HANDBOOK ON

Good Building Design and Construction

Aceh and Nias Islands

BRR NAD – Nias

ISDR International Strategy for Disaster Reduction

Special Unit for South-South Cooperation

UNDP

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Purpose of the Handbook

This Handbook is made to provide simple information to house owners, house designers and builders, and building monitors to teach principles of good design and good construction in a natural hazard prone area. Thoroughly studied, they will also guide on whether to repair or rebuild damaged houses. The descriptions are followed by a code of minimum standards for construction of houses in Aceh and Nias Islands.

Since many concepts are not easy to describe, the hand- book contains pictures to facilitate understanding. The photographs have all been taken of construction practices in the reconstruction of Aceh and Nias since the great Tsunami and earthquake of 26 December 2004 and the second major earthquake of 28 March 2005. Aceh, Nias and nearby islands, and other areas along the west coast of Sumatra, are earthquake and tsunami prone, and are also subject to flooding due to sudden downpours of rain. The principles of this book are designed to minimize vulnerability to these natural hazards.

In an area that is prone to earthquakes, not only principles of design are important, but also principles of construction, since the best designed house, which has been well covered and painted, may hide serious structural defects in the construction. These defects may lead to serious injury and death, and loss of property, when the forces of nature strike the house.

Let us develop a culture of safety in all our buildings, not just doing the minimum and the cheapest, but building houses that will safeguard families and assets in times of emergency.

Forewords

Kuntoro Mangkusubroto
Director, Executing Agency of Rehabilitation & Reconstruction for Aceh & Nias

The task of rebuilding a region devastated by a major disaster is formidable. Issues hindering progress have to be resolved quickly while supporting regulations are still being developed and precedents have yet to be established. Limited local capacity to meet the required pace of the reconstruction progress further complicates the challenges as a number of outside players are brought into the process.

In the area of housing, outside contractors are brought in to provide additional construction capacity. However, outside agencies may not be clear on the existing national housing regulations and building designs may not suit the environment.

UNDP has been assisting BRR in addressing these challenges in the recovery of Aceh and Nias, Indonesia, from the massive earthquakes and tsunami hitting the area at the end of 2004 and early 2005. It developed a simple Handbook for single-storey house construction in hazard prone areas. This Handbook emphasizes earthquakes and flood hazard. This initiative is supported by the Mitigation Centre of Syiah Kuala University, Aceh's largest university, which has taken the initiative to distribute the Handbook on CD.

The Handbook is designed for house builders and owners so that they can better understand the principles of house design and construction. It incorporates the national building standards and explains them in a simple way. It includes the code of minimum standards for construction and a checklist for good house construction. Aiming to promote good practices, the Handbook clearly illustrates good and bad practices as well as common mistakes.

BRR initially published this Handbook in Bahasa, Indonesia for distribution in Nias Islands. It is used to socialize and teach local communities on how to better build a house within their environment.

Through this Handbook, BRR NAD-Nias hopes all readers in the region and also other countries will benefit, so that the learning from its experience can be shared broadly to mitigate potential mistakes, shortcomings, and challenges in housing construction.

Kuntoro Mangkusubroto

Director, Executing Agency of Rehabilitation & Reconstruction for Aceh & Nias

Bo Asplund
UN Resident Coordinator
Indonesia

Some areas of the world are especially prone to major natural disasters. One such location is the northern part of Sumatra. Its vulnerability was demonstrated by the earthquake and tsunami of 26 December 2004 (magnitude 9.1), and the second major earthquake of 28 March 2005 (magnitude 8.7). Hundreds of thousands died or were injured due, in part, to limited understanding of disaster preparedness. Had people known more about preparedness and mitigation activities, large numbers of injuries and deaths could have been avoided. The importance of having a safe shelter in a secure location cannot be overemphasized.

In rebuilding a devastated community, it is crucial that rehabilitation and reconstruction efforts deliver the best possible improvements to ensure safety. It is simply not acceptable to let families and children go back to houses and schools that are unsafe because they have not taken into account safety features relevant to hazards experienced in that region. Commitment to quality design and construction must be a priority in recovery work. Rebuilding must be undertaken in a sustainable way so that life and health are better protected for the future.

Shelter is a basic human need, alongside food, clothing, education and health. A house protects from the climate and animals, and it also has a socio-cultural role as the centre of family life and as a manifestation of self-identity. The house also serves as a capital good, an asset through which to conduct economic activities in supporting livelihoods. A well-designed house is a house that supports the lifestyle of the dweller, and a well-constructed house protects the lives of its residents.

UNDP is pleased to present this Handbook as an aid to assist local communities to design and build stronger houses and to make themselves safer against extreme climatic and seismic events. It is written with the aim of making technical information available and understandable to those who build so many of the homes: the homeowners themselves. While it is being used primarily as a guide in the reconstruction of houses in the recovery from the tsunami, we hope that its longer-term impact will be to improve building culture for the future.

Bo Asplund
UN Resident Coordinator
Indonesia

Yiping Zhou
Director
Special Unit for South-South Cooperation, UNDP

Over the last fifty years, the frequency and severity of natural hazards resulting in disasters has risen dramatically mainly due to an increase in the size and vulnerability of exposed populations. The international community has acknowledged in different fora that disasters constitute one of the main threats to development in Small Island Developing States and other vulnerable countries.

The tsunami of 26 December 2004 in the Indian Ocean resulted in an incalculable damage to five affected countries in Asia, including Indonesia. In Indonesia, the coastal communities in the provinces of Aceh and Nias were severely affected and many families were rendered homeless. Another earthquake occurred in Nias on 28 March 2005 with further destruction. The combined losses in lives, livelihoods and shelter were immense.

When the hazardous events occurred in Nias and Aceh, the vulnerabilities of the communities were ruthlessly exposed. In rebuilding a devastated community, it is crucial that rehabilitation and reconstruction efforts build on the lessons learned. It is unacceptable to let families go back to unprotected houses. Hence, commitment to quality design and construction of shelter must be a prerequisite in disaster recovery.

Apart from its traditional function as shelter, a house has sociocultural roles as a centre of family education, cultural and life values, and as an expression of self identity. For most in Indonesian society, the house serves as a venue through which livelihood activities are transacted. A well designed and constructed house will protect the lives and livelihood of its residents from the threat posed by natural hazards.

The Special Unit for South-South Cooperation is proud to co-publish the “Handbook on Good Building Design and Construction” with the UNISDR. This handbook, developed out of the learning in Aceh and Nias, provides useful information for home owners, house designers, builders and construction monitors. It explains how to design and build houses in such a way as to resist major natural hazards such as earthquakes and floods.

We hope that it will not only be useful in Indonesia but also in other disaster vulnerable countries.

Yiping Zhou
Director
Special Unit for South-South Cooperation, UNDP

Sálvano Briceño
Director
United Nations Secretariat of the International Strategy for Disaster Reduction

Accumulated climate change and disaster risk impose a growing threat to people's lives and livelihoods, increasingly affecting socio-economic development. The 2004 tsunami claimed more than 220,000 lives and left millions without shelter. Among the tsunami-affected communities, Aceh and Nias suffered the most damage, which is strongly felt even today – two years after the disaster.

Against the tragedy caused by the vulnerability to the tsunami, 168 governments gathered at the second World Conference on Disaster Reduction, Kobe, Japan, 18-22 January 2005, where they adopted the Hyogo Framework for Action (2005-2015): Building the Resilience of Nations and Communities to Disasters. The desired resilience of nations to disasters can only be possible when communities develop their capacities to reduce risk and vulnerability to natural hazards.

The Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), which has the global mandate for coordinating disaster risk reduction in line with the Hyogo Framework for Action, attaches great importance to the community-based risk reduction initiatives. UN/ISDR has increased its efforts in strengthening the exchange of information, experience and knowledge on community risk reduction.

Factoring disaster risk reduction in post-disaster rehabilitation and reconstruction is an ongoing endeavor of UN/ISDR with the purpose of protecting people's lives and livelihood from future possible disasters. At the international level, UN/ISDR has, in partnership with UNDP and ILO and support from Japan, Switzerland and Italy, established the International Recovery Platform (IRP). The IRP aims to guide disaster-affected communities to build back better, safer and resilient to disasters. At the community level, UN/ISDR is also actively engaged in supporting partners, in the reconstruction process in Pakistan earthquake-hit areas through partnerships with UNDP and NGOs to ensure the integration of risk reduction into the rebuilding of villagers' houses and schools.

With the same endeavor, UNDP Indonesia has produced a guide "Handbook on Good Building Design and Construction" based on concrete reconstruction experiences in tsunami-hit Aceh and Nias in Indonesia. As well, the handbook explained eight design principles and eight construction and material principles in a simple language, supported by photos of good and bad practices in housing construction. The handbook is a contribution to the ongoing international effort in guiding communities to integrate risk reduction in reconstruction process.

The handbook can be used as an easy tool to increase understanding and knowledge of those individuals and organizations that will be involved in the post-disaster rehabilitation and reconstruction of individual houses and public facilities, such as schools and health centers. Finally, the handbook can be used as an easy guide on how to build back better and stronger. I strongly encourage community-based organizations and NGOs working in disaster prone areas to utilize and promote it as much as possible.

Sálvano Briceño
Director
United Nations Secretariat of the International Strategy
for Disaster Reduction

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The development of this Handbook was encouraged by Mr. Fakri Karim of UNDP Indonesia and Mr. T Nirarta Samadhi (Koni) of UNDP Indonesia; then BRR –Nias, who translated the final draft into Bahasa Indonesia, the first language in which the Handbook was published.

Contents

Purpose of the Handbook iii

Forewords v

- Kuntoro Mangkusubroto v
  Director, Executing Agency of Rehabilitation & Reconstruction for Aceh & Nias
- Bo Asplund vii
  UN Resident Coordinator, Indonesia
- Yiping Zhou ix
  Director, Special Unit for South-South Cooperation, UNDP
- Salvano Briceno xi
  Director, International Strategy for Disaster Reduction

Acknowledgements xiii

Design Principles

Summary Description 1

1 Foundations 2

2 The building needs a coherent structure 5

3 Joining walls to roof structure 14

4 Tying walls to building structure 20

5 Roof truss ties 26

6 Cross bracing of walls and roof 29

7 Drainage principles 32

8 House elevation 33

Construction and Materials Principles

Summary Description **37**

1 Foundations 39

2 Sand and gravel 45

3 Mixing concrete 52

4 Making columns 53

5 Reinforcement 59

6 Roofing 62

7 Tying walls to structure 66

8 Wells and septic tanks 68

Code of Minimum Standards for House Building 71

House Building Checklist 77

Design Principles

Summary Description

To meet the cultural, social, and physical requirements of the residents, and to provide a safe dwelling to shelter them from the hazards that may impact from their environment, a house must be properly designed. In order that the house provides for all the family needs, and keeps them and their loved ones and belongings safe, the following aspects of a house or a structure must be considered in the design:

A safe house must be based on a strong foundation and therefore it must be given primary attention. Problems with foundations not properly designed lead to unequal settlement, cracking of walls and floor, and structural weakness. To resist outside forces, a house needs a coherent and simple structure. House structure is like the skeleton to the body. If it is strong, it protects the whole house. Walls must be joined to the roof. Walls and roof can strengthen each other if joined properly. Walls also must be joined to the building structure. Walls should be supported by the columns, and need to be connected to them. Roof trusses must be flexible but strong enough to enhance safety. Walls and roof need bracing against lateral movement. Drainage plans are essential to good house design. The design should carefully consider whether the house needs to be elevated to safeguard its contents from flooding.

1 Foundations

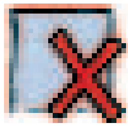
A safe house must have a strong foundation.

- The ground under the building has to bear the weight of a house. If it is weak soil, the foundations must be made stronger. If the house has more than one floor, the foundation must also be made stronger. Foundations are best when continuous under the house.

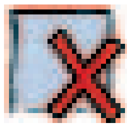
- Is the building built on sand, rock, clay?

- Soil for a good foundation that can carry the weight of a house must be well drained so that it is dry and not waterlogged.

- Waterlogged soil can become liquefied in an earthquake - turn to a semi-liquid – so that structures sink into the ground.



Example of **bad foundations**. The houses are being built in a swampy, flood-prone area. Soon after they were built the houses were flooded when there was heavy rain and water entered the houses. These foundations in permanently wet soil will also be weak when an earthquake shakes the ground.

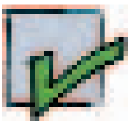


Liquefaction. Example of a well-built and well-structured house that was not quite finished when a major hazard struck. The house was good but the foundations were poor. Due to a major earthquake the foundations suffered from liquefaction of the ground, and due to the weight of the house, it subsided unevenly into the ground.

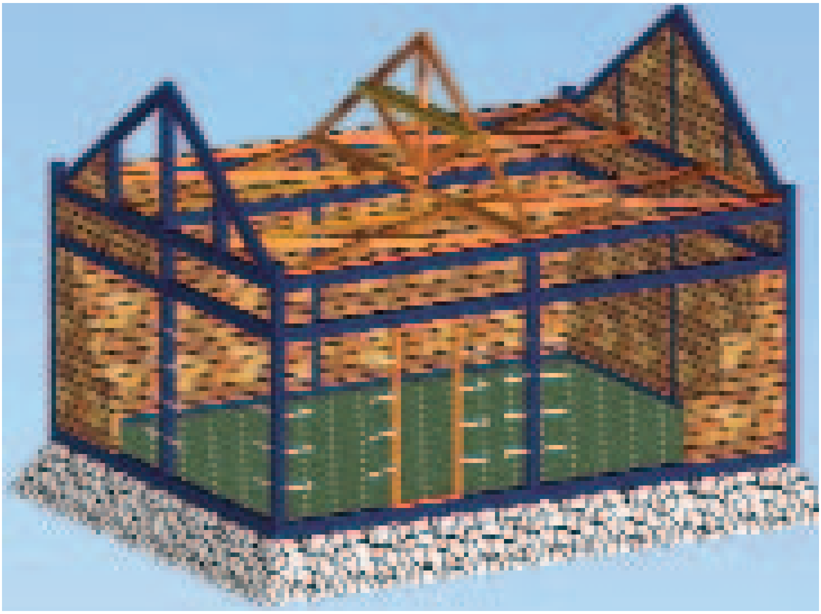
2 The Building needs a Coherent Structure

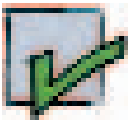
If the structure is coherent and strong, it protects the whole house.

- A regular structure
- An integrated structural ring beam around tops of doors and windows connected to columns
- An integrated structural ring beam around top of walls connected to columns
- Triangular gable end walls must be structurally supported

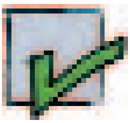


This **good, regularly-structured building,** withstood the tsunami when all buildings around it were totally destroyed. Notice the structure of columns and floors which are all joined to each other in a regular format. Overhanging parts of the building are all well supported by columns.

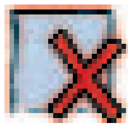




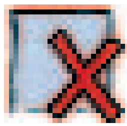
This illustrates **good structural design** principles for a reinforced concrete structure and brick wall building. A complete structural frame around the building is tied in to the foundation, the walls and the roof structure. Doors and windows have a beam over them to carry the weight of the wall above and to strengthen the columns. The top of the walls is also tied together with the columns, by a second reinforced concrete ring beam, and end walls are strengthened.



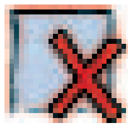
Good structure. This is a well-structured house that follows all the above design principles. Notice the good foundation, the good structure framing the building, and the two ring beams connecting all the building elements at the top of doors and windows and at the top of the walls.



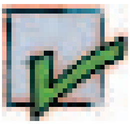
This is an example of **bad practice**. The columns are very poor, made in many stages with gaps in concrete in between so that the reinforcing will rust. The columns are also too small because the bricks were laid first, the columns were made to fit within the thickness of a brick, and there was not enough room for properly covering the column reinforcement. There is no ring beam over the window, which has a wooden frame that has been placed in the wall after most of the window opening was made, making it very weak to a lateral force from a hazard impact. If the wood of the window frame deteriorates, the wall will begin to crack and may then collapse.



Another example of a **poorly structured house**, despite having good columns and a ring beam at the top of walls. In earthquakes, despite the fact that this is a new building, the walls have already begun to crack diagonally from all the corners of the windows. This is why the building remains unfinished. This building is hard to repair in its current situation.

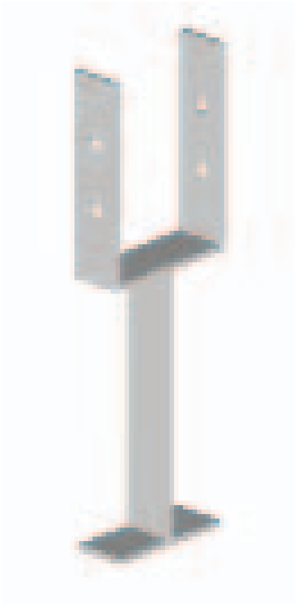


Not good structure. Another example of a reasonably designed house which has too little attention given to bracing the walls against lateral forces. No strengthening is provided around openings in the walls, and they will be subject to cracking when the forces of nature strike, as well as to progressive deterioration which will be hard to repair.



Good practice. Reinforced concrete column inserted to strengthen the triangular gable end wall so that it will not fall when a lateral force strikes the building. The reinforcing steel must be cast into the concrete ring beam at the top of the walls. All end walls of this nature need reinforcement to strengthen them, or they are liable to fall when the building is subjected to a major lateral force.

Connection of wood frame building to concrete frame/brick stub walls

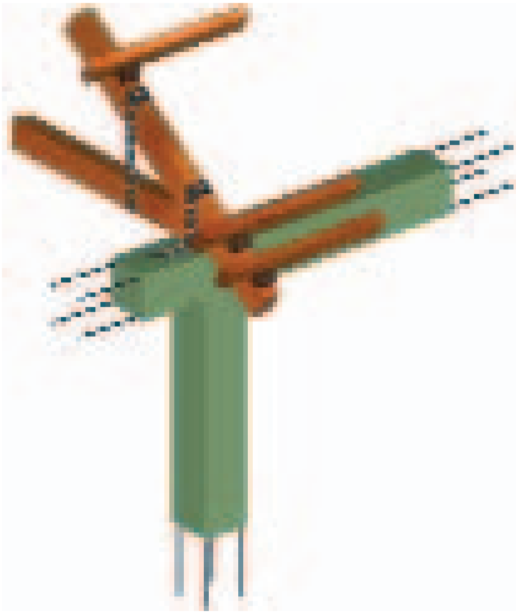


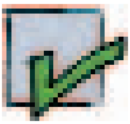
It is essential that a wood frame structure mounted on a concrete frame/brick stub wall must be fully anchored together. A bracket, as shown above left, made of non-corrodible metal, must be cast into the bearing structure to provide a structural connection for the whole wall through to the foundation. The wood column must be bolted to the bracket as shown, and the bracket must be fully secured into the concrete as shown on the right.

3 Joining Walls to Roof Structure

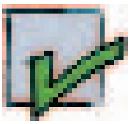
Join walls and roof to strengthen each other.

- Column reinforcement should protrude from the top of concrete columns and be bent around roof trusses for structural strength, or roof trusses should be strapped with metal ties to the wall structure.

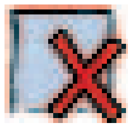




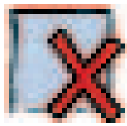
An illustration of binding roof trusses to building structure. Roof trusses should be constructed over columns, and for a concrete column the reinforcement should protrude at the top and be bent over roof trusses to join the roof structure with the wall structure. Metal straps can be used for this role, particularly where the building structure is made of wood.



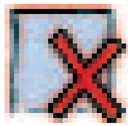
An example of column steel reinforcement bent over roof truss to tie house structure to the roof structure. This is an essential detail in areas subject to earthquake and to winds, to maintain house integrity when a natural hazard strikes the structure. The ring beam at the top of the wall has not yet been constructed on this house.



Example of **bad practice**. Roof trusses are not constructed over columns or connected to the building structure. Reinforcing steel from the column is bent down out of the way instead of being bent over the roof structure to tie it down and to tie the roof structure to the wall structure for greater strength.



Example of **incorrect practice**. The roof structure is good, but no connection is made between roof trusses and the building structure. The roof is just standing on the top of the house walls and is subject to moving with high winds or other forces of nature.



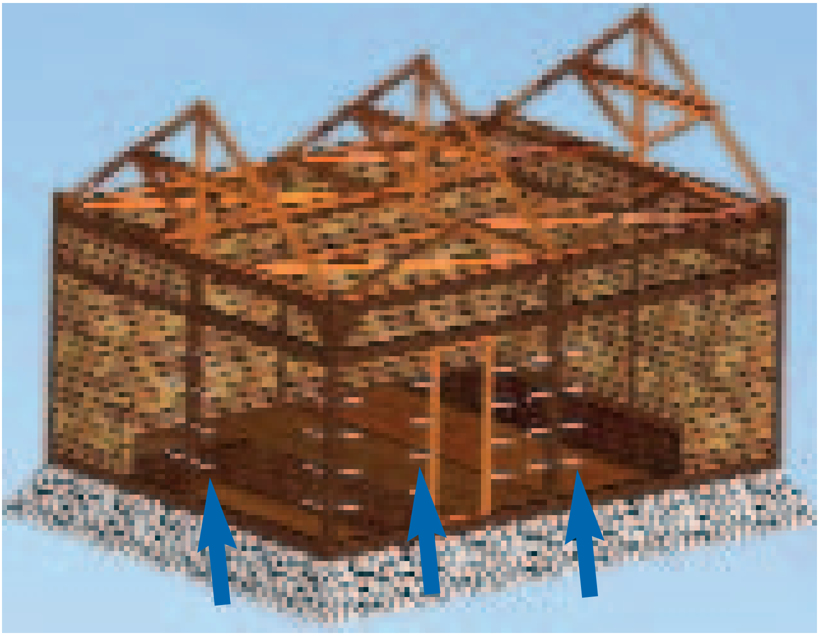
Poor practice. This strengthening of the triangular end walls of a reinforced concrete structure and brick wall building is insufficient. The steel reinforcement is not long enough to brace the entire height of the wall and to be wrapped around the apex of the roof truss. It also has too few hoops for adequate strength. The reinforcing steel of the gable end strengthening column must be cast into the concrete ring beam at the top of the walls.

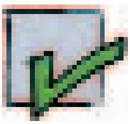
4 Tying Walls to Building Structure

Walls tied to columns protects them from falling.

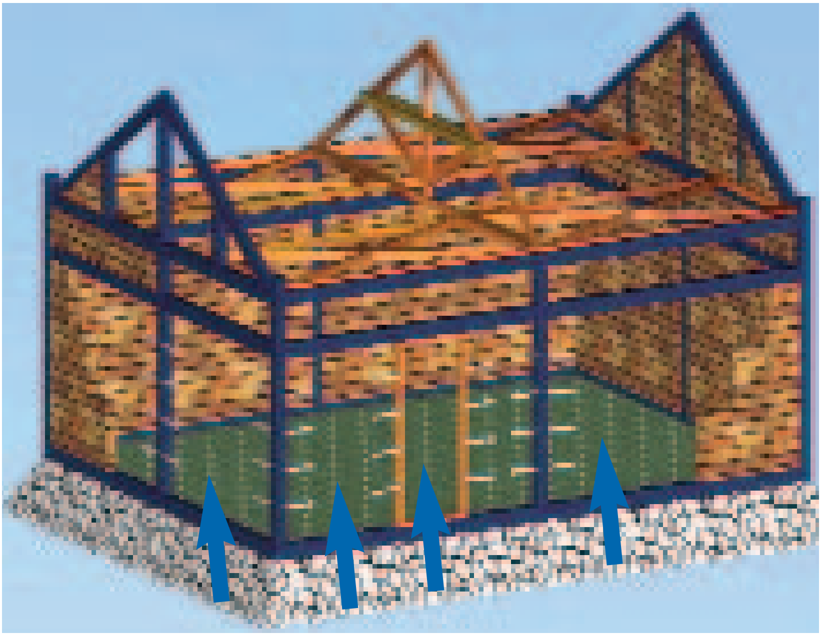
- Walls must be tied into the building structure so that they do not move separately when the forces of nature impact them.

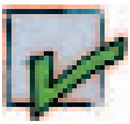
- Wall ties should be hooked into the wall structure.





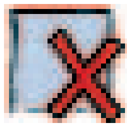
Good practice. An illustration for a wood frame building, where metal ties are used to tie wall materials to the main structure of the building. Steel wall ties are to be at 40cm spacing.



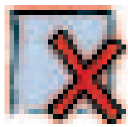


Good practice. An illustration of a reinforced concrete frame and brick wall building, where metal ties are used to tie walls to the main building structure. Steel wall ties are to be at 40cm spacing and a minimum of 8mm diameter, and bent at the end. They are for all openings in the walls.

A good example of wall ties cast into columns to connect the walls with the building structure. Ties are at 40cm spacing from bottom to top of the wall. However, in this illustration they lack hooks at the ends at this point in construction.



Result of no ties. This is an example of what happens when walls are not tied to columns. The main part of this building (two floors on the left) withstood the force of the tsunami striking it, but the one floor extension collapsed. The columns could not support the force of the tsunami on the walls of this house extension because of the lack of ties between the walls and the columns. The one floor part also lacked a strong structure.

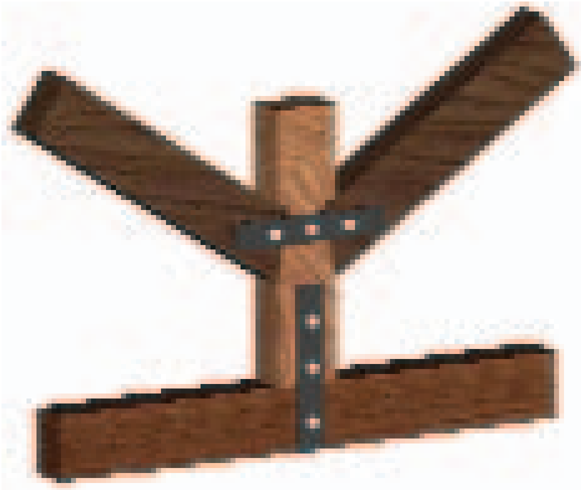


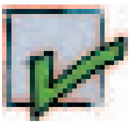
Result of lack of ties. Another example of what happens when the walls are not tied to the columns. The wall panel on the left is moving away from the column because it has not been tied into the column.

5 Roof Truss Ties

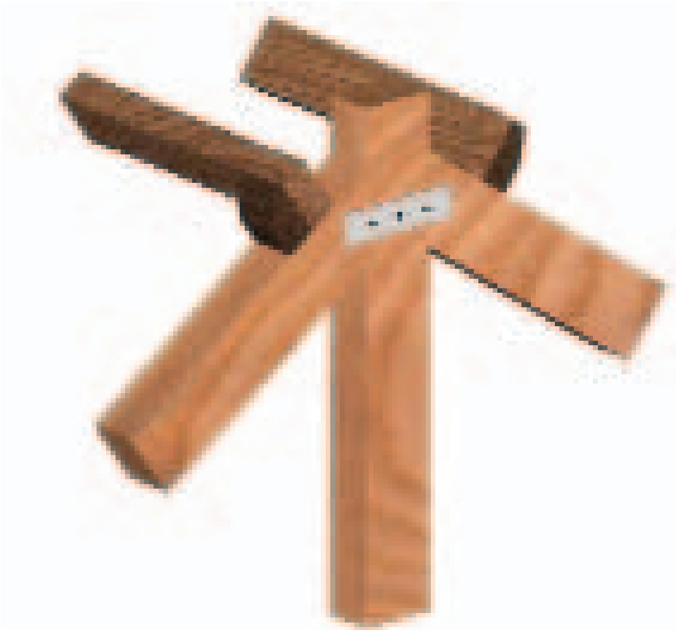
Flexible but strong roof trusses enhance safety.

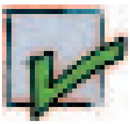
- The joints of roof trusses need to be bolted together and tied with metal straps to provide flexibility but not collapse under the forces of nature.





This illustration shows the metal straps tying together the different elements of the roof structure at this joint in the roofing, so that they will be held together when affected by extreme forces of nature.





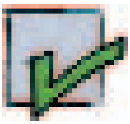
This illustration shows a strap across the joint at the apex of the roof structure. This is always **good practice**. Notice also that for a wooden roof structure, wooden blocks should be used for support, not a single nail and not nails into the wood.

6 Cross Bracing of Walls and Roof

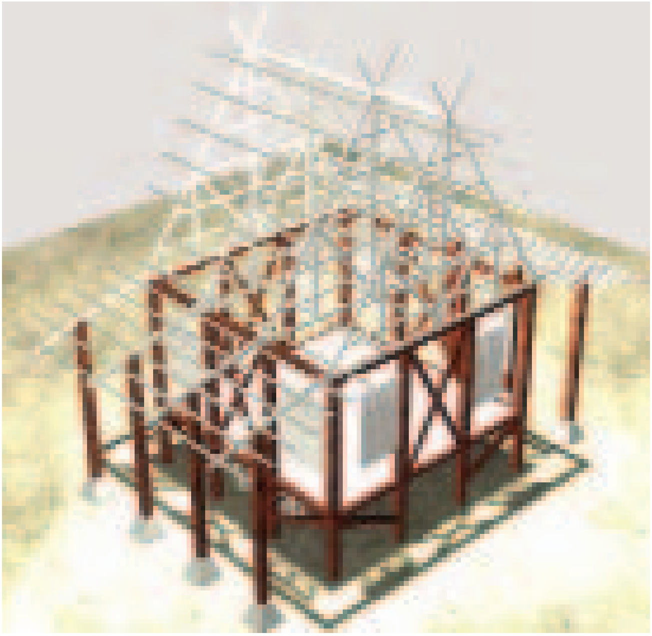
The walls and roof need bracing against lateral movement.

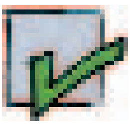
- In order to resist lateral forces, walls and roof structure need cross bracing at all levels, particularly if it is a wooden structure.

- This is a major principle in the construction of traditional houses.



Good practice. Traditional Nias houses, which have stood through many earthquakes, are well supported and well cross braced throughout. Notice a large amount of supporting columns under the house and in the walls, and a lot of solid cross bracing in all directions under the house to prevent lateral movement.





Example of a **cross bracing** system for the walls and also for the columns under the house for a wooden house structure. The cross bracing system provides strength against lateral forces so that the building does not collapse sideways but is held together. This is a system used in traditional houses and needs to be continued in modern houses.

7 Drainage Principles

Drainage plans are essential to good house design.

- A high rainfall area requires a drainage plan for roof water to a common drain. Levels of the drainage system need to be included on plans so that rain water flows away and does not form puddles that breed insects around houses.

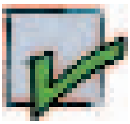
- Drains should be covered or bridged where necessary to allow access over the top for people and vehicles.

- Drains should have a "V" form at the bottom to reduce accumulation of water if levels are incorrect.

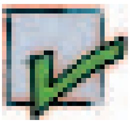
8 House Elevation

Safeguard house contents from flooding.

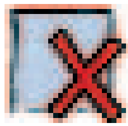
- The house floor should be elevated above the surrounding ground level, and extra height is needed in vulnerable situations such as locations close to the sea, or close to a floodable waterway, or in a tsunami-prone area.



Good house elevation in an area vulnerable to tsunamis. The houses are elevated on well-reinforced concrete column structures, which are also designed to withstand lateral forces by the reinforced angle cross bracing at the top of the columns.



Good house elevation. A larger building with a similar good raised base. This building has a concrete raft foundation to spread the load of the building over a weak foundation soil.



A **poor development** because the new houses are built on the ground, where subsidence and scouring due to the earthquakes and tsunami have led to a lower ground level than before. There is danger of flooding from the river which runs round the site, as well as vulnerability to the sea. These houses should be elevated on stilts in this location.

Construction and Materials Principles

Summary Description

The design of a building may incorporate all the good design principles, and yet the way it is constructed may lead to its failure when the forces of nature are applied. This section deals with good construction methods, and principles for choosing good materials for construction.

Even with the best design, poor construction practices and wrong materials can prevent a house from protecting its residents. If it is not constructed properly or if wrong materials are used, the house itself may injure or kill people when outside forces impact it.

In constructing a house the first and foremost thing is to follow the design. Foundations must form a strong base for the house. The choice of building materials, such as sand and gravel, affect the strength of the building, and care must be taken to choose the best materials. Mixing good clean ingredients with little water makes strong concrete. Wrong ingredients seriously weaken concrete. Strong columns provide strength to the structure. The reinforcement of columns is important, as it strengthens concrete like bones in the body. Use the best in order to be safe. A strong roof provides lasting weather protection. Tying walls to the structure strengthens the walls from collapse in an emergency. Wells and septic tanks are essential health supporting components of a house and therefore must be planned wisely.

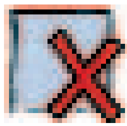
1 Foundations
Make a strong base for the house.

- Foundations must be founded on solid ground.

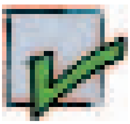
- Only broken rock should be used in foundations, not unbroken rounded river stone or rounded seashore stone. River stone can be used if broken.

- Sufficient mortar is needed to join stones into one solid foundation that will not subside unequally.

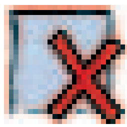
- Reinforcement is needed to connect the bases of column reinforcing steel in the foundations.



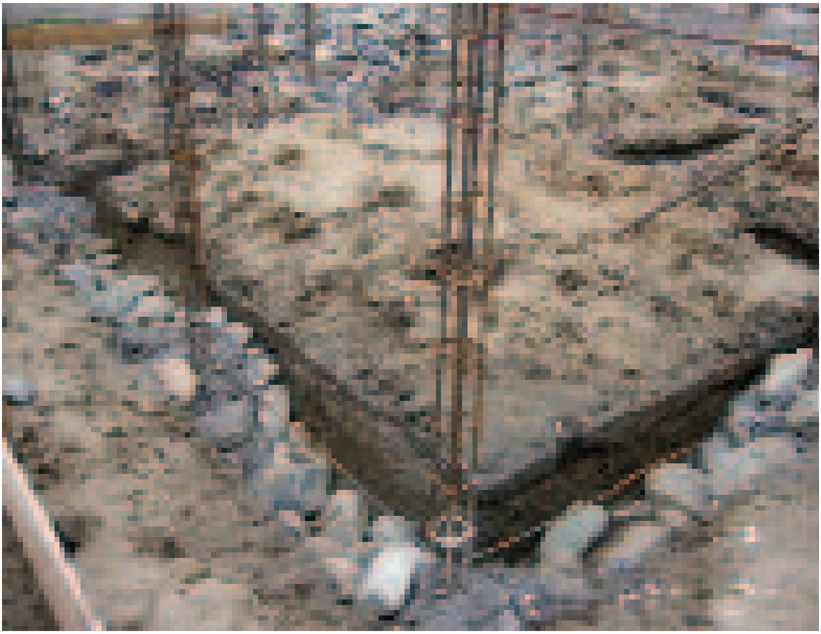
A good foundation, well laid, cemented and joined together, made of broken stone. But there is no column steel fixed in the foundation. The building built on this good foundation will not be anchored to it.

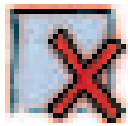


Good material for foundations – broken rock. This material is of a harder rock, of sufficiently large size and rocks will not slip between each other. If it is properly laid and properly cemented, it will make a good foundation.

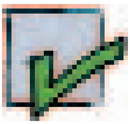


Poor material for foundations. Rounded river or beach rocks do not make good foundations unless they are broken, because they are liable to slip between each other. They need to be broken to avoid slipping, and they need to be carefully cemented between each other.





This **foundation is weak**, since it has too many rounded stones that are not properly laid, and are not adequately bonded together with cement. The result is often that the floor and walls will crack as the foundations settle or move unequally.



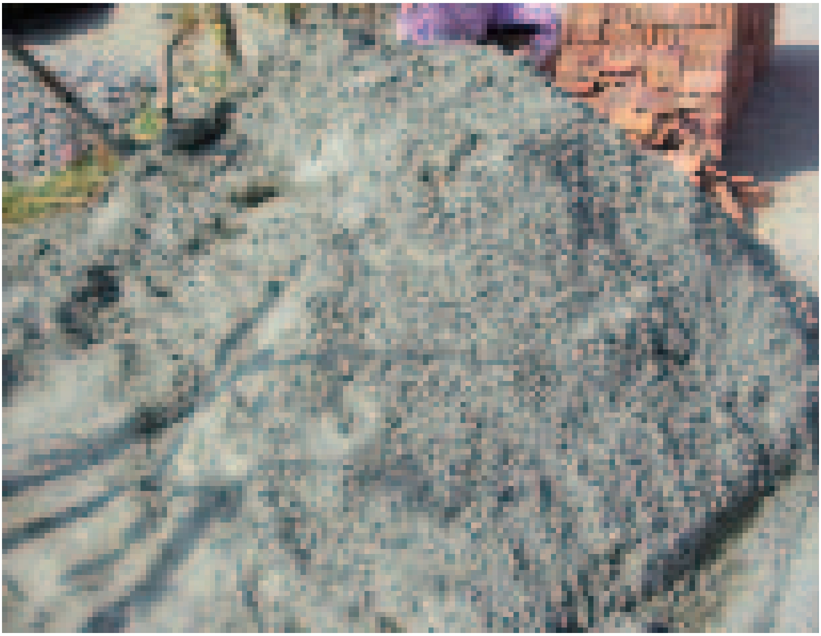
Good concrete foundations. The foundations of these houses have been constructed on a foundation material of sand, so they have been well laid using sufficient cement. This site is also well drained to avoid possible liquefaction.

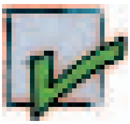
2 Sand and Gravel

Choice of materials affects the strength of the building.

- Coral sand should never be used in any construction.
- Coarse sand should be sieved to remove stones, fine particles and dust.
- If the sand comes from a dirty or sea water source, it must be washed.

Bad example of concrete using coral sand. Example of the disintegration of concrete due to the use of coral sand. This concrete is returning to powder. The only action possible at this point is to dig it out and to start again, wasting time, money and resources.



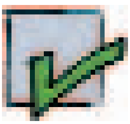


Example of **good quality sand**. This sand is all of about the same coarse texture and does not have stones in it or a lot of dust. Sand can be tested by lifting up a handful and letting it fall back to the ground. If a significant portion of it blows away instead of falling straight down, it has too much dust and needs to be sieved.

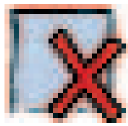
Example of **poorly-graded sand**. This sand has not been separated from the stones, so it is already a sand/gravel mixture. If gravel is now added to this mixture, it will not be suitable for making concrete because there will be too little fine material in it to bind it together.

Bad practice. Debris should not be allowed to be mixed with any of the ingredients for making concrete. Such debris seriously weakens the strength of concrete. This sand will need to be cleaned before it is used for mixing into concrete. All plastic, leaves, grass, and other debris must be removed before using sand or gravel for making concrete. Harmful debris particularly enters the concrete when it is mixed by hand on the ground.

Gravel is best made of crushed rock, not of river rounded stones



Good gravel, made of crushed rock, with no larger stones. Gravel should have maximum size **20mm** in order for it to fit within and around reinforcement and to strengthen concrete.



Poorly-graded gravel, with many stones too large for making good construction concrete, and also some fine sand. For house building the gravel should not have stones larger than 3/4 inch (20mm).

3 Mixing of Concrete

Good clean ingredients with little water makes strong concrete.

- Ensure adequate cement is added.
- Mix ingredients well.
- Limit water, and use only clean water. Concrete should stand up when mixed, not flow away due to excessive water.
- Do not use any water that is salty. This destroys concrete strength.
- Use only properly selected, clean ingredients.
- If the sand contains stones, reduce the amount of gravel added.

4 Making Columns

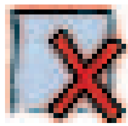
Strong columns provide strength to the structure.

- All reinforced concrete columns should be made in one part before walls are built up. They should not be made in small steps as walls are built up. They should contain bars for wall ties and ring beams when constructed.

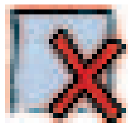
- Column reinforcement should be 4 vertical bars with hoops holding them together, spaced at approximately the same as the width of the column. Bars should be anchored in the foundation.

- End of hoop steel should be bent 135º into the center of the column.

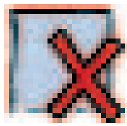
- Column steel must be covered with a minimum of 2cm of concrete all around.



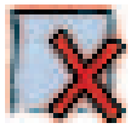
Poorly constructed column made in parts as the wall was built up around it, without wall ties between the column and the wall. The column steel is not properly covered because the steel cage was wider than the width of the bricks making up the wall. The result is that the formwork for the concrete was against the steel, and when concrete was poured, the steel was not within the column, but on its edge. The windows have been placed in the walls in a very weak way. All of this wall is weak and will be subject to collapse when under stress.



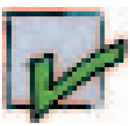
Poor concreting of column in a particularly important area – the connection between the column and the ring beam at the top of the walls. This may lead to failure of this joint when a major lateral force is applied by nature. It will gradually rust and deteriorate even when covered over with mortar.



Bad construction practice. The column is poured in multiple stages, and instead of being vertical, it follows the lean of the reinforcement as it came out of the foundation. Notice again that the steel reinforcement of the column is exposed to corrosion.



Bad practice. There is only one reinforcing bar in the centre of the structural columns at the corners of this house which all collapsed. A round bar can pull through the column concrete and provides little strength to it when it is in the center of the column. Columns should have at least 4 bars.

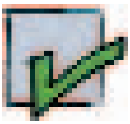


Ends of steel bent at 135º for earthquake resistance.

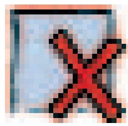
5 Reinforcement

This strengthens concrete like bones in the body.

- Reinforcement steel is best made of twisted deformed steel bar, or deformed bar, rather than plain round bar. Plain round bar is significantly weaker, and can pull through surrounding concrete and hence has a weaker effect.



Structural deformed steel bars

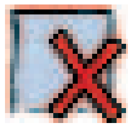


Round bars

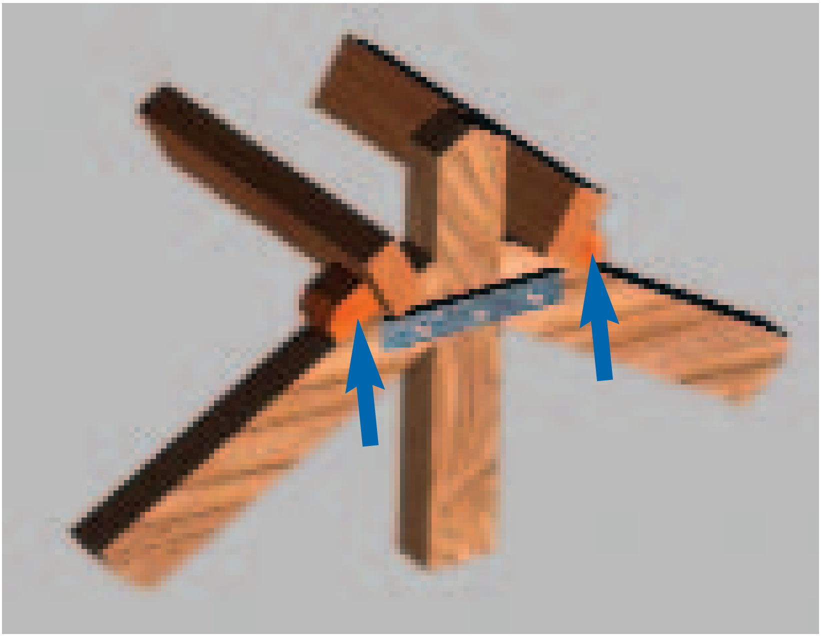
6 Roofing

A strong roof provides lasting weather protection.

- Roof trusses must be made with a triangular frame, placed over columns and tied to them.
- Roofing supports must be made of a block of wood rather than just a nail.
- Roofing structure should not be joined near the middle of a span, and not joined with a 45º cut.



Not good practice. Roof trusses are near but not over the columns, and column steel is not long enough and not bent over roof structure to connect between roof structure and column structure. This is a weak building method.



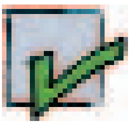
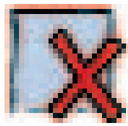


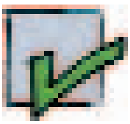
Illustration of wood blocks for securing roof structure. Do not use a single nail, which is a weak support, and may corrode and cease its function quickly in the Nias climate. Nails through the wood structure itself also are a weak support.



Bad jointing practice. Roof structure joined near mid span with a 45º joint. This is a weak joint, not properly made, and it will gradually give way, leading to a sagging roof. It will not support workers building or working on the roof.

7 Tying Wall to Structure
Good connections strengthen the walls.

- Wall ties to connect walls with the building's structure are to be at regular intervals of 40cm and extend from the bottom to the top of the wall.
- Wall ties must be cast into reinforced concrete columns, along with reinforcement for ring beams.
- Wall ties must be bent at the end to hook into the wall material.



A **good example of wall ties** inserted into columns before they were made, so that walls will be well tied in to the structural columns. They lack hooks at their ends at this point in the construction.

8 Wells and Septic Tanks

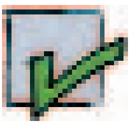
These are essential health-supporting systems to a house.

- A well should not be located closer than 30 meters to the nearest septic tank. If they are located closer, liquid from the septic tank may contaminate the well, which may bring disease to the users of that well.

- It is best to have a common water supply from a tested clean source rather than individual wells.

- In urban areas, a common sewage system is recommended, and not hard to install.

- In rural areas, rain water from the roof should be collected in covered tanks to provide a source of good household water.



A **good example** of collecting roof water in tanks for household use. This water is freely available and is usually of good quality, if many leaves are not falling on the roof. A screen at the entrance to the tank will filter out unwanted debris.

Code of Minimum Standards for House Construction*

1 Foundations

a Foundations must be designed specifically for the house in its location, according to:
- The size of the house, number of floors, weight of construction materials
- The foundation ground
- The height of the water table
- The possibility of liquefaction

b Each house must have a ground water, household water, and roof water drainage plan.

c Foundations are to be made of crushed rock laid on solid ground, well cemented, with a sloof of reinforced concrete laid on it that has connections for the house structure cast into it, brackets for wood structure, reinforcement for concrete structure.

d Rounded river or sea stones are not to be used unbroken for foundations.

* Reference can also be made to *Pedoman Teknis, Rumah dan Bangunan Gedung Tahan Gempa,* Departemen Pekerjaan Umum, June 2006

2 House elevation

a The house floor must be elevated above the surrounding area, with special consideration for possible area flooding, either by ground water, sea storm, or by tsunami.

b The possibility of landslides must also be considered.

3 Building materials

a Sand. Must be coarse, clean, and without stones. It should not contain dust. It must never be coral sand, and if it is from the sea shore it must be thoroughly washed first and contain no shell or coral fragments.

b Gravel. Must contain broken stones, not plain rounded river stones. The maximum stone size for house construction concrete is 2cm.

c Water. Must be clean and free of salt and algae.

d Concrete:
- No vegetable matter is to be mixed into concrete, no grass, wood, leaves, or roots.
- It must be well mixed. Use a minimum of water. It must be stiff. If the mixture flows like water, it has too much water.
- It must be vibrated or tamped with a round rod to ensure proper filling of the form and proper cover to all reinforcing.

e Reinforcing steel. Deformed steel or twisted deformed steel is best for structural use.

4 Structural columns

a Must be vertical, and must be constructed before wall construction, and made in one part.

b Must be integrally connected to the foundation.

c If made of reinforced concrete, must contain 4 bars, one at each corner, of minimum size 12mm and minimum spacing 12cm.

d Vertical steel must have hoops around the outside, of a minimum size of 8mm.

e Column hoop steel must be covered with a minimum of 2cm of concrete all round.

f Hoops must be spaced at no further apart than the width of the column.

g To avoid a stone rich mixture at the bottom of the column, the first mixture should contain a higher proportion of cement and sand, and less stones.

5 Building structure

a The building must have a regular structure.

b The structure must be strongly connected from foundation through walls to the roof trusses.

c For a reinforced concrete structured house, an integrated ring beam around the top of doors and windows must connect between and into the columns.

d A second reinforced concrete beam must connect the top of all walls with the columns.

e Ends of hoop steel must be bent 135º, as shown in the Handbook.

f Triangular gable end walls of houses must be structurally supported.

g For a wood structure, wood posts must either be connected directly to the foundation, or if above stub walls, must be securely bolted to a metal bracket concreted into stub walls.

6 Tying wall material to structural columns

a Wall material must be tied to the building structure with metal ties.

b Metal wall ties are to be hooked at the end.

c All wall openings are to be tied to wall material.

d For reinforced concrete frame buildings with brick walls, ties are to be cast into columns at 40cm spacing, and are to be a minimum of 8mm diameter.

7 Joining walls and roof

a In a reinforced concrete structure, column reinforcement should protrude sufficiently from the top of columns to be able to be wrapped around roof trusses, and nailed to them.

b For wooden houses, or in the absence of sufficient protruding steel, a steel strap should tie the roof trusses securely to columns.

8 Roofing and roof truss joints

a All houses are to have completely framed pitched triangular roof trusses.

b Roof trusses are to be placed over columns and tied to them, as mentioned in Section 7.

c Most roof truss joints, and particularly central ones, are to be bolted, not nailed, as explained in this Handbook.

d Roof truss joints of three or more elements are to have a metal strap joining each roof component.

e Wood blocks are to be used for fixing purlins to roof trusses.

f Joints in roof structural wood are to be made with step joints, not with 45º cuts.

g Joints in roof structure are not to be made near the middle of a span.

9 Cross bracing of walls and roof

a All wooden parts of a house structure are to be cross braced, stumps, walls, and roof.

b Wood roof structures are to be cross braced in both directions.

10 Drainage

a A comprehensive drainage plan must be part of each house design. This must include drainage of ground water and household water, as well as of roof water.

- b All drains must have a constant fall towards a common drain.
- c Drains must be covered or have bridges for access across them, where needed.
- d The bottom of drains should have a “V” formation to minimize water accumulation due to improper fall or debris in the drain.

11 Well and septic tank

- a No well is to be constructed closer than 30m from the nearest septic tank.
- b It is strongly recommended that a common water supply from a tested clean water source be provided for a cluster of houses.
- c For clusters of houses, and particularly in urban areas, a common sewerage system should be provided.
- d In rural areas, rain water from the roof should be collected in covered tanks for household usage.

House Building Checklist

1 Foundations

House built on ☐ Sand ☐ Rock ☐ Clay
☐ Dry foundation ☐ Wet foundation

Well-made foundation ☐ Yes ☐ No

Broken rock, well concreted ☐ Yes ☐ No

2 House elevation

Adequate elevation ☐ Yes ☐ No

3 Building Materials

Sand and gravel:
Clean, coarse sand, without stones ☐ Yes ☐ No

Mixing concrete:
Well mixed, with limited water ☐ Yes ☐ Inferior

Water quality used for making concrete
☐ Good ☐ Poor

Making columns:
All columns well constructed, before walls
☐ Yes ☐ No

Reinforcement:
☐ Round steel ☐ Deformed ☐ Twisted Deformed

4 Building has a regular structure

☐ Yes ☐ No

Structural ring beam above doors and windows, and at top of walls

☐ Yes ☐ No

Triangular end walls supported ☐ Yes ☐ No

5 Tying walls to columns

Wall ties at 40cm from top to bottom ☐ Yes ☐ No

6 Joining walls to roof structure

Column reinforcement or straps between roof trusses and walls

☐ Yes ☐ No

7 Roofing, and roof truss joints

Roof trusses over columns and tied ☐ Yes ☐ No

Joined with bolts and straps ☐ Yes ☐ No

8 Cross bracing of walls and roof

Cross braced ☐ Yes ☐ No

9 Drainage principles

Proper drainage plan ☐ Yes ☐ No

10 Well and septic tank

Well more than 50m from septic tank ☐ Yes ☐ No

Overall assessment of the building:

Our homes contain the people and things which are closest to us. Let us ensure that our buildings are constructed more safely, so that the people inside them, and their property, will be better protected in the event of a major hazard impact. Even in more minor hazard events, the effects can be cumulative. Each one of the principles in this Handbook will have an added effect in reducing the vulnerability of the house to collapse when the forces of nature impact it.

Monitoring house design and construction will enable you to correct poor practices as they happen so that your house will better protect your family and belongings in an emergency. The expense involved in building a stronger house is little compared to the added security and protection it gives to you and your family.