Engineered buildings are characterized to be properly designed and constructed for satisfactory performance under applicable loading conditions. Most public facilities fall into this category, including school buildings, government offices, mosques, and other buildings.
Most buildings in Aceh are masonry structures with one or two stories. This type of structure gained popularity during the 1970s and continues to be the first choice in Indonesia. The existing structures show that they can survive earthquakes with little or no damage, provided that they were built properly using materials and workmanship of good quality. Our survey, consisting of field surveys on damaged houses and a series of interviews of researchers, workers, and government officials, reveals that masonry structures built in the 1970s or 1980s performed better than those built in the 1990s. Almost all damaged structures from the 1990s were not designed properly according to the seismic codes.

3.2 Planning and design

The planning and design aspect relates to the needs and demands of the reconstruction projects. The survey shows that some problems arose due to limited study of feasibility prior to implementing reconstruction projects. Examples of planning problems include temporary and permanent houses being built at the same time as well as construction plans/schedules not being well coordinated with those of infrastructure for housing. There were several finished projects that were uninhabitable because of lack of infrastructure such as electricity and drainage, or because the community refused to live in the project area. The interviews in communities revealed several serious problems. First, some communities were relocated apart from their former villages and were thus uprooted from their previous background. A typical example is the relocation of a fishing village to a location about two kilometers from the coastline. The fishermen refused to be moved because easy access to their boats and to the sea is part of their lifestyle. Second, as mentioned above, we found not a few houses uninhabitable because of lack of electricity, drainage, or water supply. Third, the lack of planning also leads to houses being built very far from public facilities. Finally, some communities refused to move due to inadequate delivery of correct information and non-transparency in official procedures.

Figure 1 Type 36 houses

The design of structures for housing and schools generally follow typical design structures. Most school buildings surveyed show that one- or two-story buildings are commonly used for school buildings, and the two-story buildings are often engineered buildings while most of the one-story buildings can be categorized as non-engineered buildings. The houses are mostly what is called type 36 houses, which means that the total floor area is 36 m^2. This type of housing is a one-story building; most of them can be categorized as non-engineered building. Type 36 houses were endorsed by the government as replacement houses for the victims. Most buildings are made of burnt brick walls with reinforced concrete columns and beams. Roofs are constructed with wood trusses and galvanized iron sheets or roof tiles. Because these materials are commonly used for buildings in Indonesia, these buildings conform with the local culture. Figure 1 shows a typical example of this type constructed by BRR. However, some projects use imported materials and technology, which makes for questionable maintenance and sustainability.

3.3. Contracting

The construction industry in Aceh is not as powerful nor active as that in Java Island or other more developed regions. The political conflict in Aceh for more than three decades has limited the growth of private sector investment, resulting in a relatively smaller private sector construction market. The main construction market consists of government infrastructure investment, while large international investment (oil and gas processing and related industry) is limited to large scale contractors, usually coming from outside the province. Many local contractors depend mainly on government works, resulting in tight and unhealthy competition among the local contractors. As a result, the local contractors have not invested in developing their human resources, construction plants, and technology. The tsunami disaster worsened the situation, as it caused the loss of contractors and family members, construction facilities, skilled human resources, and financial networks, reducing capacity and competitiveness.

Local small scale contractors (SSCs) are generally involved in small/medium sized infrastructure works such as road and small bridge construction and their maintenance, small scale irrigation schemes and their maintenance, residential and non-engineered public facilities (school buildings, government offices, tertiary health centers, etc.), and building maintenance and rehabilitation. A typical SSC employs three to ten permanent staff members (managerial and technical); most of them are not skilled technical personnel. This situation does not allow SSCs to develop their capacity and accumulate experiences and knowledge. Another problem for SSCs is complicated procedures (proposals, supporting letters, collateral, etc.) that make it difficult for them to obtain financing from formal financing institutions.

Community contracting by implementing agencies is also used in reconstruction of Aceh, particularly in donor-driven projects. This process is mostly utilized together with a community participatory and bottom-up planning process, where the implementing agency provides a block grant and the community decides what it wants at the local level. These programs are becoming very popular in recent years and the community perceives that they are efficient and cost effective. Community contracting can be implemented in the following three modalities:
(1) Community procures the services of (local) contractors to implement works using their own funds provided by donors.
(2) Community is contracted by government or donor agencies to implement infrastructure construction such as drainage and sewage.
(3) Community is contracted by the contractors who are requested to sublet part of the work to local communities.

3.4 Construction aspects

(1) Material and workmanship
The procurement of materials for the projects is crucial but the supply of materials is scarce. The survey found some projects were halted or cancelled due to the unavailability of materials. Materials found in the area can be divided into two categories: local and imported. The local materials supplied from Aceh include sand, gravel, bricks, and wood. Imported materials from outside Aceh come mostly from North Sumatra, but some are from Java, or even as far away as Australia, South Africa, or Europe. Usually, these imported materials have been

chosen by the donors. Examples include bricks from North Sumatra and Jakarta, cement from West Sumatra, roof tiles from East Java, and metal frames from Australia. As long as the materials are widely used in Aceh Province, maintenance and sustainability of the imported materials can be ensured. However, if the materials used are new for the locals, maintenance and sustainability will be a problem in the future. We found that some projects used imported materials that are new and rare in Aceh, such as prefabricated steel frames and lightweight concrete panels.

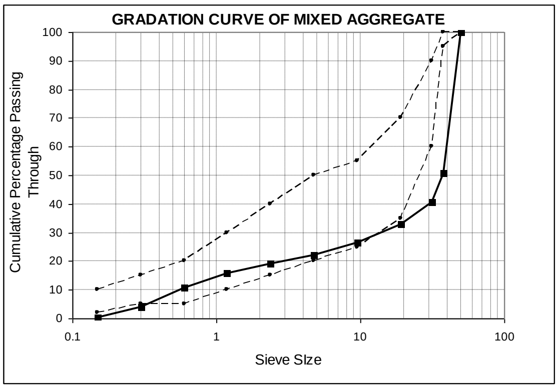

Figure 2 Gradation curve of mixed aggregate of three samples from construction sites in Aceh (The two dashed lines show the range of ASTM C33-90.)

In terms of materials and structure, most of the houses and school buildings conform with typical local materials. The houses and school buildings are constructed in burnt brick confined masonry structure with sand and portland cement mortar, with confinements of RC columns and beams. A typical flat footing is usually used for the column foundation in two-story buildings, while a spread footing is commonly used for one-story buildings. Metal roof decks are the most popular choice for roofs due to their cost, workability, and durability.

The design of houses is similar to the designs used prior to the disaster. Post-earthquake design is not much improved, including the seismic aspect. Moreover, in most drawings, structural details that are important for seismic design are still left unclear, such as the beam-column connection, spacing for hoops, seismic stirrups, lap splices, and anchorage, so workers are left to “improvise” on these details. On the other hand, most designs for two-story school buildings show a conservative approach regarding seismic loading, emphasized by the large number of columns and the substantial dimension of structural elements. It should be noted that there is another big problem of the quality of construction. The field observations found that not a few of the materials being used were different from the specifications and requirements of the drawings.

The concrete mixture is a serious problem for reconstruction of houses. The materials used for the mixture were adequate in most cases. However, almost no projects used the proper composition for the concrete mixture (volume ratio of 1 cement : 2 sand : 3 gravel). The most common mixture is cement and sand-gravel (sand with some gravel) with composition of 1 bag of cement for 3 carts of sand-gravel (about 1 : 5.25 in volume ratio). No sieving process was done to comply with the standard material gradation used for concrete mixture and no effort was made to avoid large aggregates getting into the mixture, which leads to a mixture having a very poor gradation with a high percentage of coarse aggregates. Our laboratory tests clearly illustrate this fact, as seen in Figure 2. Another critical issue concerning concrete is cement/water ratio. We found excessive water in most of the cases. Proper curing for concrete is also not common in the area. Considering all these facts, we have to conclude that the quality of concrete is one of the most serious problems in the reconstruction projects.

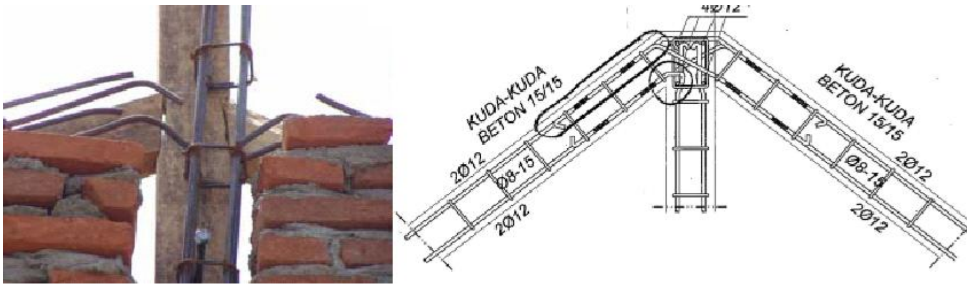

Figure 3 Construction does not follow the drawing, which requires longitude rebars in columns bended and connected to beams

The usual reinforcements used in the buildings are plain rebars of diameter 10 mm for longitudinal, and plain rebars of diameter 6 mm for hoops. In some construction sites, even weaker reinforcements were found: diameter 8 mm for longitudinal plain rebars and diameter 4 mm for hoops. The Indonesian seismic code specifies the following minimum diameters for materials to be used in earthquake resistant buildings: 12 mm for deformed bars for column longitudinal reinforcements, 10 mm for deformed bars for beam longitudinal reinforcements, and 8 mm for plain bars for hoops. Most of the reinforcements found in the field survey violated the building codes. Even worse, detailing of reinforcement such as bending work does not satisfy seismic demands for safety. Figure 3 shows the contrast between the drawing (the intended design) and the actual situation, a difference that is quite common in the area.

Figure 4 Widely spaced hoops

The spacing of the hoops also poses a problem, with spaces averaging 200-250 mm, in contrast to the code's requirement of minimum spacing of 150 mm or less (see Figure 4). The lab tests show that the strength of the steel bar is also below standard (see Table 2). All these facts indicate that the strength capacity of the structural elements for bending and shear in the buildings being constructed could be much lower than what was expected.

Table 2 Tensile tests of steel reinforcements of seven samples of plain bars of 8 mm and 10 mm respectively from construction sites in Aceh

Type of Reinforcement	Average Yield Strength (kg/mm^2)	Standard Yield Strength (kg/mm^2)
Bj. TP 24	29.56	39
Bj. TP 30	43.95	49

The quality of bricks used in the area is very low. The lowest class of bricks in the Indonesian code is Class III, which requires strength of minimum 25 kg/cm^2. Most bricks fall below the minimum strength and even "melt" when soaked with water (Figure 5). The mortar quality is also questionable because of poor composition: too little cement and too much water. The bricks observed at construction sites were not installed in straight lines and mortar was often excessive (spacing of more than 15 mm).

The structures are also lacking in structural integrity, due to insufficient connections between structural components. For example, connection did not comply with the requirements in the codes/drawings, and no anchorage was provided from the walls to the columns.

Figure 5 Melting bricks

(2) Workers

While the low quality of materials causes low structural quality, the low quality of workmanship amplifies these problems. With the huge amount of work arising from reconstruction activities, trained and qualified workers are scarce in the area. The results of most projects show that the workers were not adequately skilled for the job. They tend to ignore the important issues for producing safe structures, such as the sieving process for aggregates, curing of concrete, soaking of bricks before placement, water ratio for concrete mixture, and bending details. All these problems arise due to the workers' lack of the concepts of quality of structures. The workers simply do what they think of as the easiest way to construct the buildings—without concern for the quality—because they are not equipped with knowledge of proper construction methods nor basic concepts of quality of structures.

(3) Project Management and Supervision

The investigation shows that there are two types of reconstruction projects. In the first type, NGOs or other donors assign the construction project to a contractor. This type of reconstruction project is usually called the

"project type". In second type, the NGOs or other donors provide full or partial funding to owners or groups of owners while the construction project is carried out. This type of project is called the "community-driven type". Each method shows advantages and disadvantages. The project type is prone to sub-contracting, which is done an average of 2-3 times, and in some cases up to 4-5 times. Every time a project is sub-contracted, each involved party gains a profit of a certain percentage of the original budget. This causes serious friction between parties, which often causes political upsets and scandals. In contrast, the community-driven type is affected by the shortage of qualified construction workers and supervisors.
The survey also shows that quality controls were not implemented due to the shortage of trained and qualified supervisors. The shortage of supervisors makes daily inspections difficult and results in them being conducted less frequently; cases of weekly, bi-weekly, or even monthly inspections were found. Unfortunately, the building permit system, which can be one of the mechanisms to ensure the quality of the structure, is suspended due to the massive number of construction projects and the limited capacity of the authorities. Thus, houses and other facilities damaged by the earthquake and tsunami are currently allowed to be repaired or reconstructed without building permits.

(4) Problems in Official Procedures
The victims of the earthquake and tsunami disasters are eligible to receive assistance for rebuilding houses based on their own reporting. The victims are requested to report the damage to their houses to the head of the village (known as Keuchik) or other village officials. However, this is not an easy procedure for the victims: because most of their official documents were lost or damaged in the disasters, it is difficult for them to provide proof of their ownership of land and houses. Many people have had difficulty in securing assistance or have had to wait a very long time for their assistance to be provided. On the other hand, governmental agencies have difficulties in confirming that each victim receives only a single unit of housing for each family, causing some people to end up with no houses while others receive two or more units.

4. STRUCTURAL ANALYSIS

We conducted a case study of structural analysis on a house funded by a donor. We selected the type mainly because of the availability of complete documentation and technical information. The house is has a floor area of 45 m^2 and is a single story confined masonry structure with burnt brick walls. All of its structural elements are common in houses in Aceh. We employed modal analysis in an elastic range. For structural analysis, the house was modeled as a confined masonry structure in which both the frame and walls support earthquake loads. All structural components including columns, beams, roof, and walls were modeled as frame and shell elements. The properties for these materials were taken from the results of the field survey and material testing. Our analysis finds that the house for the case study has sufficient structural capacity in terms of the Building Codes and Standards of Indonesia when it is constructed according to the structural drawing and specifications with adequate quality of materials and construction. This means that safe structures could be realized under the severe conditions in Aceh if appropriate designs, materials, and construction work are made available.

5. RECOMMENDATIONS

A one-day workshop was conducted on 22 February 2006, with the purpose of disseminating facts obtained from the survey and preliminary analyses, to obtain input from all related parties in the reconstruction process, and to find solutions for problems in the reconstruction process. During the workshop, findings from the field survey, material tests, and structural analyses were presented to the audience. We produced the following recommendations after incorporating the input from the workshop.

- Community awareness about building safety should be raised so that the community becomes involved in improving the quality of the structures.
- Good communication and coordination between donors, community, and government agencies should be built so that the society can participate.

- Building codes and standards should be enforced.
- Internal mechanisms for quality control should be set up by each related party, such as owner, consultant, contractor, donor, and government agency. If necessary, each party should have its own supervisor for each project to ensure the quality of the structure.
- Appropriate building construction methods should be disseminated.
- Feasibility studies should be done prior to conducting reconstruction processes. These should include the participation of the community so that the reconstruction efforts match the needs and demands of the community.
- Training for workers and supervisors should be carried out to ensure proper construction methods, which will lead to better construction.
- A pocket guide for building construction should be developed to facilitate dissemination of proper construction methods.

6. CONCLUSION

Several important findings were obtained from this study. The survey on planning and design aspects shows that improvement is needed so that the reconstruction efforts match the needs and demands of the communities. The study of design aspects found that proper seismic design should be ensured to avoid severe damage from future earthquakes. In this context reliable technical information should be delivered to engineers through seminars, publications, or other means. The construction aspect shows that materials used in the reconstruction projects should be improved so that they meet the minimum qualifications for building materials as specified by the codes/standards. The quality of workmanship should be improved to reduce the vulnerability of the structures. For this purpose practical training programs should be implemented. Good project management and supervision should be conducted to ensure that the components in a building can work properly and together form an integrated structure.

The workshop confirmed that problems that occurred in the reconstruction projects were caused by the aforementioned problems. Several possible solutions were produced from this workshop, including raising community awareness on building safety, the enforcement of building codes and appropriate construction methods, internal mechanisms for quality controls from each related party involved in a construction project, and improvement of the skills and knowledge of workers and supervisors. The findings from this study show that unless there is a change of direction in the reconstruction process from quantity to quality, rebuilding a safer Aceh against earthquakes cannot be achieved.

This study was conducted in partnership with the Bandung Institute of Technology (ITB) as a part of the Study on Development of Earthquake Disaster Mitigation Policy in Developing Countries, which was carried out jointly by the National Graduate Institute for Policy Studies (GRIPS) and the Building Research Institute (BRI). The Indonesian team members were Dr. Krishna S. Pribadi (Center for Disaster Mitigation (CDM), ITB, Research Coordinator), Ir. Teddy Boen (WSSI, Senior Researcher), Dr. Dyah Kusumastuti (CDM-ITB, Researcher), Dr. Suharwanto (CDM-ITB, Researcher), Mr. Aryo Seto (CDM-ITB, Research Assistant), Mr. Ari Soemarsono (Ministry of National Education, Field Support), and Mr. Yudi Nurman (Ministry of National Education, Field Support). We would like to express gratitude to the following organizations which supported the study: Provincial Government of Nanggroe Aceh Darussalam (NAD), City Government of Banda Aceh, District Government of Aceh Besar, Faculty of Engineering and Structural Laboratory of University of Syiah Kuala, Structural and Material Laboratory of ITB, Ministry of Education, and BRR.