

## REVIEW OF RECONSTRUCTION IN ACEH FOLLOWING THE 2004 BOXING DAY TSUNAMI

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### ABSTRACT

This paper summarizes the findings of two field trips to the Aceh Province, which were made by the authors, in early 2006 and late 2007. The purpose of the trips was to assess and provide guidance to the rebuilding process following the 26 December 2004 earthquake and tsunami. The paper will discuss the key issues raised and show how the various agencies involved in the rebuilding process have met the challenges encountered.

**KEYWORDS:** Aceh, Tsunami, Disaster Risk Reduction, Reconstruction



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## 1. INTRODUCTION

The Indian Ocean earthquake that occurred at 07:58:33 local time on the 26 December 2004, originated just north of Simeulue Island, off the western coast of northern Sumatra, Indonesia. The earthquake triggered a series of tsunamis that spread throughout the Indian Ocean, killing large numbers of people and devastating coastal communities in Indonesia, Sri Lanka, India, Thailand, and as far a field as Somalia. Aceh, in Northern Indonesia, was the worst hit region where it is estimated some 170,000 people died, and numerous buildings and infrastructure were completely destroyed, leaving more than 500,000 people without homes, access to water and sanitation, and livelihoods. A second major earthquake on 28 March 2005, with its epicentre north of Nias caused further loss of life and damage.

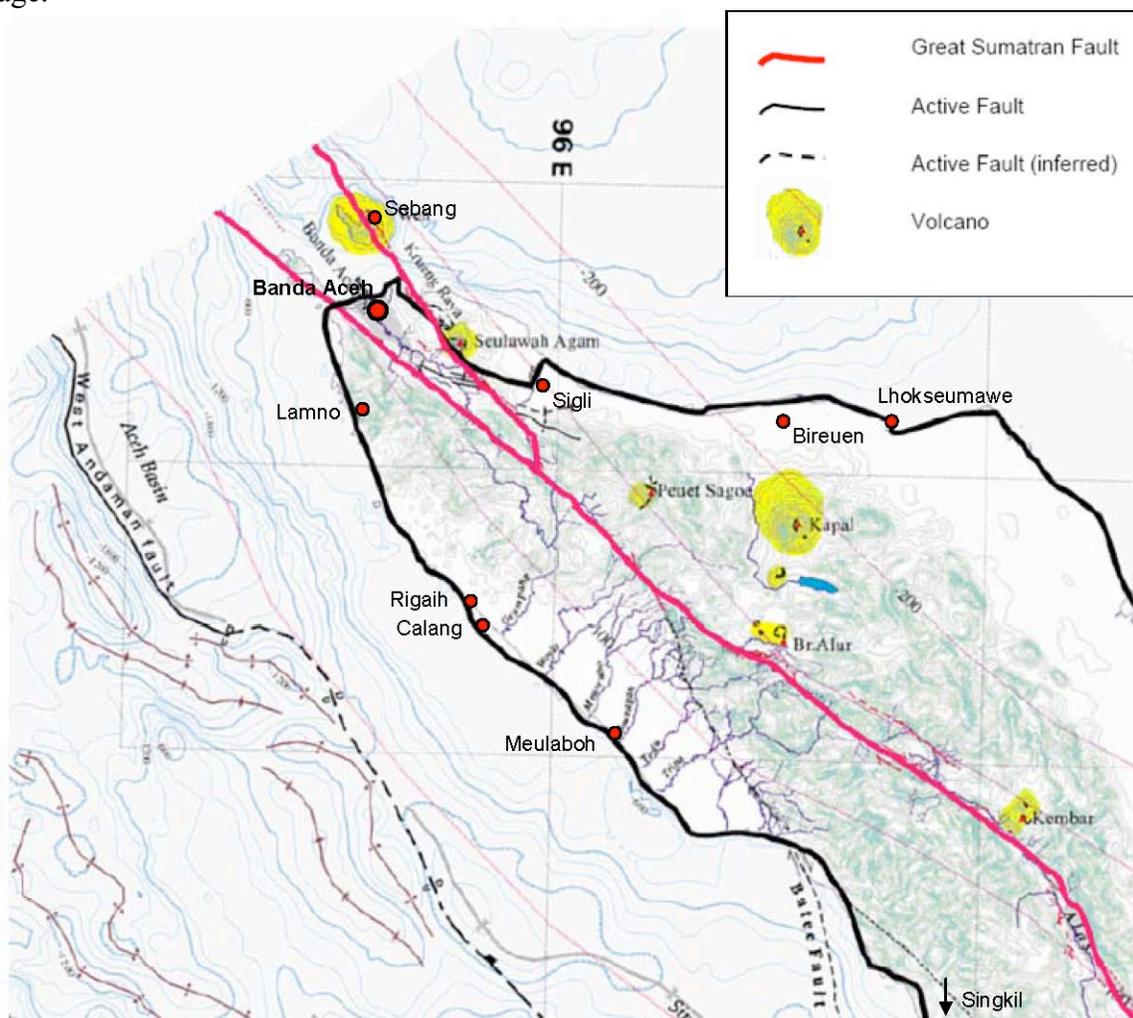


Figure 1 Principal Locations and Geological Features of the Aceh Province

This paper presents the findings of two field trips to the Aceh Province. The purpose of the initial trip, in early 2006, was to carry out a technical review of the existing construction programme of the NGO Muslim Aid, in order to assess the adequacy of their structures. As a consequence of the information gathered during the trip we also provided key findings to UN agencies and other NGOs so that these could benefit all parties and the wider reconstruction effort. The second trip, in late 2007, looked at reviewing the achievements made by various organizations involved in the rebuilding process. This paper also provides recommendations for the ongoing process in Aceh and future earthquake reconstruction and disaster risk reduction projects in developing regions.

The focus of the trips was on the construction of rural housing, water and sanitation, schools and health centres. For the purpose of this paper we shall concentrate purely on the rural housing and water and sanitation issues, though many of the observations apply to all forms of construction.

Figure 1 shows the Aceh region and identifies the principal locations that were visited during the two visits, from Singkil on the south west coast to Lhokseumawe on the north east coast of Aceh. Each trip covered more than 1000km of the Aceh coastline.

We would like to thank all the people and organisations who gave up their precious time to meet and discuss their respective projects and in particular Fadullah Wilmut the Country Director for Muslim Aid.

## **2. NATURAL HAZARDS**

One of the key issues identified was a lack of understanding of the various natural hazards which could affect Aceh. Many of the parties involved in the re-construction process were focused on protecting against another tsunami, to the detriment of other potentially more important concerns (see Figure 1).

This paper does not present a once and for all authoritative list of all natural hazards relevant to Aceh, rather we hope to show the need for a holistic assessment of natural hazards and so provide an insight into the difficult balances that need to be struck between available location for building, economic means to engineer against and methods of managing the implications of the various natural hazards.

In an ever increasingly populated world due care and attention must also be given to man made hazards and sustainability principles to ensure that any building process is properly understood in its entirety and appropriate strategies to handle the situation are decided upon.

### **2.1 Tectonic Setting**

Sumatra lies just to the east of the Sunda Trench and delineates the subduction of the Indian and Australian Plates below the Sunda Plate. Aceh province lies at the apex of this junction. This tectonic collision zone has given rise to the mountain range along the spine of Sumatra and the numerous volcanoes, earthquakes and tsunamis that have characterised the geological history of the region.

## 2.2 Volcanoes

Most of Indonesia's volcanoes lie along the Sunda arc. Data on the current activity of volcanoes can be obtained from the Volcanological Survey of Indonesia (see <http://www.vsi.esdm.go.id/>), whilst a list of active volcanoes in Aceh can be found at the following web site: <http://www.volcano.si.edu>.

Since the probability of a major event may be very small, it often proves neither politically nor economically viable to prohibit building within the volcano eruption risk zone. Neither is it practical to design structures for pyroclastic eruptions. Instead, monitoring of potentially active volcanoes, such as Seulawah Agam, and the design, training and implementation of evacuation plans, can ensure that future lives are saved. Structures outside the most hazardous zones will be affected by ash fall from eruptions. It is therefore important to consider the additional weight of ash when designing roofs.

## 2.3 Tsunami

Indonesia has a long history of damaging tsunamis, which have been caused by earthquakes and volcanic eruptions. Other non-seismic events, such as landslides, man-made explosions and meteorite impact can also generate a tsunami. Information on historic tsunamis that have affected Sumatra can be found at: <http://www.ngdc.noaa.gov/>.

Designing structures for tsunami with water heights of more than a couple of metres is both difficult to achieve and costly. One possible solution is therefore to locate structures away from exposed coastline areas. However, local economics and social needs dictate that people will tend to relocate back to where they lived previously. For a small more common event, the combination of planting and landscaping of the coastline can be used to protect vulnerable communities. Wherever possible, housing should be built away from the sea on higher level ground to mitigate a tsunami risk.

For a large rare event, tsunami warning systems have been shown to work effectively in both Japan and Hawaii. However, for such systems to be effective they require suitable evacuation routes to be provided together with an extensive education program. This will ensure the population at risk will be able to self-evacuate prior to any future event. Unfortunately in Aceh houses are being constructed on an individual basis rather than as part of an integrated urban plan that facilitates provision of evacuation routes.

## 2.4 Earthquakes

Major earthquakes that have affected Sumatra over the last two centuries are generated either along the Sunda Trench in the Indian Ocean or from the Sumatran fault, which runs the length of Sumatra.

Earthquakes on the Sunda Trench are generated by the subduction process. These are amongst the world's largest earthquakes. There is a general academic consensus (McClosky et al., 2005, Sieh, 2005 and Nalbant et al., 2005) that there is now an increased risk that the next part of the subduction zone to the south will rupture in the next few years.

Earthquakes on the Sumatran Fault are generated by the strike slip motion along that fault. It is interesting to note that the Aceh segment has no recorded rupture in the last century, which may

suggest that an earthquake may be imminent. Furthermore, McClosky et al. (2005), Sieh (2005) and Nalbant et al. (2005) all raise concern that segments of the Sumatran Fault closest to the 26 December 2004 and 28 March 2005 events might also be triggered by the changes in stress associated with these large events.

It should be noted that any earthquake induced rupture along the Sunda Trench would be at least 100km from Banda Aceh, whilst an earthquake rupture on the Aceh section of the Sumatran Fault could be less than 10km away. As a result, the ground motion and hence damage due to the more local event could potentially be more significant even though the magnitude of an earthquake along the Sunda Trench is larger.

## **2.5 Other Hazards**

### **2.5.1 Wind**

Aceh Province lies just to the south of the tropical storm belt however it is still subject to relatively high prevailing winds. Appropriate design to the latest structural codes and competent construction should ensure adequate structural performance of buildings.

### **2.5.2 Flooding (Rainfall)**

The average rainfall for Banda Aceh is about 1.6m in a year, with the principal rainy season being between September and January. The region is therefore susceptible to large water run-off that can lead to flash flooding. This requires adequate drainage design. Locating housing on high ground, or elevating it on stilts reduces the impact of flooding. Where developments are to be built on or near slopes, it is important that terraces and drainage channels are sufficiently engineered to ensure their stability (Figure 2a).

The cost of properly designed engineering works to create suitable sites for housing development from steep hillsides, is significant but irresponsibly ignored all too often because there are not enough people with the appropriate professional skills in a position to influence early plans of those engaged in the building process.

### **2.5.3 Flooding (Plate Movement)**

Flooding can also occur due to changes in topography following major earthquakes. Following the 26 December 2004 and 28 March 2005 earthquakes, the Sunda Plate has sunk by about 1m with respect to sea level. This has had a dramatic effect on towns such as Singkil (Figure 2b) and Rigaih, where large areas have been “lost to the sea” or highly susceptible to tidal flooding (the maximum tidal range along the Aceh coast is about 1.5m). As a result many villages have been displaced or have been made uninhabitable.

Where there has been significant loss of coastline due to large scale plate movements, one must consider the future viability of the affected settlements. Engineering solutions can be provided, but they will require detailed investigations and significant civil engineering works to provide a safe, flood free environment. Hydrological and topographical surveys will be needed to assess the validity of potential re-location sites, and re-location carefully planned to ensure access to utilities, community

facilities and livelihood activity. If only part of a community wishes to re-locate, consideration needs to be given to the on-going care and maintenance of the fragmented community which remains, as well as those who re-locate.



Figure 2 Examples of housing at risk due to non-tsunami hazards (a) landslides due to rainfall (b) inundation by the sea

### 3. HOUSING GUIDANCE AND LEGISLATION

#### 3.1 Seismic Design Code

The Indonesian seismic design code (SNI.03-1726-2002) provides an appropriate methodology for designing against the forces induced by an earthquake. It is comparable to seismic design codes from USA, Japan and Europe. The intent of the code is to prevent damage in a small earthquake that has a high probability of occurring during the life of the structure (maybe several times), and to protect loss of life in a major earthquake that has a low probability of occurring during the life of the structure. In the later case the building may be significantly damaged but should not collapse. Unfortunately the design of single storey residential houses and other similar structures falls outside the scope of the Indonesian seismic code.

### ***3.2 Building Regulations***

In July 2005 the Ministry of Public Works issued a Building Code for Aceh. This document provides minimum requirements for the design of single storey residential houses termed “dwelling houses”. Section 2 of the document provides the technical requirements for reliability of a building structure. These cover several design issues and principles which should be followed, including: building type and form, type and minimum dimensions of foundations, minimum column and beam dimensions, minimum reinforcement quantities and spacing, requirements for diagonal bracing and types of concrete mixes permissible.

During our first visit it became clear that the requirements of the Building Code were not being enforced, and many houses built at that time did not comply with these basic requirements (see Figure 3). Furthermore, it is noted that most international codes have restrictions on the use of unreinforced masonry for regions of moderate and high seismicity, such as Aceh. However, the Building Code for Aceh permits the use of masonry for walls panels, but provides no guidance on fundamental seismic principles including: maximum size of wall panels, openings in wall panels, minimum thickness of wall panel, tying of wall panels and provision of ring beams.

## **4. HOUSING IN ACEH**

### ***4.1 Housing Types***

Housing in Aceh can be classified into three main categories, namely:

- The “permanent” houses, which are built from brick, often with reinforced concrete frames.
- The “semi-permanent” houses, which are built from brick and timber.
- The “traditional” houses, which are timber structures.

It should be noted that the definition of “permanent” and “semi-permanent” reflects terminology used during colonial times when the Acehnese were discouraged from building “permanent” houses in order to prevent acquisition of land title. “Semi-permanent” houses are therefore considered inferior.

Examples of these housing types are given in Figure 3. Most houses are the minimum size 36m<sup>2</sup> “core” house, but frequently have veranda and/or kitchen extensions which increase the size up to 48m<sup>2</sup> which is sufficient for a five person family based on a minimum of 9m<sup>2</sup> per person. Most people in Aceh lived in “permanent” houses prior to the tsunami, and many were larger than those being provided.

### ***4.2 Assessment Methodology***

During the initial field mission ten different housing projects were reviewed as a benchmark of housing quality. This was done using a modified FEMA 154 approach (FEMA, 2002). Since, at that time, many of the houses were under construction, it was not possible to assess quality in terms of habitability, durability, access to water and sanitation, electricity and adequate communal facilities. The focus of benchmarking was therefore whether, both in terms of design and construction quality, the new houses were earthquake tolerant. During the second mission the other issues were also be assessed.



“Permanent”

“Semi-permanent”

“Traditional”

Figure 3 Examples of housing types

#### 4.3 Key Observations

The key observations from the initial field surveys were as follows:

- “Permanent”, “semi-permanent” and “traditional” timber houses have been constructed, though most of the “semi-permanent” houses were intended as transitional shelters only.
- The design and workmanship quality for many houses (reinforced concrete frame with unreinforced masonry infill) were found to be very poor when reviewed using the FEMA 154 approach. Many new constructions are thought likely to collapse in the next major earthquake.
- It was interesting to note however that the good examples were designed by experienced engineers and used a high degree of on-site supervision to assure that the quality of construction met the design intent.
- A variety of other construction methodologies including pre-cast frames, and reinforced blockwork has been used for “permanent” houses. These structural systems have all been developed by experienced engineers, to withstand earthquakes.
- The lightweight construction of “traditional” housing means these houses will probably meet life safety criteria, and their seismic resistance depends less on either design or workmanship. However, there was evidence of other problems including leaks due to poor workmanship or timber shrinkage, and termites.

As a consequence of our observations Arup highlighted these issues to the agencies involved and provided general guidance to the rebuilding process (see <http://www.arup.com/geotechnics/project.cfm?pageid=8403>).

The key conclusions were:

- Experienced earthquake engineers should survey structures that survived the earthquake of 26 December 2004 and address the issue of retrofitting.
- Experienced engineers should develop a basic and comprehensive code of practice for post-tsunami housing, and possibly a complimentary training programme to reinforce it.

- Procedures should also be developed to regulate the quality of construction. These are critical to deliver a product that is fit for purpose, and reduce vulnerability to future events. In particular experienced engineers should review construction of critical facilities; hospitals, schools, bridges etc.
- An education programme on hazards should be implemented at all levels of government, in NGOs, and within the wider community to raise awareness.



Openings/Wall Panels



Concrete Quality



Quality of Materials

Figure 3 Examples of poor workmanship

This was just one of several initiatives during 2006 to address these concerns. On the second mission we were very pleased to observe a marked improvement in the quality of both design and workmanship of the housing. Many agencies had employed experienced engineers and/or contractors to achieve these improvements. Furthermore there was often a large degree of training to develop a more skilled local workforce. However, some construction issues still remain.

The second mission also allowed the issues of habitability, durability, access to water and sanitation, electricity and adequate communal facilities. A series of questionnaires were developed to understand whether these issues had been properly addressed. It became apparent that many agencies had taken a holistic approach, which encompasses these factors, so that the houses that they were building could become homes that families could live in and grow. Furthermore, based on local government statistics, it was clear that the occupation rates for those agencies who had just delivered houses were much less than those who had taken the holistic approach.

## 5. SITE SELECTION

Site provision was the responsibility of the local Government. There appeared however, to be no formal process, either within local government or the various agencies, for assessing the suitability of a site identified for development or carrying out the enabling and infrastructure works that may be required to ensure the selected site is viable. Typical site selection checklist, guidelines and background information can be found in Corsellis and Vitale (2005), Coburn et al (1995) and The Sphere Standards (2004).

There are many issues than can affect the site selection process, and they may be geographical, economic or political. One example where this has impacted is in the development of the US Aid Road from Banda Aceh to Calang. Many new houses have been demolished soon after their completion to make way for the new road.

Prior to commencing any housing program it is essential that the roles and responsibilities of various stakeholders are clarified. A site assessment should be carried out at each location to identify the needs for local infrastructure, identify who is responsible for implementation, and how this impacts on the housing programme. It is also recognised that short term and long term solutions for water supply may be required. It is also noted that water supply was a large problem in Aceh prior to the tsunami.

## 6. CONCLUSIONS AND PRACTICAL RECOMMENDATIONS

This paper summarises the findings of the authors following two missions to Aceh in early 2006 and late 2007. It is hoped that the principal findings can help direct further work in Aceh and influence the decision making process carried out in other post-disaster situations and where disaster risk reduction is being implemented.

- There a number of different natural hazards that should be considered in providing new housing for those affected by the tsunami.
- The consequences of volcanoes and large tsunamis are impractical, if not impossible to design against, and can only be mitigated through management, education and planning. This includes early warning systems, evacuation plans and routes which should be accounted for in urban planning and site layouts.
- Risks including flooding, landslides, and fault rupture can be avoided completely by locating houses away from these hazards. However, this is not always possible, particularly where people wish to re-build on their own land which is at risk. Alternatively these risks can be mitigated to some extent by providing well engineered drainage systems, and earthworks. The need, cost and timescale for carrying out such works, must be considered at the outset as part of a site selection process.
- The post conflict and disaster situation place severe stress on traumatised communities and requires careful managements to ensure appropriate quality and speedy delivery of housing whilst also resolving land rights issues to avoid future problems.
- Providing appropriate training to those who actually do the construction will ensure that the construction workforce has a greater understanding of seismic design considerations, the special

significance of good quality robust seismic detailing to ensure houses will withstand future earthquakes safely, and their vital role in ensuring that houses are compliant with the appropriate requirements.

- The importance of specifying the appropriate quality for the raw ingredient that are used to build
- The importance of high quality and functional detailing to ensure correct construction.
- The importance of quality control and quality assessment, especially in a post disaster or conflict environment.

In the end however, the most important issue is that we recognise the needs of the people who have been affected by these and similar tragedies. An earthquake tolerant house is an engineer's goal, but we must also recognise the people's needs and follow a holistic approach in the construction process. The new houses therefore need adequate water and sanitation, access to community facilities, electricity etc., and only then will these houses become homes where families and communities can re-build their shattered lives.

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