The People of Aceh

Aceh & Nias Post Tsunami Reconstruction

Review of Aceh Housing Program

ARUP

The People of Aceh

Aceh & Nias Post Tsunami Reconstruction

Review of Aceh Housing Program

April 2006

Ove Arup & Partners Ltd
13 Fitzroy Street, London W1T 4BQ
Tel +44 (0)20 7636 1531 Fax +44 (0)20 7755 3667
www.arup.com

Job number 119982

Job title	Aceh & Nias Post Tsunami Reconstruction		Job number 119982
Document title	Review of Aceh Housing Program		File reference
Document ref			

Revision	Date	Filename	0002Report-Muslim Aid-jds.doc		
Draft 1	07/04/06	Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Zygmunt Lubkowski	Jo da Silva	Jo da Silva
		Signature			
Issue	27/04/06	Filename	0006Report-jds.doc		
		Description	Final issue		
			Prepared by	Checked by	Approved by
		Name	Zygmunt Lubkowski	Jo da Silva	Jo da Silva
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

References

Figures

Appendices

Executive Summary

This report summarises the findings of a field trip on behalf of Muslim Aid to the Aceh Province, which was made by Jo da Silva and Zygmunt Lubkowski from Arup, between 20 February and 3 March 2006. The purpose of the trip was to assess and provide guidance to the rebuilding process following the 26 December 2004 earthquake and tsunami. We would like to thank all the people and organisations who gave up their time to meet and discuss their respective projects.

The key conclusions from the review are as follows:

- There a number of natural hazards including volcanoes, tsunami, earthquakes, flooding and landslides that should all be considered when providing new housing and structures.
- Volcanic eruptions and large tsunamis are impractical, if not impossible to design against. They can however, be mitigated through management, education and planning.
- Risks as a consequence of flooding, landslides, fault rupture can be avoided completely by locating houses away from such hazards. These issues should be considered as part of a site selection process, and further guidance is provided in this report.
- Earthquakes remain the most significant risk in Aceh. Banda Aceh itself straddles the Great Sumatran Fault, which could generate a major earthquake and cause significant damage.
- It is essential that that all new design is appropriate, correctly engineered and embraces current legislation, guidance and good practice. It is also essential that the quality of construction does not compromise the design intent.
- The Building Code issued by the Ministry of Public Works in July 2005 is not comprehensive with respect to seismic design single storey residential houses. As a result several agencies have developed their own guidance. Whilst these all contain useful data, they have not been developed with reference to each other, and in some cases provide incorrect or conflicting information. Further guidance is provided in this report.
- Several of the new houses have been reviewed using the FEMA approach. The majority are “permanent” houses, which are mostly in-situ reinforced concrete frames with brick infill. The quality of the design and workmanship for many of these houses was very poor, and countless numbers are likely to collapse in the next major earthquake.
- 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 in “semi-permanent” and “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.

We therefore recommend the following actions should form part of the ongoing rebuilding program.

- 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, NGOs, and the wider community to raise awareness.

1 Introduction

The undersea Indian Ocean earthquake that occurred at 07:58:33 local time on the 26 December 2004, Muslim Aid 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 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.

This report summarises the findings of a field trip on behalf of Mulsim Aid to the Aceh Province, which was made by Jo da Silva and Zygmunt Lubkowski from Arup, between 20 February and 3 March 2006. Figure 1.1 shows the Aceh Province and the key areas visited during the field trip. The purpose of the trip was to assess and provide guidance to the rebuilding process following the 26 December 2004 earthquake and tsunami. We would like to thank all the people and organisations who gave up their time to meet and discuss their respective projects.

The report is divided into four main chapters as follows:

- Section 2 provides a summary of the key hazards and risks relevant to current and proposed post-tsunami housing, and identified measures for mitigating these risks through design, management and construction.
- Section 3 comments on the adequacy and appropriateness of current local and national building codes and guidance relating to post-tsunami housing.
- Section 4 provides a summary of the design and construction methodologies being used by several NGOs and agencies, and comments on their structural adequacy.
- Section 5 comments on issues relating to sites for post-tsunami housing

2 Natural Hazards

This chapter describes the numerous natural hazards that should be considered in the design and construction of building and civil engineering structures in the Aceh Province. To aid the reader a glossary of technical terms is provided in Appendix A.

2.1 Tectonic Setting

Figure 2.1 shows that Sumatra lies just to the east of the Sunda Trench, which is one of the world's major plate boundaries. It delineates the subduction of the Indian and Australian Plates below the Sunda Plate. Aceh province lies at the apex of this junction, the western side on the Burma Microplate, whilst the eastern side is on the Sunda Plate. 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.

Global Positioning System (GPS) measurements indicate that near Sumatra, the Indian and Australian Plates are moving NNW at about 50 to 60 mm/year. This motion is distributed between the Sunda Trench and the strike-slip Sumatran Fault that runs along the Sumatran mountain range.

2.2 Geological Hazards

2.2.1 Volcanoes

2.2.1.1 The Threat

Most of Indonesia's volcanoes lie along the Sunda arc; a 3,000-km-long line of volcanoes extending from northern Sumatra to the Banda Sea. Indonesia has 76 volcanoes that have erupted in historic time - the largest number for any volcanic region. These volcanoes have had at least 1,171 eruptions. Furthermore, Indonesia has had the highest number of eruptions that have:

- produced fatalities
- caused damage to land used for agriculture
- generated mudflows
- generated tsunami
- grew lava domes
- produced pyroclastic flows

Data on the current activity of volcanoes can be obtained from the Volcanological Survey of Indonesia (see http://www.vsi.esdm.go.id/).

Several volcanoes are located in the Aceh province, their location is shown in Figure 2.2. Details of their history are described in Table 2.1. It should be noted that Seulawah Agam, the closest volcano to Banda Aceh, has the potential to cause pyroclastic type eruptions. Though rare, these are devastating events which destroy all in their path.

Name	Notes
Geureudong (Kapal)	This massive volcanic complex consists of two adjacent volcanoes. One is eroded and Pleistocene in age, but the other has shown repeated activity in the 19th and 20th centuries.
Kembar	This andesitic shield volcano is capped by a complex of craters and cones. Active fumaroles and hot springs are present at several locations.
Peuet Sague	This complex volcano had its latest eruption in April 1998 when it erupted ash up to 3 km into the air. A prior eruption began in 1918 and ended in 1921.
Pulau Weh	This island of the north coast of Sumatra is the remnants of a stratovolcano. Volcanism is assumed to be of Pleistocene age, but fumaroles and hot springs are found along the summit and on the north of the island.
Seulawah Agam	This stratovolcano is the closest volcano to Banda Aceh. It erupted in 1600, caused a phreatic eruption in January 1839 and most recently was active in August 1975

Table 2.1 – Active Volcanoes in Aceh (http://www.volcano.si.edu)

2.2.1.2 The Solution

Since the probability of a major event may be very small, it often proves neither politically nor economically viable to prohibit building within the zone at risk. Clearly, it is also not practical to design structures for a pyroclastic volcanic eruption. Instead, monitoring of potentially active volcanoes, such as Seulawah Agam, and the design, training and implementation of an evacuation plan, can ensure lives are saved in any future event.

It is noted that structures outside the most hazardous zones, could still be affected by ash fall from any future eruption. It is therefore important to consider the weight of ash when designing roofs.

2.2.2 Tsunami

2.2.2.1 The Threat

Tsunami is a Japanese word represented by two characters, the first character, "tsu," means harbour, while the second character, "nami," means "wave". Indonesia has a long history of damaging tsunamis, most recently that generated by the 2004 Indian Ocean earthquake. However, as illustrated in Table 2.2, volcanic eruptions have also caused devastating events. It should also be noted that other non-seismic event, such as a landslides, man-made explosions and meteorite impact can also generate tsunami.

2.2.2.2 The Solution

Designing structures for tsunami with water heights of more than a couple of metres is both difficult to achieve and costly. The optimum 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. Where ever possible, housing should be built away from the sea on higher level ground.

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. It is noted that in Banda Aceh, houses are being constructed on an individual basis, rather than as part of an integrated urban plan that facilitates provision of evacuation routes.

Date	Notes	Water Height	Fatalities
1797	Great earthquake felt near Padang which was flooded by powerful waves.	unknown	300
1833	Great earthquake caused a huge tsunami flooded southern part of the western Sumatra. Numerous victims.	unknown	unknown
1843	Major earthquake west of central Sumatra. Tsunami flooded all the coast of the Nias Island. Many fatalities.	unknown	unknown
1861	Exceptionally strong earthquake affected all the western coast of Sumatra.	unknown	1700
1883	Tsunami due to eruption of Krakatoa in the Sunda Strait.	35m	36,500
1907	Major earthquake affecting south-west coast of Sumatra.	2.8m	400
2004	Great earthquake which generated a tsunami affecting most of the Indian Ocean coastlines.	34.9m	283,100

Table 2.2 – Selected Tsunamis Affecting Sumatra (http://www.ngdc.noaa.gov/)

2.2.3 Earthquakes

2.2.3.1 The Threat

Figure 2.3 shows a summary of major earthquakes that have affected Sumatra over the last two centuries. It is clear that they 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. Four earthquakes with magnitude (MW) greater than 8 have occurred in the region within the last two centuries, including the recent MW 9.3 event on the 26 December 2004 and the MW 8.7 event on the 28 March 2005 which affected the island of Nias. 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, in the area of the 1833 event (see Figure 2.3) will rupture in the next few years.

Earthquakes on the Sumatran Fault are generated by the strike slip motion along that fault. Sieh and Natawidjaja (2000) have identified 19 segments along the fault each with an average rupture length no greater than approximately 100 km. Because of this it is considered that the maximum magnitude event that could occur is about MW 8. 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 would be more significant even though the magnitude of an earthquake along the Sunda Tench is larger. This is shown clearly in Table 2.3, which compares the peak ground acceleration (PGA), for a range of possible events.

Location	Magnitude (M_W)	Rupture Distance (km)	PGA (m/s^2)
Sunda Trench	9.5	100	2.1[A]
	8.5	100	1.1[A]
Sumatran Fault	8.0	10	4.8[B]
	7.0	10	3.7[B]
A: Mean result using the Youngs *et al.* (1997) attenuation relationship B: Mean result using the Sadigh *et al*. (1997) attenuation relationship			

Table 2.3: Comparison of PGA in Banda Aceh

2.2.3.2 The Solution

There are four principal hazards which can result from an earthquake. Examples are shown in Figure 2.4 and their consequences are explained below:

- Ground Shaking – This is the motion of the ground due to the earthquake. It is the principal earthquake effect which causes structures to collapse. Appropriate design to the latest seismic codes and competent construction should ensure adequate structural performance.
- Liquefaction – This is the loss of strength in saturated sand deposits due to cyclic loading. It can cause both significant settlement and lateral movement of foundations. The key here is to identify the location of liquefiable deposits and either avoid those areas, improve the density of the ground or provide suitable deep foundations to a competent stratum below.
- Fault Rupture –This is relative movement across the fault that generated the earthquake. Depending on the nature of the fault it could either result in vertical or horizontal movements. Structures should be located at least 15m away from an active fault to mitigate its effects, according to the 1972 Alquist-Priolo Act.
- Landslides – These are often caused as a result of earthquakes. It is therefore imperative that structures are not built on susceptible slopes or near edges of cliffs.

2.3 Other Hazards

2.3.1 Wind

2.3.1.1 The Threat

Figure 2.5 shows that the Aceh Province lies just to the south of the tropical storm belt. It is however, still subject to relatively high prevailing winds.

2.3.1.2 The Solution

Appropriate design to the latest structural codes and competent construction should ensure adequate structural performance of roof elements.

2.3.2 Flooding (Rainfall)

2.3.2.1 The Threat

Figure 2.7 shows the average rainfall for Banda Aceh, taken from www.worldclimate.com. This equates to 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 could lead to flash flooding.

2.3.2.2 The Solution

Adequate drainage must be provided to reduce the effect of flash flooding. Locating housing on high ground, or elevating it on stilts reduces the impact of flooding.

Where developments are to be built on slopes, it is important that terraces and drainage channels are sufficiently engineered to ensure their stability. Figure 2.6 shows two development sites on Sabang Island, where this has not happened. The first has already been subject to one significant landslide, whilst the second is considered to be highly unstable, due to the apparent uncontrolled manner of land clearance and subsequent earthworks. It is noted that the cost of properly designed engineering works to create suitable sites for housing development from steep hillsides, is very significant.

2.3.3 Flooding (Plate Movement)

2.3.3.1 The Threat

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 appears to have sunk by 1m or so with respect to sea level. This effect has had a dramatic effect on towns such as Singkil, where large areas have been "lost to the sea" or are partially underwater 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 are uninhabitable.

2.3.3.2 The Solution

Where there has been significant loss of coastline due 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 asses 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.

2.4 Conclusions

1) There a number of natural hazards that need to be considered in providing new housing for those affected by the tsunami.
2) 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.
3) Risks including flooding, landslides, 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. 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 (see Section 5).

4) Earthquakes remain the most significant risk in Aceh. To date it appears that no liquefaction surveys have been carried out in Aceh, and these should be carried out in order to inform the location and foundation design of larger structures, but are less critical for housing. For housing, ground shaking is the most significant issue, as this can lead to collapse. It is therefore essential that the design is appropriate, correctly engineered and embraces current legislation, guidance and good practice (see Section 3), and that the quality of construction does not compromise the design intent.

5) There are many structures within Banda Aceh which survived the 26 December 2004 earthquake, but they could be susceptible to a major earthquake on The Great Sumatran Fault. All structures, especially those such as hospitals and schools, should be assessed by qualified earthquake engineers.

3 Housing Guidance and Legislation

This chapter presents the legislation and guidelines that exist in Aceh for the design of building and civil engineering structures.

3.1 Legislation

3.1.1 Seismic Design Code

The Indonesian seismic design code (SNI.03-1726-2002) provides an appropriate methodology for designing against the forces of 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.

Figure 3.1 presents the seismic zoning map for Indonesia. This shows that Aceh falls into zones 3, 4 and 5, whilst the island of Nias falls into zone 6, the highest zone. Table 3.1 provides the peak ground acceleration in each zone on rock and other soil categories, which should be assumed in designing structures.

Zone	**1**	**2**	**3**	**4**	**5**	**6**
PGA (g) – Rock	0.03	0.10	0.15	0.20	0.25	0.30
PGA (g) – Hard Soil	0.04	0.12	0.18	0.24	0.28	0.33
PGA (g) – Medium Soil	0.05	0.15	0.23	0.28	0.32	0.36
PGA (g) – Soft Soil	0.08	0.20	0.30	0.34	0.36	0.38

Table 3.1: Peak Ground Acceleration for Return period of 500 years

The following points should be noted:

- It is understood that the design of single storey residential houses falls outside the scope of the Indonesian seismic code (see 3.1.2 below).
- For facilities that are required to operate in a post earthquake situation, such as hospitals, water and power supply facilities, emergency relief stores, radio and television facilities, the values given in Table 3.1 should be increased by 40% (i.e. importance factor of 1.4).

3.1.2 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; including minimum size 36m^2, minimum space/person 9m^2
- Type and minimum dimensions of foundations.
- Minimum column and beam dimensions (e.g. 150x150mm).
- Minimum reinforcement quantities and spacing (e.g. 4no. 12mm diameter main bars with 8mm links at 150mm centres).
- Requirements for diagonal bracing
- Types of concrete mixes permissible

However, evidence on the ground suggests that the requirements of the Building Code are not being enforced, and many houses built to date do not comply with these basic requirements (see Section 4).

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
- Provision of ring beams

Whilst the importance of connections between different building materials is highlighted, no details are provided. For example no clear guidance is provided as to how to provide out-of-plane support to the masonry walls.

For Muslim aid's programme, other key issues to note are:

- All buildings with a site elevation of less than 5m above mean sea level and less than 5km from the coast should be raised by at least 0.3m above ground level.
- Wood frame buildings appear to only be permitted within 5km of the coast where the site elevation is less than 15m above mean sea level.

3.2 Guidelines

Various UN agencies, NGOs and individuals have prepared guidance documents in a variety of forms targeted at different audiences.

3.2.1 UN Habitat Check-list

UN Habitat has developed a checklist, which is intended for NGOs, of typical details which are important in the design of new housing. This is reproduced in Appendix B. It covers the following three areas:

1. Sitting
2. Material types
3. Construction details

This is a good clear and concise document, but there are a few critical flaws in the construction section, namely:

- Item 2 – Foundations should be constructed from concrete rather than rubble.
- Item 10 - Masonry details should show continuous sill or lintel beams below and above openings.
- Item 10 - Minimum sizes and spacing of openings in masonry panels should be provided.
- Item 11 - Reinforcement connection details between beams and columns should show L-bars to transfer loads between the elements in question.
- Item 18 - Masonry lintels are inappropriate in earthquake regions.

Alternative details for items 2, 10 and 11 are shown in Figures 3.2, 3.3 and 3.4.

3.2.2 UN Habitat/Architecture Clinic Comic

This document is intended to provide the community with a walk-through of the house-building process. It includes items on defining the hazards, procurement, suitability of materials and construction.

This is a well developed document, though it may be a little long winded and it is unclear whether the intended audience would have the patience to read it in its entirety.

It should be noted that the reinforcement details shown on pages 50 to 53 do not have appropriate reinforcement details, namely:

- No closed links
- Beam/column connections
- Plain rather than deformed bars shown

Currently drafts of this document have only been produced in local language, and as result only very limited feedback has been obtained from international staff within NGOs, UN Agencies, many of whom have valuable expertise they could contribute.

3.2.3 UNDP Handbook

This document is intended to provide the community with examples of good and poor construction. It is a useful document, though it may be more beneficial to architects, design engineers and contractors rather than the community. It could be improved by adding typical reinforcement details such as those in the UN Habitat checklist and Figures 3.2, 3.3 and 3.4.

3.2.4 Others

It is understood that IFRC are currently producing guidance for the various national Red Cross housing programmes.

Teddy Boen's paper "Building a Safer Aceh", is a useful reference point which highlights the shortfalls in construction to date with numerous examples of poor construction. This was presented in January 2006, but the observations made do not seem to be impacting on houses being built now.

A survey carried out by students at Unsiyah University on behalf of UN-Habitat raises a wide range of issues regarding the quality of housing and progress with the implementation of the housing programme. However, it makes absolutely no reference to mitigation of seismic risk through appropriate design and good quality workmanship.

3.3 Conclusions

1) The Indonesian seismic code specifically excludes single storey residential houses, but these are covered in the Building Code issued by the Ministry of Public Works in July 2005. However, this is not comprehensive with respect to seismic design.

2) As a result a number of UN agencies and NGOs have chosen to develop their own guidance. Whilst these all contain useful information, they have not been developed with reference to each other, and in some cases provide incorrect or conflicting information which can cause confusion. There appears to be no consensus amongst NGOs as to what constitutes "good practice", and what guidance should be followed, particularly with regard to seismic considerations. Both BRR and UN-Habitat consider it the responsibility of the local authority to enforce good practice, but at the same time recognise that they do not have the capacity to so.

3) Until procedures (whether self-regulatory or mandatory) are put in place to regulate the quality of housing being provided, it remains in the hands of each organisation. It is

heavily dependent on who is leading each housing programme, and whether they have the skills and expertise to design and deliver a product that is fit for purpose, and at the same time reduce vulnerability to future events.

4 Housing in Aceh

This chapter presents a review of the earthquake design and construction of the new housing that is being built in Aceh and Nias.

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.

Most people in Aceh lived in permanent houses prior to the tsunami. 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.

Prior to the tsunami, particularly in urban areas, most people either lived in or aspired to a “permanent” house. “Semi-permanent” houses are considered inferior.

4.2 Assessment Methodology

During the field mission a number of housing projects were reviewed as a benchmark of housing quality.

Since many of the houses were under construction, and due to limitations on time, 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 whether, both in terms of design and construction quality, and whether this resulted in an earthquake resistant house.

4.2.1 Design Issues

In order to achieve an earthquake resistant house, the following simple rules should be addressed:

- Foundations should be substantial and linked together. This will ensure the house settles as a single entity in the case of liquefaction.
- The structure should be regular in plan, elevation and have symmetrical window/door openings.
- Structures should be spaced apart – buildings too close together can hit each other
- The materials used should be flexible – they must be able to withstand repeated loads. For example masonry is not flexible, whilst reinforced masonry and timber are flexible.
- Details (e.g. joints, gables, roof connections etc) should be carefully designed – these are often the weakest points.
- Materials should be of good quality and used appropriately.

4.2.2 Construction Issues

It is important to understand that poor construction can ruin good design. To achieve suitable construction:

- Contractors should be suitably educated, so they understand the importance of the construction quality and how to achieve this.
- Clients should have sufficient supervision of the contractor to ensure that the correct materials are used and that good construction practices are followed.
- Financial matters are transparent so that corruption does not prevent the design intent being achieved.

4.2.3 FEMA 154

The survey was carried out following the basic procedures laid out in FEMA 154 (http://www.fema.gov/plan/prevent/earthquake/pdf/fema-154). This handbook provides a simple survey approach that enables the quick classification of surveyed buildings into two categories: those acceptable as a risk to life safety or those that may be seismically hazardous and should be evaluated in more detail by a design professional experienced in seismic design.

Appendix C presents the completed survey forms for each of the houses considered.

4.3 Housing Survey Results

4.3.1 World Vision Permanent House, Meulaboh

Permanent 36m^2 RC frame with masonry infill walls.

- Foundation appears to be a ring beam which is good.
- RC beams and columns are small 100x100mm, have smooth 10mm reinforcement bars and 6mm links at about 300mm spacing.
- Masonry is single skin and of poor quality, including masonry gables. There appeared to be a crude attempt at adding vertical reinforcement around openings which is unlikely to provide any structural integrity.
- The window and door openings are too large for wall panels and generally not symmetrically spaced. No lintel beams are provided above openings.
- Construction quality is generally very poor.

This house will not meet life safety criteria.

4.3.2 KJRC Permanent House, Meulaboh

Permanent 36m^2 RC frame with masonry infill walls.

- Foundation is a RC ring beam.
- Beams and columns are larger than World Vision house, though it is not clear what reinforcement details were used.
- Gable is timber rather than masonry, therefore reduced falling hazard.
- Masonry walls are single skin and do not look to be reinforced.

- Window and door opening small and symmetric within wall panels, but no lintel beam provided.
- Construction quality reasonable.

Due to the use of unreinforced masonry walls this house will not meet life safety criteria.

4.3.3 Caritas Traditional House, Singkil

Traditional 45m^2 timber house.

- Structure rests directly onto individual concrete plinths.
- It is not clear how the timber connections between columns and beams are meant to work.
- Construction quality appears reasonable.

This house probably meets life safety criteria, though some connection details may need to be changed.

4.3.4 IOM Permanent House, Singkil

Permanent 36m^2 precast RC frame houses with unreinforced brick masonry walls.

- Foundation is a RC ring beam.
- Precast elements ensures good quality concrete.
- The structure relies on the strength of steel bolts in tension. Their failure could lead to a non-ductile collapse of the frame.
- The frame probably works well with the light weight panels, but it is not clear how will it perform with unreinforced masonry walls.

This house may meet life safety criteria, though the use of unreinforced masonry is questionable.

4.3.5 CRS Permanent House, Meulaboh

Permanent 45m^2 RC frame masonry infill walls

- Columns are 250x150mm with six 12mm bars and 8mm links at 150mm centres.
- The main reinforcement uses deformed bars.
- Windows and doors are generally small and lintel beams are provided.
- There is evidence that limited reinforcement is provided within the masonry panels.
- Construction quality is good and there is a supervisor on site ensuring the contractors achieve the design requirements.
- The cost is R75million.

This house probably meets life safety criteria.

4.3.6 BRR Permanent House, Meulaboh

Permanent 36m^2 RC frame masonry infill walls

- Columns and beams are 100x100mm with 10mm plain bars and 4mm links at 250mm spacing.
- Generally masonry panels are large, and no lintel beams are provided.
- Internal ply walls to reduce cost.
- Windows and doors are very large compared to the wall panel.
- Windows with nails round frames to supposedly tie into masonry. This is ineffectual
- Construction quality average.
- The cost is R38million.

This house will not meet life safety criteria.

4.3.7 Mercy Malaysia Semi-Permanent House, Banda Aceh

Semi-permanent 36m^2 house.

- Foundation is a RC ring beam.
- Due to the nature of the construction, low masonry walls and timber frames and walls, the building should be life safe in an earthquake.

This house probably meets life safety criteria.

4.3.8 Oxfam Semi-Permanent House, Banda Aceh

Semi-permanent 36m^2 house.

- Foundation is a RC ring beam.
- Due to the nature of the construction, low masonry walls and timber frames and walls, the building should be life safe in an earthquake
- Showing significant signs of termite attack in the timber walls.

This house probably meets life safety criteria.

4.3.9 UNHCR Permanent House, Chalang.

Permanent 36m^2 reinforced blockwork "core" house.

- Foundation is a RC ring beam.
- The structure is designed to survive a zone 6 earthquake and a 1.3m high tsunami wave.
- Windows and doors are generally small and symmetrically spaced.
- Gable ends are timber, so falling hazard is reduced.
- Construction quality is good.

This house probably meets life safety criteria.

4.3.10 Zero-to-One Permanent House, Nias

Permanent 36m^2 precast RC "core" house.

- Foundation is a RC ring beam.
- This is a precast RC structure using columns and wall panels with steel roof trusses. They are interlinked using grooves in the columns.
- Certified for zone 6 earthquakes. This appears to be a well thought out design, and better than concrete frame and masonry both in terms of build time (5days/house) and structural integrity.
- The system can be adapted for schools and clinics.

This house probably meets life safety criteria.

4.4 Conclusions

1) Most houses are the minimum size 36m^2 "core" house, but frequently have veranda and/or kitchen extensions which increase the size up to 48m^2 which is sufficient for a 5 person family based on a minimum of 9m^2 per person.
2) "Permanent", "semi-permanent" and "traditional" timber houses have been constructed.
3) "Permanent" houses are mostly in-situ reinforced concrete frames with brick infill. With the exception of the CRS house, the quality of the design and workmanship for these houses was poor, and it is unlikely they would meet life safety criteria. The CRS house uses the same construction methodology but is a well engineered, as opposed to a "non-engineered" structure, with a high degree of on-site supervision to assure that the quality of construction meets the design intent.
4) 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.
5) The lightweight construction in "semi-permanent" and "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.

5 Site Selection

5.1 Site Selection and Infrastructure

It is understood that site provision is the responsibility of the local Government. There appears however, to be no formal process, either within local government, BRR or NGOs, 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. A typical site selection checklist based on Kelly (2005) is provided in Appendix D. Similar guidelines and background information can be found in Corsellis and Vitale (2005), Coburn *et al* (1995) and The Sphere Standards (2004).

BRR has recently been re-structured so that the housing unit now also has responsibility for local infrastructure. BRR recognise the limited capacity of the Public Works department and there appears to be an expectation that NGOs will carry out some if not all site preparation, and infrastructure associated with their housing programmes.

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 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.

5.2 Sloping Sites

The risk of flooding and landslides can be mitigated by:

- Locating housing on flat ground with a gently slope (<5 degrees) to facilitate drainage.
- For sloping sites (5 to 20 degrees), creating small level platforms on which to seat individual houses, as opposed to varying the height of the plinths and/or posts. See representative sketch in Figure 5.1.
- Building houses at least 1.5m away from slope edges or small retaining walls
- Landscaping the whole site with appropriate drainage, retaining walls and earthworks, designed and supervised by geotechnical and civil engineers. This will tend to take some time and be very costly.

REFERENCES

[1] Boen, T. (1978). Detailer's Manual for Small Buildings in Earthquake Areas

[2] Boen, T. (2006) Building a Safer Aceh, Reconstruction of Houses, One Year After the Dec. 26, 2004 Tsunami. Presented during 40th Anniversary of Trisakti University, "*Answering the Challenges in Today's Civil Engineering*".

[3] Coburn, A., Hughes, R., Pomonis, A. Spence, R (1995), Technical Principles of Building for Safety. Intermediate Technology Publications.

[4] Corsellis, T. and Vitale, A. (2005) Transitional settlement displaced populations. University of Cambridge Shelter Project, Oxfam.

[5] Dowick, D. (2003) Earthquake Risk Reduction, Wiley.

[6] FEMA (2002) Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, FEMA 154 2nd Edition

[7] Kelly, C. (2005) A Sri Lanka Checklist-Based Guide - Identifying Critical Environmental Considerations in Transitional Shelter Site Selection, Construction, Management and Decommissioning. Rapid Environmental Impact Assessment Project, A Benfield Hazard Research Centre/CARE Collaboration

[8] McCloskey, J., Nalbant, S.S. & Steacy, S. (2005). Earthquake risk from co-seismic stress. Nature. Vol. 434, 17 March 2005, pp291.

[9] Nalbant, S.S., Steacy, S., Sieh, K., Natawidjaja, D. & McCloskey, J. (2005). Earthquake risk on the Sunda trench. Nature. Vol. 435, 9 June 2005, pp756-757.

[10] Natawidjaja, D.H. (2002). Neotectonics of the Sumatran Fault and Paleogeodesy of the Sumatran Subduction Zone, PhD Thesis, California Institute of Technology, USA.

[11] Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi. F. & Youngs, R.R. (1997). Attenuation relationships for shallow crustal earthquakes based on California strong motion data. Seismological Research Letters, Vol. 68(1), pp180-189.

[12] Sieh, K. (2005). What happened and what's next. Nature, Vol. 434, 31 March 2005, pp573-574.

[13] Sieh, K. & Natawidjaja, D.H. (2000). Neotectonics of the Sumatran fault, Indonesia. Journal of Geophysical Research, Vol.105, No.B12, pp28,295-28,326.

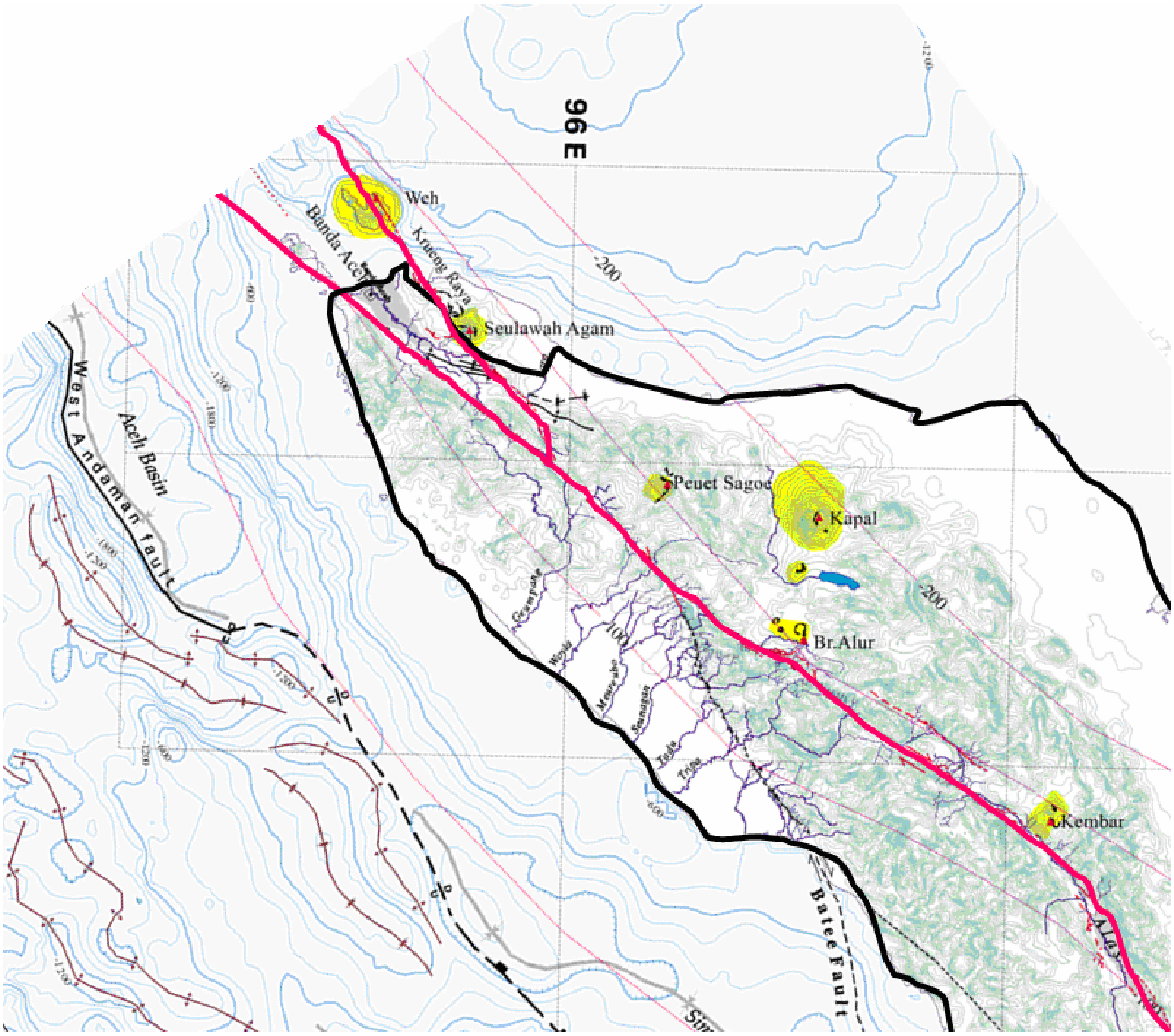
[14] The Sphere Project (2004) Humanitarian Charter and Minimum Standards in Disaster Response.

[15] Youngs. R.R., Chiou, S-J, Silva, W.J. & Humphrey, J.R. (1997) Strong ground motion attenuation relationships for subduction zone earthquakes. Seismological Research Letters, Vol. 68(1), pp58-73.

FIGURES

Figure 1.1 **Mission Map**

Figure 2.1 **Tectonic setting of the Aceh region (USGS, 2005)**



Great Sumatran Fault

Active Fault

Active Fault (inferred)

Volcano

Figure 2.2 Principal Geological Features of the Aceh Province

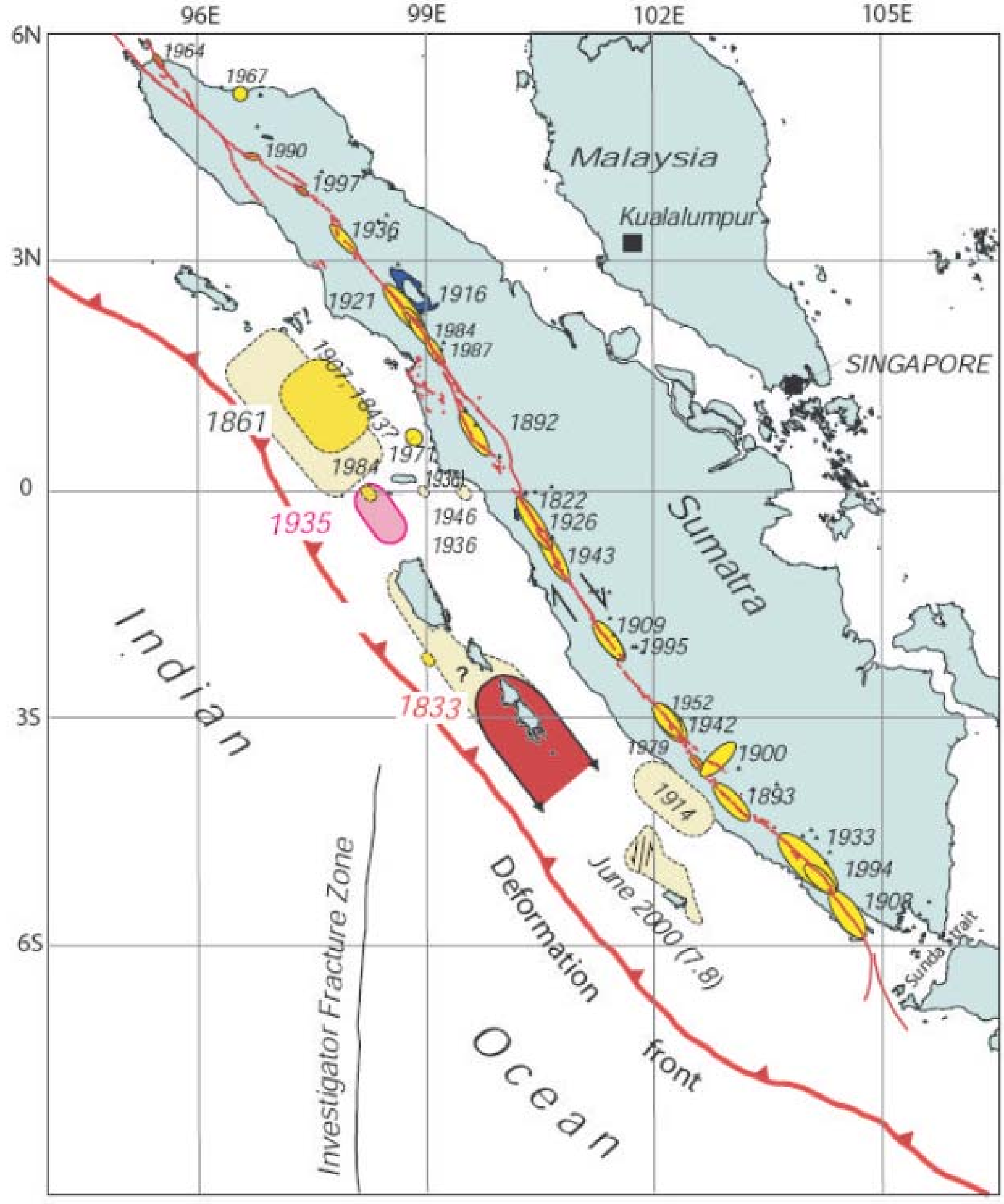


Figure 2.3 **Summary of Sumatran Earthquakes 1800 to 2002 (Natawidjaja, 2002)**

Ground Shaking

Liquefaction

Fault Rupture

Landslide

Figure 2.4 Direct Earthquake Hazards

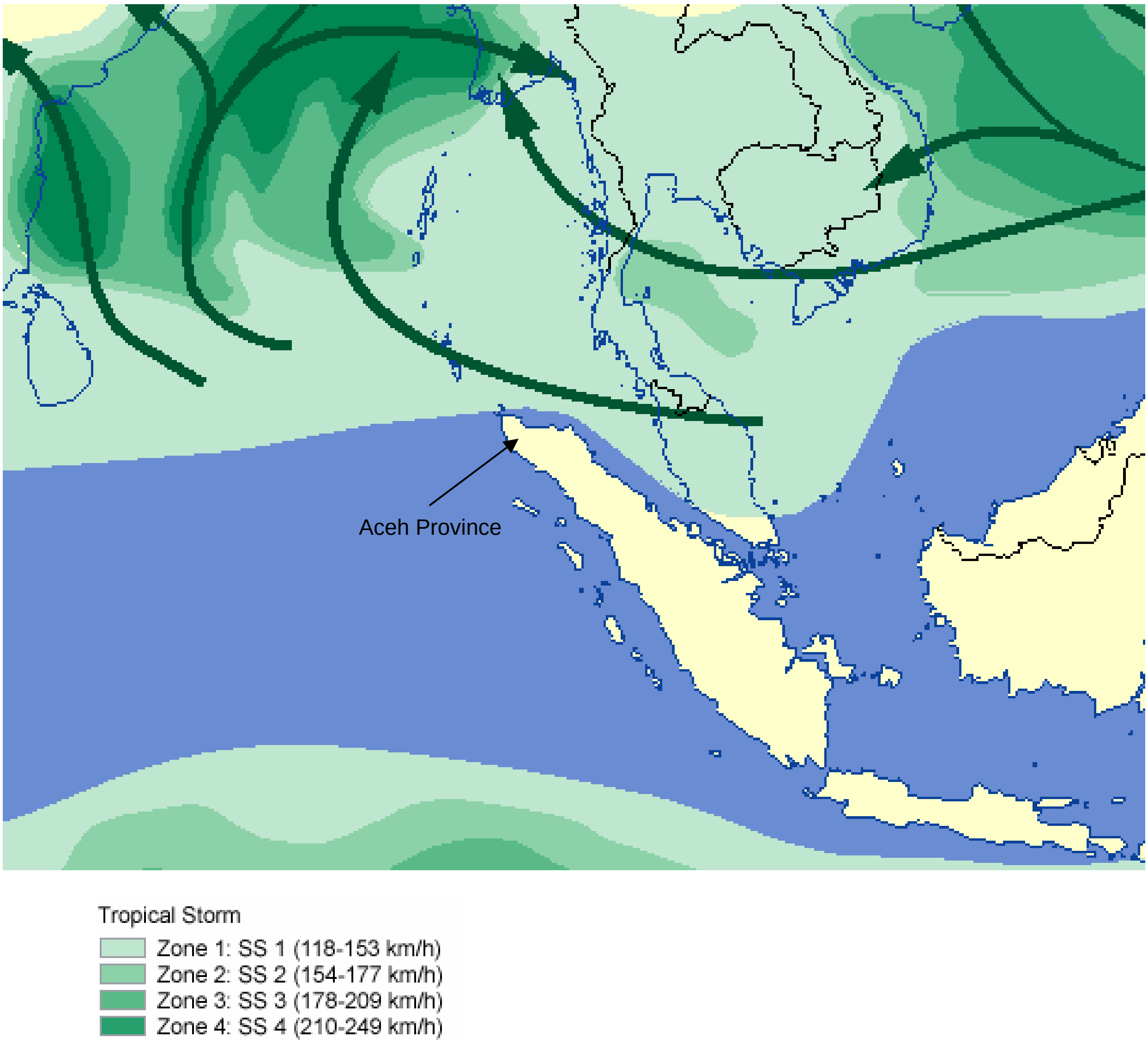


Figure 2.5 Tropical Storm Hazard (Munich Re, 2004)

German Red Cross site near Kampang Nelayan

Figure 2.6 Flood Prone Unstable Slopes, Sabang Island

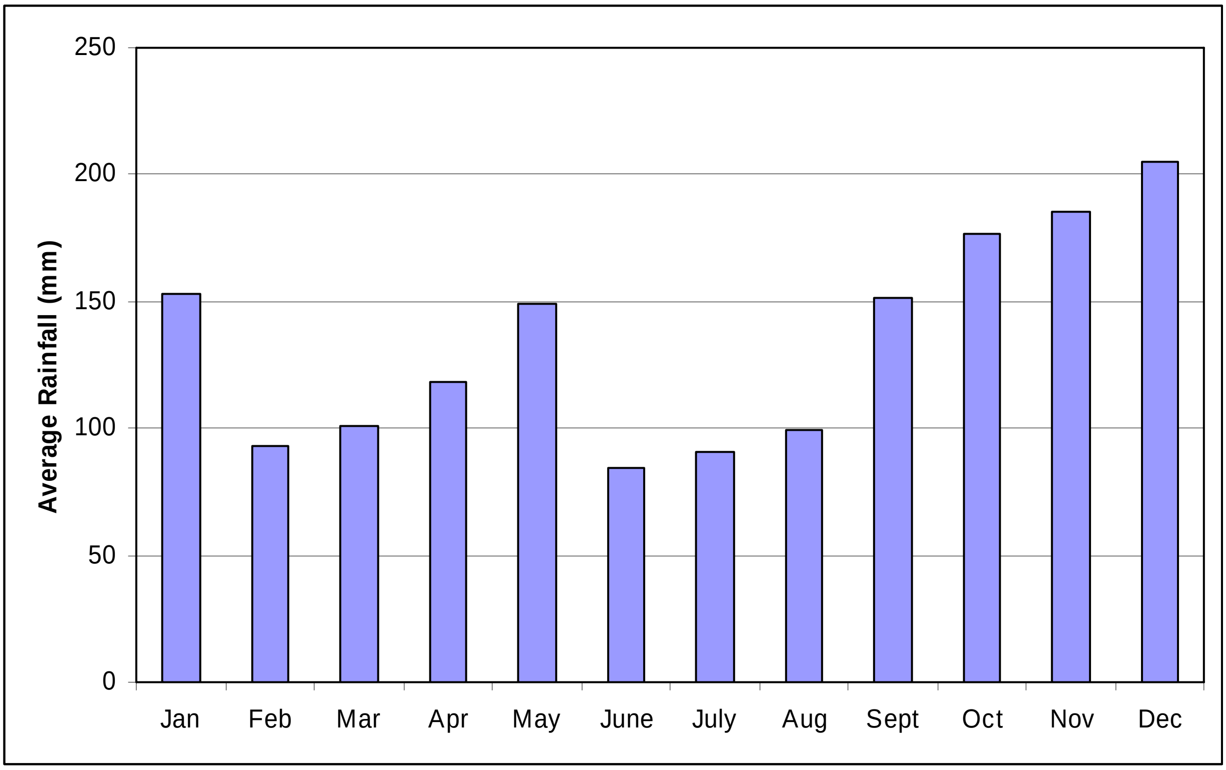


Figure 2.7 Average Yearly Rainfall for Banda Aceh

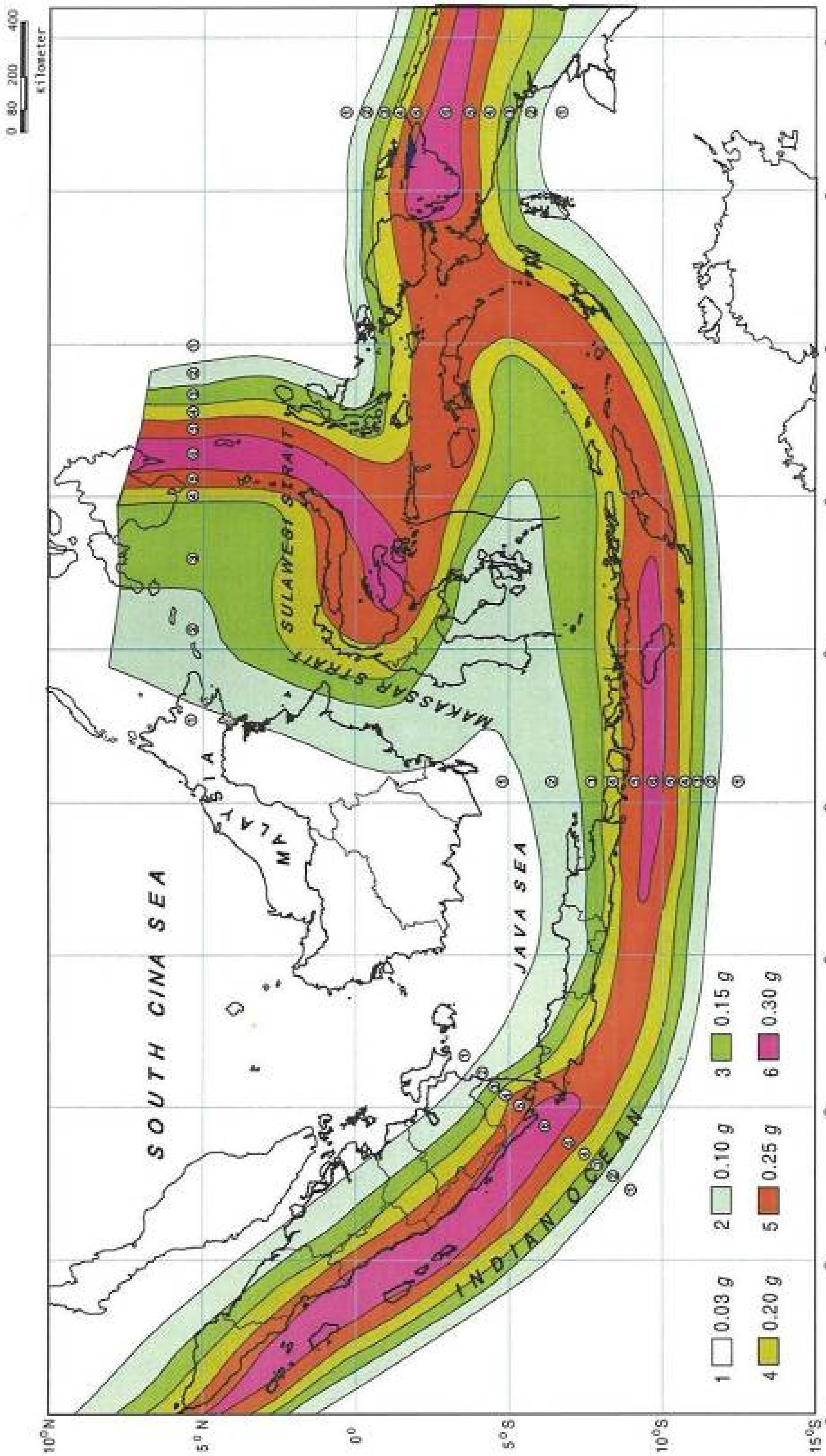
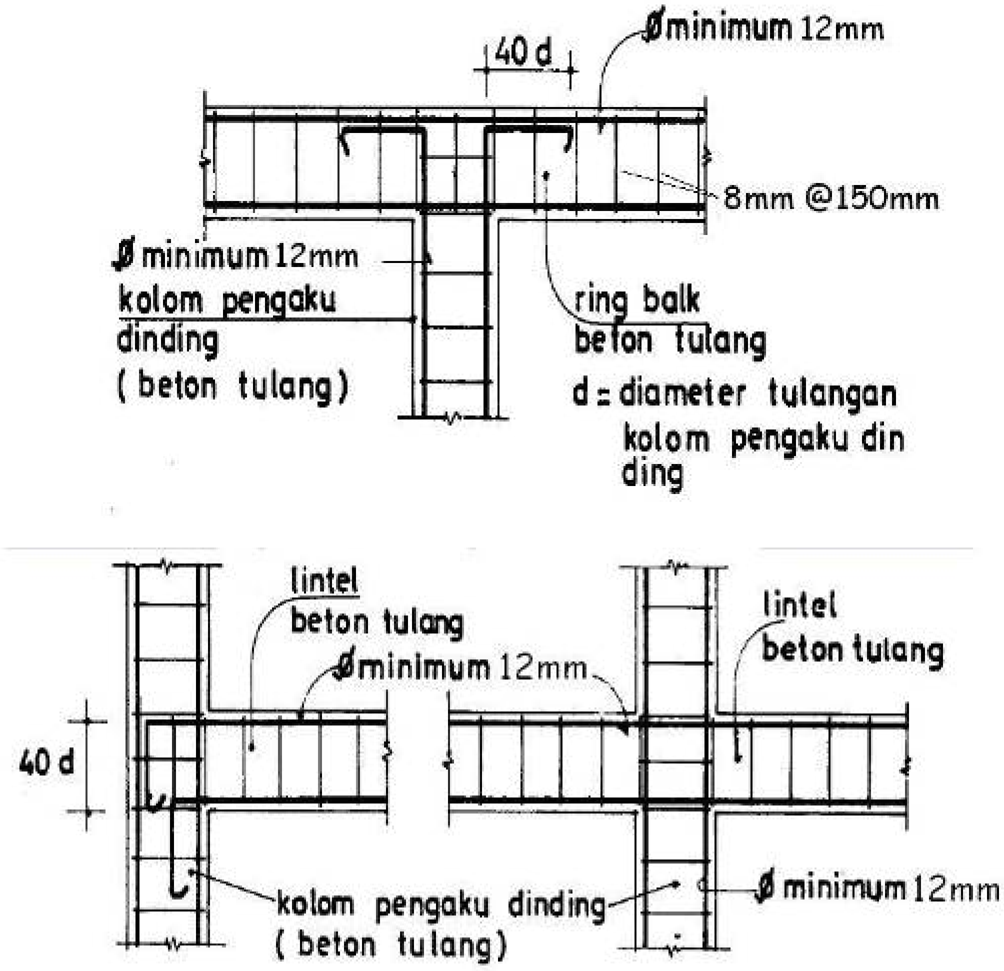


Figure 3.1 Seismic Zoning Map of Indonesia

Beam to Column Connections (modified from Boen, 1978)



Ring Beam Connection (after Boen, 1978)

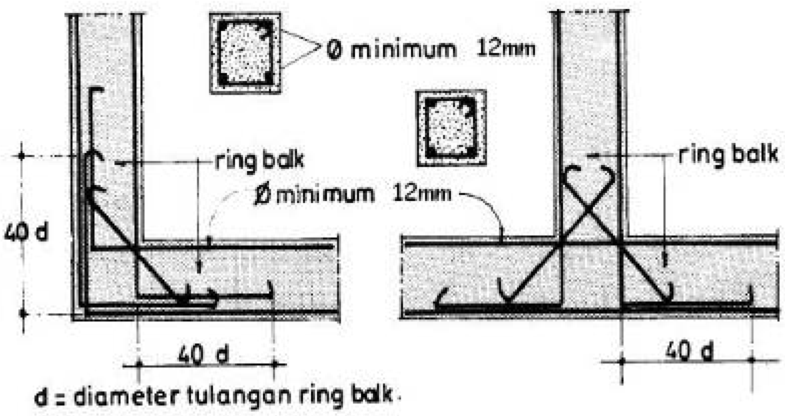
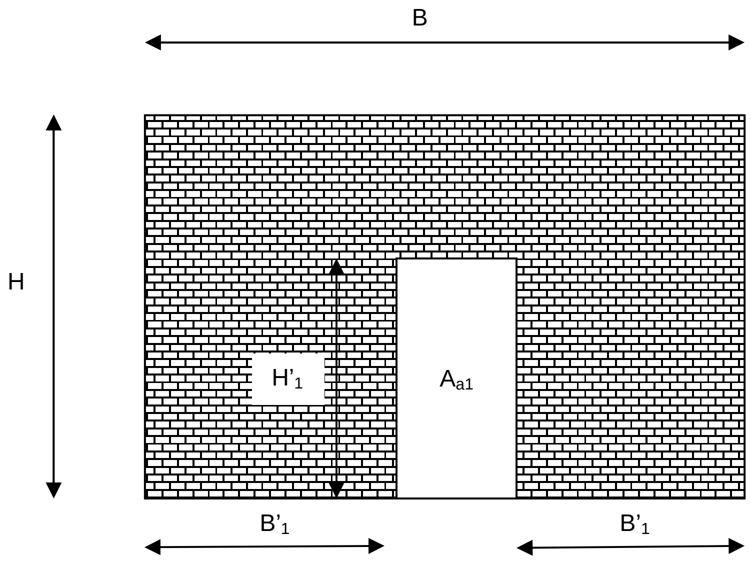


Figure 3.2 Typical Reinforcement Details

Apertures in Masonry Walls (after Dowrick, 2003)



Aspect Ratio of Wall - $H/B < 2/3$
Aspect Ratio of Edge Elements - $H'_1/B'_1 < 1$
Ratio of Aperture to Wall Area - $A_{a1} / HB < 1/3$

Lintel and Sill Beams (after Boen, 1978)

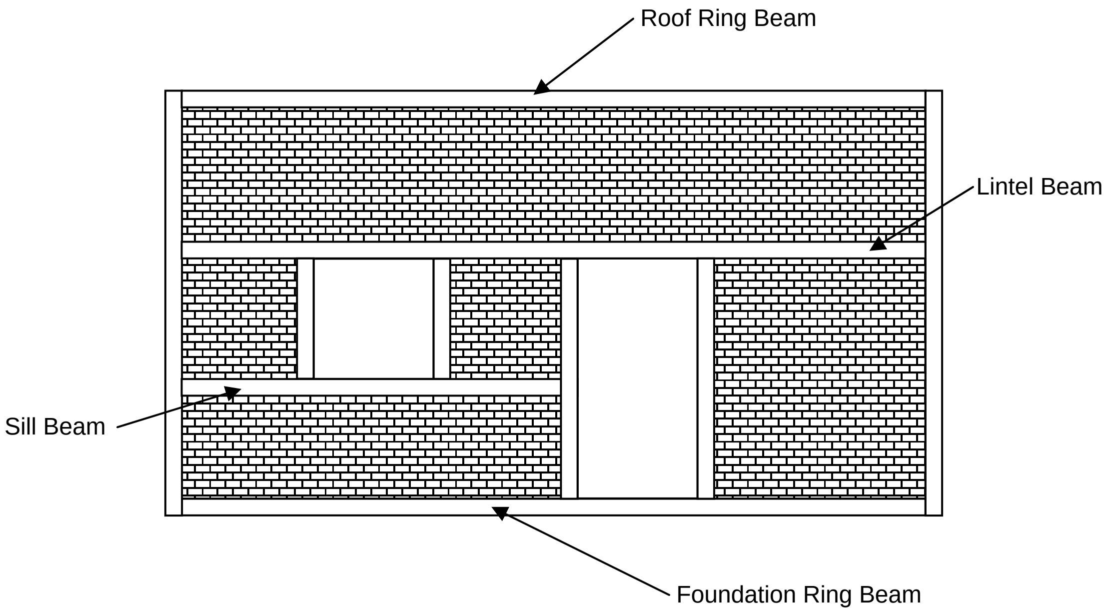
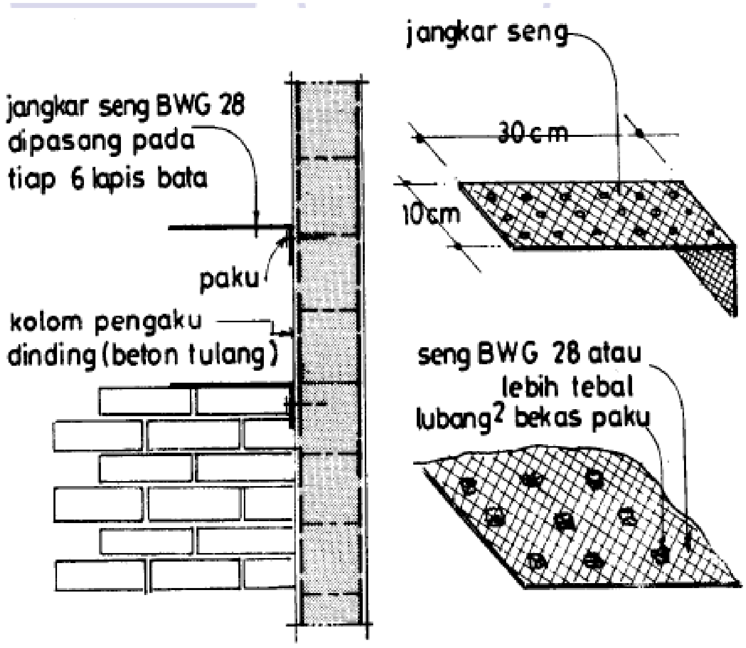


Figure 3.3 Typical Masonry Wall Details

Connection between Aperture and Wall (after Boen, 1978)



Connection between Column and Wall (after Boen, 1978)
(Appropriate for Timber and RC Columns)

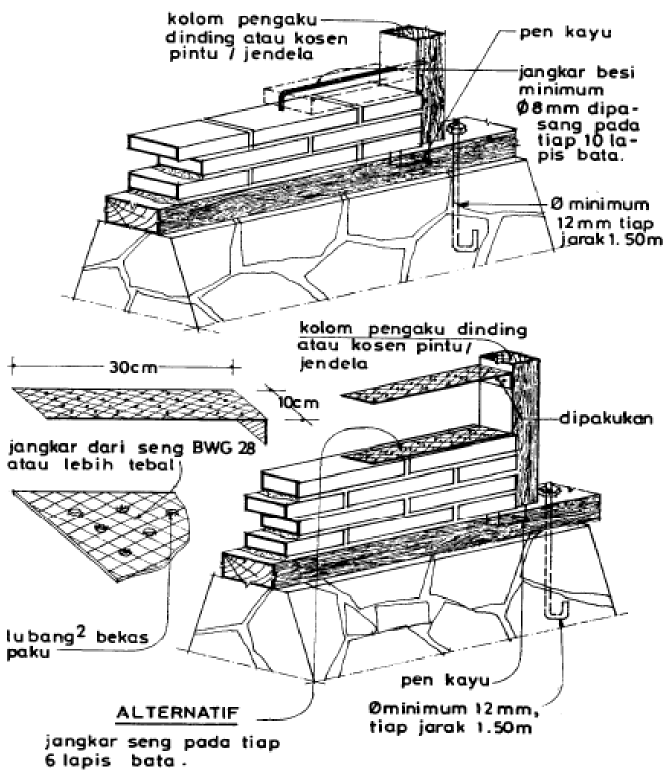


Figure 3.4 Typical Masonry Connection Details

Poor Layout for Sloping Ground

Suggested Layout for Sloping Ground
(not to scale, walls need to be sized, fill compacted and suitable drainage provided)

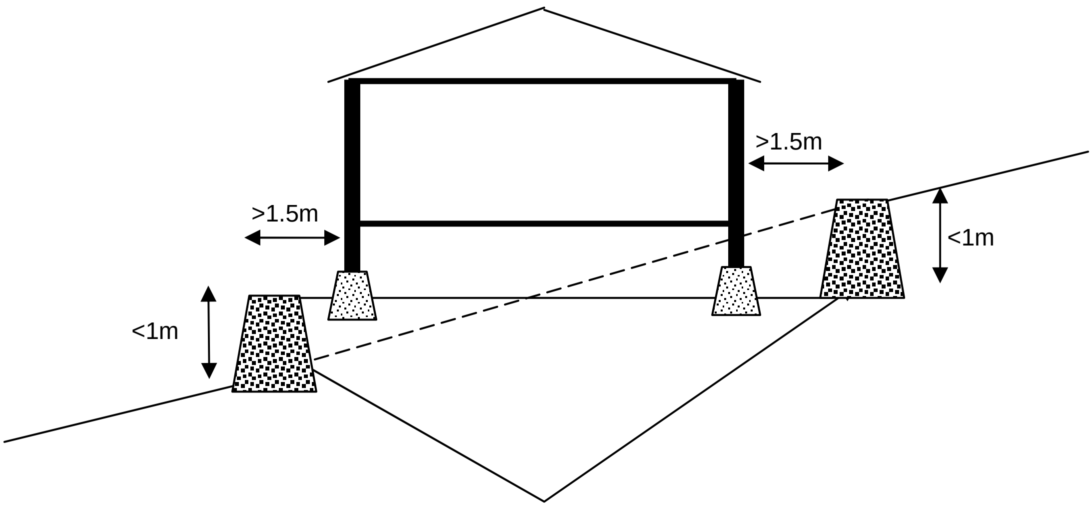


Figure 5.1 Siting on Sloping Ground

Appendix A

Glossary of Terms

A1 Glossary of Terms

A1.1 Earthquake Terms

An **earthquake** is a sudden occurrence of vibration in the earth caused by the abrupt release of energy in the Earth's lithosphere. The wave motion may range from violent at some locations to imperceptible at others.

The **epicentre** is the point of the Earth's surface vertically above the **focus** of the earthquake.

A **fault** is a fracture in the Earth's crust along which relative displacement occurs and from which seismic waves emanate.

The **focus** is the point in the Earth where the seismic disturbance originates, sometimes termed **hypocentre**.

Magnitude is a logarithmic scale of earthquake size, based on seismograph records. The magnitude is related to the total energy released by the earthquake. A number of different magnitude scales exist, including Richter or local (M_L), surface wave (M_S), moment (M_W), body wave (M_b) and duration (M_d) magnitudes. The most useful engineering scale is M_W, as this is directly related to the amount of energy released by the earthquake.

Peak ground acceleration (PGA) is the largest value of an acceleration time history during an earthquake and is the principal parameter used for earthquake engineering design.

A1.2 Volcanic Terms

A **fumarole** is an opening in Earth's crust, often in the neighbourhood of volcanoes, which emit steam and gases such as carbon dioxide, sulphur dioxide, hydrochloric acid, and hydrogen sulphide.

Phreatic eruptions occur when rising magma makes contact with ground or surface water. The extreme temperature of the magma causes near-instantaneous evaporation to steam resulting in an explosion of steam, water, ash, rock, and volcanic bombs.

Pyroclastic flows are a common and devastating result of some volcanic eruptions. They are fast moving fluidized bodies of hot gas, ash and rock which can travel away from the vent at up to 150 km/h. The flows normally hug the ground and travel downhill under gravity, their speed depending upon the gradient of the slope and the size of the flow.

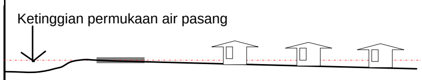
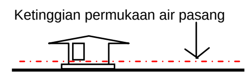
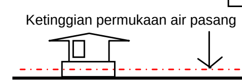
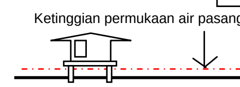
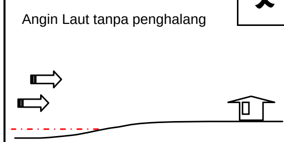
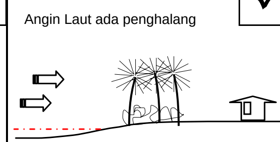
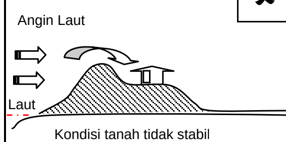
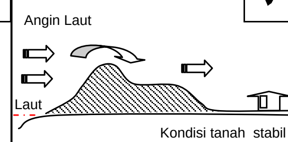
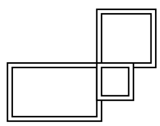
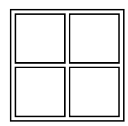
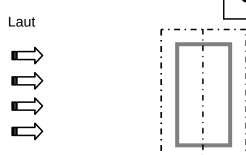
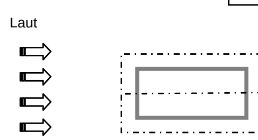
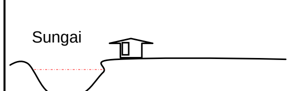
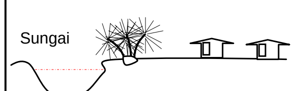
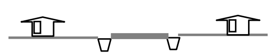
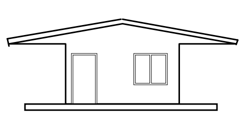
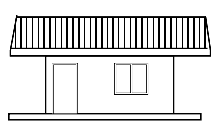
A **shield volcano** is a wide volcano with shallowly-sloping sides. Shield volcanoes are formed by lava that flows easily. Consequently, a volcanic mountain having a broad profile is built up over time by flow after flow of relatively fluid basaltic lava issuing from vents or fissures on the surface of the volcano.

A **stratovolcano** is a tall, conical mountain composed of both hardened lava and volcanic ash. The shape of these volcanoes is characteristically steep in profile because the lava flows that formed these volcanoes were highly viscous, and so cooled and hardened before spreading very far. They are often created by subduction of tectonic plates

Appendix B

UN Habitat Checklist

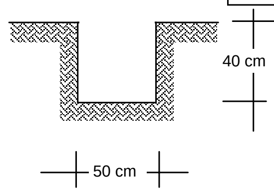
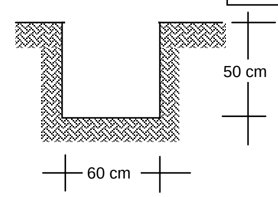
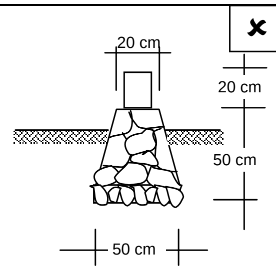
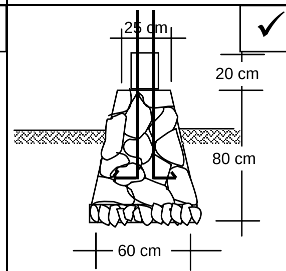
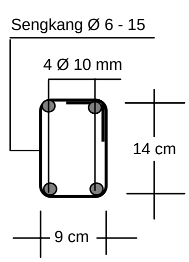
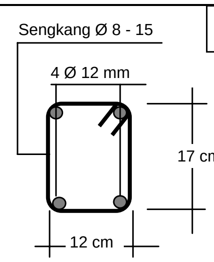
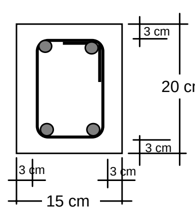
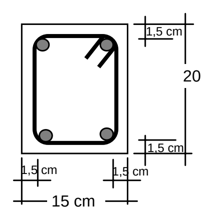
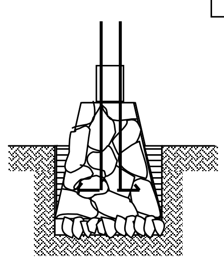
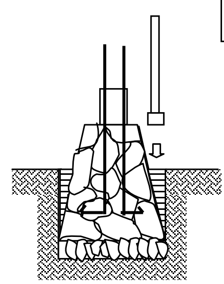
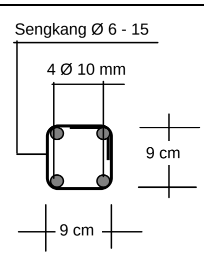
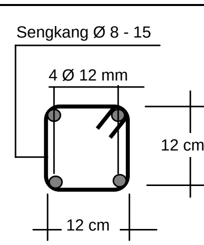
PANDUAN TEKNIS REKONSTRUKSI RUMAH

1.	**BANGUNAN DI LOKASI RAWAN BANJIR** 	✗ 	✓ 	✓✓ 
2.	**BANGUNAN DI LOKASI RAWAN BADAI**	✗ 	✓ 	
3.	**LETAK BANGUNAN DILOKASI RAWAN BADAI DAN LONGSOR**	✗ 	✓ 	
4.	**DENAH BANGUNAN**	✗ 	✓ 	
5.	**LETAK BANGUNAN**	✗ 	✓ 	
6.	**LETAK BANGUNAN DENGAN SUNGAI**	✗ 	✓ 	
7.	**LETAK BANGUNAN DENGAN JALAN**	✗ 	✓ 	
8.	**PINTU MASUK RUMAH**	✗ 	✓ 	

PANDUAN TEKNIS MATERIAL

NO.	URAIAN	TIDAK BAIK	BAIK	LEBIH BAIK
1.	**PASIR PASANG** - Jenis butiran pasir - Butiran pasir ditekan dengan jari tangan. - Genggam pasir dengan tangan dan buka.	✗ Kasar Lunak Gumpal	✓ Halus Keras Terurai	
2.	**PASIR BETON** - Jenis butiran pasir - Butiran pasir ditekan dengan jari tangan. - Genggam pasir dengan tangan dan buka. - Pasir	✗ Halus Lunak Gumpal Berbatu	✓ Kasar Keras Terurai Bebas batu	
3.	**BATU KRIKIL BETON** - Jenis batu krikil - Bentuk batu krikil - Ukuran batu krikil	✗ Tidak padat Bulat 3-5 cm	✓ Padat Pecah min. 3 sisi 2-3 cm	
4.	**BATU KALI / BUKIT PONDASI** - Jenis batu - Kekerasan - Bentuk batu - Ukuran batu	✗ Tidak padat Mudah pecah Bulat 10-15 cm	✓ Padat Tidak mudah pecah Pecah min. 3 sisi 15-30 cm	
6.	**DINDING BATU** - Jenis batu - Material batu - Proses pembuatan - Kekerasan - Ketahanan terhadap air - Ukuran	✗ **Batu bata merah** Tanah liat Cetak tangan - bakar Mudah pecah Mudah hancur 4.5 cm x 9 cm x 18 cm	✓ **Batu bata pres** Posolan & Semen Cetak Mesin Tidak mudah pecah Tidak mudah hancur 6.5 cm x 10 cm x 20 cm	✓ **Concrete block** Semen & Pasir Cetak Mesin Tidak mudah pecah Tidak mudah hancur 10 cm x 20 cm x 40 cm
7.	**SEMEN** Jenis Semen	✗ Portland cement Type. II	✓ Portland cement Type. I	
8.	**KAYU** Jenis kayu	✗ Lunak Ada mata kayu Retak Bergetah	✓ Keras Bebas mata kayu Tidak retak Tidak bergetah	
9.	**BESI BETON** **TYPE : BESI POLOS**	✗ ● Ø 6 mm ● Ø 9 mm ● Ø 11 mm	✓ ● Ø 8 mm ● Ø 10 mm ● Ø 12 mm	

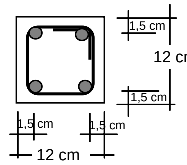
PANDUAN TEKNIS KONSTRUKSI

NO.	URAIAN	TIDAK BAIK	BAIK	LEBIH BAIK
1.	**GALIAN PONDASI**			
2.	**PONDASI BATU KALI / BUKIT** **CAMPURAN SPESI**	 1 Semen : 5 Pasir	 1 Semen : 4 Pasir	
3.	**PEMBESIAN SLOOF**			
4.	**BETON SLOOF** **CAMPURAN SPESI**	 1 PC : 3 Pasir : 5 Krikil	 1 PC : 2 Pasir : 3 Krikil	
5.	**URUGAN TANAH KEMBALI**	 Tidak dipadatkan	 Dipadatkan	
6.	**PEMBESIAN KOLOM**			

7. **BETON KOLOM**

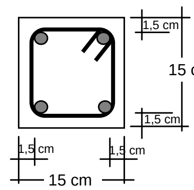
CAMPURAN SPESI

✗



1 PC : 3 Pasir : 5 Krikil

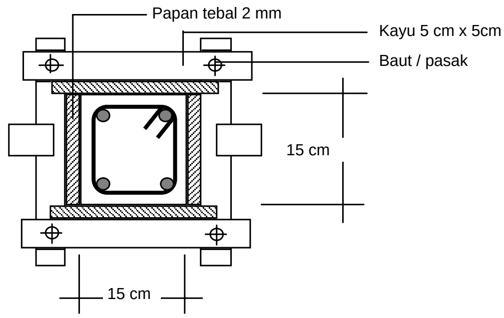
✓



1 PC : 2 Pasir : 3 Krikil

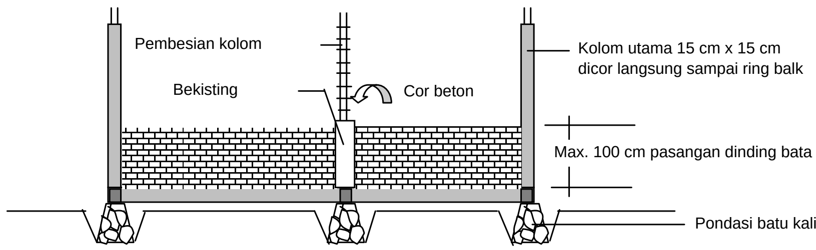
8. **BIKISTING KOLOM**

- Ukuran Kolom beton 15 cm x 15 cm
- Pengecoran beton kolom langsung sampai dengan ketinggian dinding.
- Papan bikisting bagian dalam dilabur dengan oli bekas/solar agar mudah pada waktu melepas bekisting.
- Pastikan bekisting kolom sudah LOT sebelum kolom di cor.



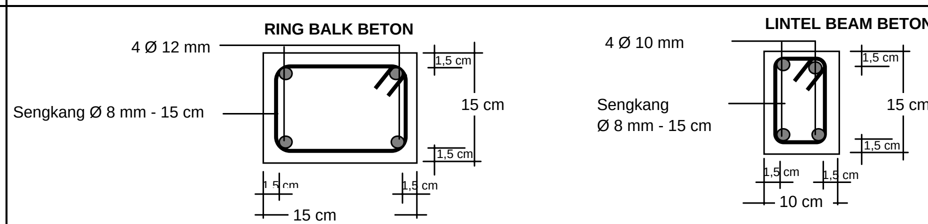
9. **DINDING BATU BATA**

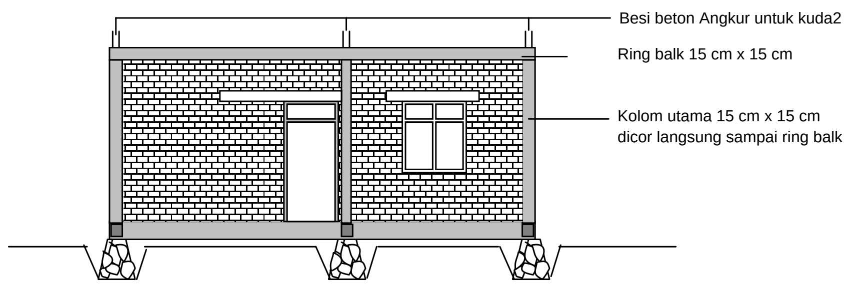
- Dinding batu bata dipasang dengan campuran spesi 1 semen : 4 pasir.
- Kolom penguat dinding dicor setiap ketinggian pasangan batu bata mencapai 100 cm.
- Cor kolom penguat dengan campuran spesi : 1 semen : 2 pasir : 3 krikil



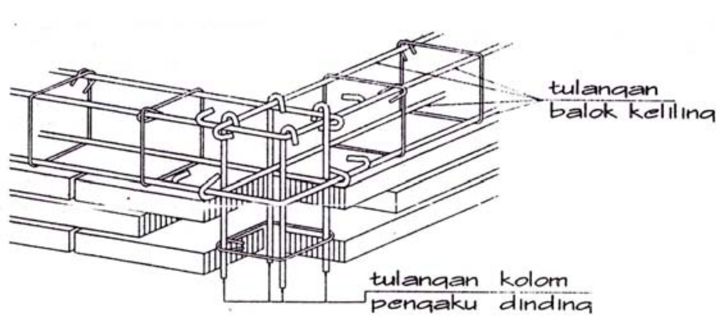
10. **RING BALK BETON**

- Ring balk beton ukuran 15 cm x 15 cm dengan campuran spesi : 1 semen : 2 pasir : krikil.
- Lintel beam beton ukuran 10 cm x 15 cm dengan campuran spesi : 1 semen : 2 pasir : krikil.



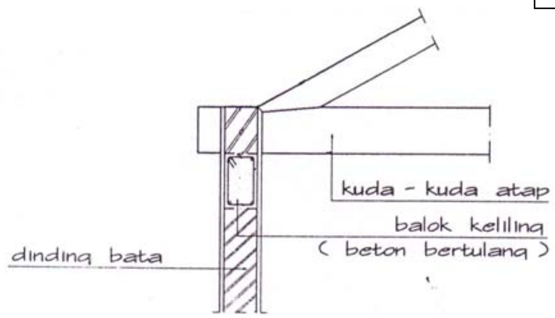


11. **SAMBUNGAN BESI KOLOM DENGAN RING BALK**

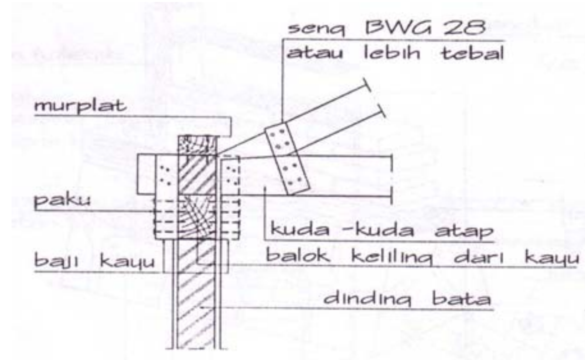


12. **KUDA-KUDA ATAP**

✗

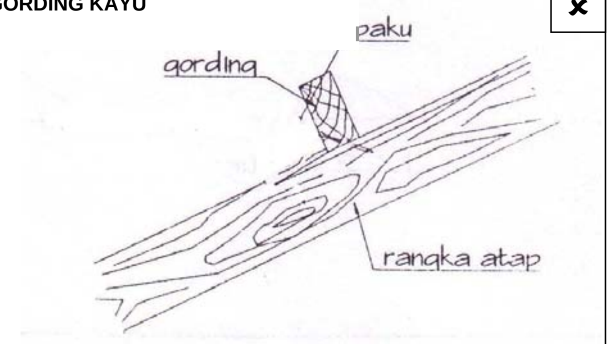


✓

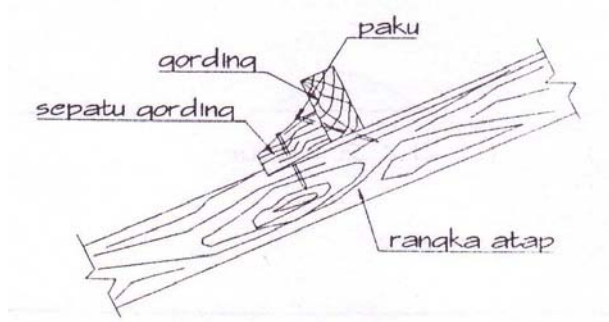


13. **GORDING KAYU**

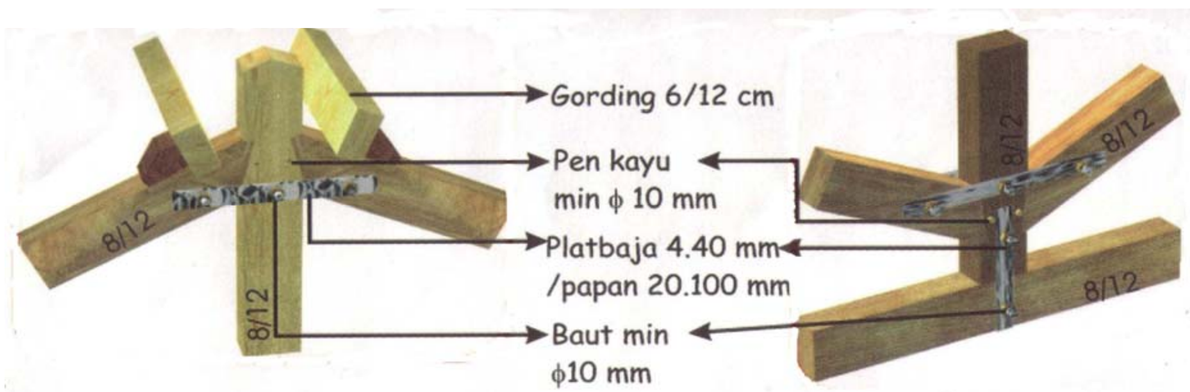
✗



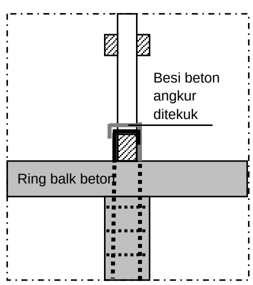
✓

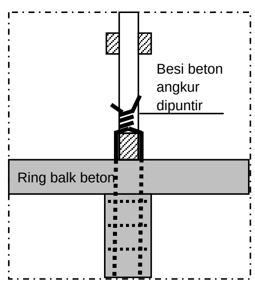


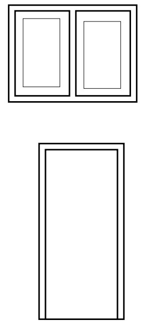
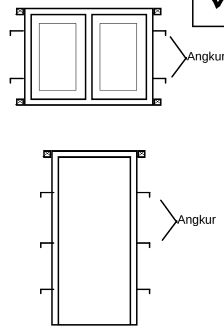
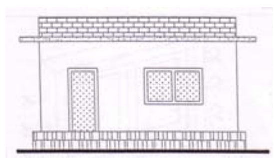
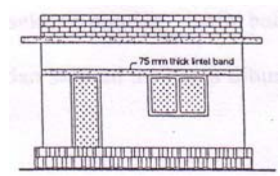
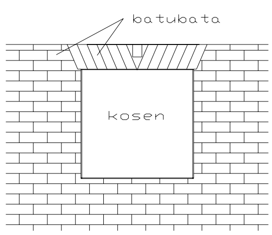
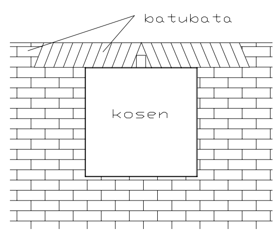
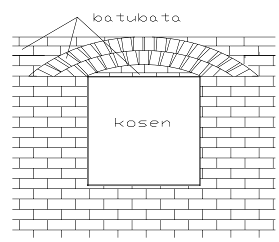
14. **HUBUNGAN ANTAR BALOK KUDA-KUDA**



15. **ANGKUR KUDA - KUDA**





16.	**KUSEN PINTU & JENDELA**	✗ 	✓ 	
17.	**LINTEL BEAM**	✗ 	✓ 	
18.	**ROLLAAG**	✗ 	✓ 	✓✓ 

Appendix C

FEMA 154 Survey Sheets

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

(1) Purpose of spreadsheet

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

(2) Structural types

W1 Light wood frame, residential or commercial, I 5000 square feet
W2 Wood frame buildings, > 5000 square feet.
C1 Concrete moment-resisting frame
C2 Concrete shear wall
C3 Concrete frame with unreinforced masonry infill
RM 1 Reinforced masonry with flexible floor and roof diaphragms
RM2 Reinforced masonry with rigid diaphragms
URM Unreinforced masonry bearing-wall buildings

(3) Definitions

Mid-Rise : 4 to 7 stories
High-Rise : 8 or more stories
Vertical Irregularity : Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Soil Type C : Soft rock or very dense soil; S-wave velocity: 360 - 760m/s; blow count > 50; or undrained shear strength > 100kPa.
Soil Type D : Stiff soil; S-wave velocity: 180 - 360m/s; blow count: 15 - 50; or undrained shear strength: 50 - 100kPa.
Soil Type E : Soft soil; S-wave velocity < 180m/s; or more than 30m of soil with plasticity index > 20%, water content > 40%, and undrained shear strength < 25kPa.

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: World Vision
Orientation:
Street Name:
Area Name: Meulaboh
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S					0.8			

Comments

OK
NO

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: KJRC
Orientation:
Street Name:
Area Name: Meulaboh
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE

A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil

OTHER HAZARDS

Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S					0.8			

Comments

OK

NO

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: Caritas
Orientation:
Street Name:
Area Name: Singkil
Floor Area: 48 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S	6.8							

Comments

OK

YES

Banda Aceh Review

Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: IOM
Orientation:
Street Name:
Area Name: Singkil
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S					1.0			

Comments

OK

?

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: CRS
Orientation:
Street Name:
Area Name: Meulaboh
Floor Area: 45 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE

A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil

OTHER HAZARDS

Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S					1.0			

Comments

OK

?

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: BRR
Orientation:
Street Name:
Area Name: Meulaboh
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S					0.8			

Comments

OK
NO

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: UNHCR
Orientation:
Street Name:
Area Name: Chalang
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S							4.8	

Comments

OK
YES

Banda Aceh Review
Rapid Visual Seismic Screening of Buildings

PLAN

ELEVATION

Agency: Zero to One
Orientation:
Street Name:
Area Name: Nias
Floor Area: 36 m^2
No of Occupants:

PHOTOGRAPH

SOIL TYPE						OTHER HAZARDS			
A Hard Rock	B Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Falling Hazards	Flooding	Liquefaction	Slopes

BASIC SCORE, MODIFIERS, AND FINAL SCORE

Building Type	W1	W2	C1 (MRF)	C2 (SW)	C3 (URM INF)	RM1 (FD)	RM1 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.5**	**2.8**	**1.6**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7)	N/A	N/A	0.4	0.4	0.2	0.4	0.4	0
High Rise (>7)	N/A	N/A	0.6	0.8	0.3	N/A	0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Ductile Yes	2.4	2.4	1.4	2.4	N/A	2.8	2.6	N/A
Ductile No	0.0	-1.0	-1.2	-1.0	-0.2	-1.0	-0.8	-0.2
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-0.8	-1.2	-0.8	-0.8	-0.8	-0.8
Final Score, S				4.6				

Comments

OK

YES

Appendix D

Site Selection Checklist

ACEH NIAS POST TSUNAMI RECONSTRUCTUION

Siting Checklist

(1) Golden rules (Hold mouse over cell to view)

(2) Purpose of spreadsheet

Four steps are required to identify potential environmental issues related to siting new housing:
Step One: Answer the question in the first column of each form with a yes or no.
Step Two: Mark the answer in the second column
Step Three: Refer to the 3rd column (Guidance) to determine whether the yes or no answer identifies a potential environment-linked issue (“If the answer is…”).
Step Four: If the answer does identify an environmental issue, then review the guidance in the 3rd column as to what actions should be taken to address the issue. Key Reference documents cited above can also be used to identify how to address the issue identified.
A fourth column is provided for comments on the question and planned actions if such actions are necessary.
The Comments column can also be used to indicate when a question is not relevant to the site.

(3) Sources of data

C Kelly (2005) Identifying Critical Environmental Considerations in Transitional Shelter Site Selection, Construction, Management and Decommissioning

http://www.benfieldhrc.org/disaster_studies/rea/resources/TransFieldGuideSriLanka.pdf

ACEH NIAS POST TSUNAMI RECONSTRUCTUION
Siting Checklist

Question	Answer	Guidance	Comments
Has the community near or surrounding the site been consulted about the site selection? *Consultation is an important way to avoid or limit conflict over the location of a shelter site. This conflict often revolves around access or control over natural resources.*	**Yes – No**	**If the answer is No: Communities near or surrounding the site should be involved in the site selection process.**	
Do prospective site residents and the surrounding community have similar occupations? *Significant social or occupational differences may indicate differing views on the use and control of natural resources and could lead to conflict.*	**Yes – No**	**If the answer is No: To the degree possible, social and cultural make-up of communities before the tsunami should be maintained in the selection of new sites**	
Have the prospective site inhabitants been consulted about the site and types of shelter to be constructed? *The resources and effort made to establish a site will be wasted if the prospective inhabitants are not willing to use the site.*	**Yes – No**	**If the answer is No: Prospective inhabitants of a transitional shelter site should be involved in the site selection and shelter design process.**	
Is the site more than 15 km of a natural park, wildlife refuge or protected area? *A site near a park or similar site carries the risk that shelter occupants will extract resources from the protected site.*	**Yes – No**	**If the answer is No: Site occupants can be educated about not damaging the protected areas.**	
*Does the site avoid ecologically sensitive locations? *Ecologically sensitive areas include wet lands, lagoons, lakes, coastal zones (as defined in regulations), parks, wildlife refuge and protected areas or areas inhabited by rare or endangered animals.*	**Yes – No**	**If the answer is No: If use of this type of site cannot be avoided then activities to limit or remediate unavoidable environmental impacts needs to be developed. These activities will need to be developed by specialists as part of the site plan.**	
Does the site avoid culturally significant locations? *Culturally significant sites include mosques and archeological sites.*	**Yes – No**	**If the answer is No: Use of these types of locations should be avoided. If they need to be used, buffer zones and use rules should be established in consultation with owners of the site, local authorities and concerned populations.**	
Has the site been used for industrial or commercial purposes or as a dump in the past? *Industrial sites include mines and quarries. The types of sites indicated may contain toxic materials.*	**No – Yes**	**If the answer is Yes: Verify that there are no toxic materials present in the soil or ground water.**	
Has the site been used for housing in the past? *Former housing sites may include hazardous locations, such as garbage dumps or septic systems.*	**No – Yes**	**If the answer is Yes: Verify that there are no environmentally hazardous sites (e.g., septic systems) are located where a shelter will be built. Mark hazardous sites if they exist.**	
Is the site located near or next to an industrial site or commercial location? *These types of sites can generate air and water pollution which can affect the health and welfare of site inhabitants.*	**No – Yes**	**If the answer is Yes: Sites with a risk of air or water pollution from industrial or commercial activities should be avoided.**	
Is the site located in an area subject to flooding? *Flooding can come from rivers/streams, lagoon overflow, heavy rains and poor drainage, or from sea waves, e.g., at high tide or during storms. Note that should have a slope of 2 to 4% to facilitate natural drainage.*	**No – Yes**	**If the answer is Yes: Flood-vulnerable sites should be avoided. When such sites must be used, then provisions for raising ground level under structurs, drainage and protective dikes are necessary. Such interventions may need to be removed during decommissioning. A local flood warning system should be established.**	
Is the site subject to landslides or heavy erosion? *Sites with a slope of more than 10% (5 degrees) may be prone to severe erosion. The steeper the site the more likely landslides will occur, particularly during heavy rains and earthquakes.*	**No – Yes**	**If the answer is Yes: Landslide and erosion prone sites should be avoided. If not possible, natural vegetation should be maintained in the landslide-vulnerable slopes and throughout the site, the site should be terraced to limit run-off, and structures should not built landslide-prone slopes. A local landslide warning system should be established.**	

ACEH NIAS POST TSUNAMI RECONSTRUCTUION
Siting Checklist

Question	Answer	Guidance	Comments
Does the site have a high water table? *A high water table may indicate the potential for liquefaction in an earthquake, and also poses problems for the construction and use of toilets, particularly during the rainy season.*	**No – Yes**	**If the answer is Yes: Soil testing may be required to assess liquefaction potential. Appropriate drainage systems will be needed during the rainy season.**	
Are there any linear features or vertical offsets on the site, which could indicate an active fault? *Building across an active fault should be avoided.*	**No – Yes**	**If the answer is Yes: The feature should be investigated by a qualified geologist. Ideally buildings should be at least 50m from any active fault.**	
Is there a plan to vegetate and landscape the coastline to mitigate future tsunamis, for any site close to the coastline (say within 1km)? *Building close to exposed coastlines should be avoided.*	**No – Yes**	**If the answer is Yes: Even if the site is considered safe, an evacuation route should be identified and the residents informed.**	
Is there potable water available on a sustainable basis for the site? *The water can initially come from wells, stand pipes, bowers/tanks but a long term solution should be sought.*	**Yes – No**	**If the answer is No: A site should not be selected until a sustainable sourse of potable water is available.**	
Are there adequate health and educational facilities within 1 km from the site? *These and other public facilities are needed for a normal life of the site inhabitants. If they are too far away they cannot be easily used and increasing the hardship faced by site inhabitants.*	**Yes – No**	**If the answer is No: Adequate access to health and educational facilities should be provided as part of the site plan.**	
Does the site have easy access to roads and public transportation? *Access to roads and transportation improves livelihood options for site residents and reduces their need to locally extract environmental resources. Good access also lowers the price of commercial items in the transitional shelter site, which has a positive impact on livelihoods and demand on local environmental resources.*	**Yes – No**	**If the answer is No: Sites should have good access, or access (e.g.. roads) should be established as part of the site construction process.**	
Is there a clear and legally established agreement to use the potential transitional shelter site? *This agreement can be in the form of government decree, lease or other legal arrangement. Agreement terms should cover (1) land ownership,(2) the terms should cover (1) land ownership,(2) the conditions for the use of the site, (3) decommissioning of the site and (4) any payments or services due during the occupation or decommissioning of the site.*	**Yes – No**	**If the answer is No: No site should be selected without a legal agreement for use and decommissioning.**	