HANDBOOK ON

Good Building Design and Construction

In the Philippines

ISDR
International Strategy for Disaster Reduction

Special Unit for South-South Cooperation

UNDP

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Special Unit for South-South Cooperation

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Purpose of the Handbook

This Handbook is made to provide simple information to house owners, to house designers and builders, and building monitors to teach principles of good design and good construction in natural hazard prone areas. 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 to ensure quality and a sustainable building.

Since many concepts are not easy to describe, the Handbook contains pictures of good practice and common bad practice to facilitate understanding and to indicate how to build better. The photographs have been taken of construction practices in the Philippines. The Philippines are generally hazard prone to the whole range of natural hazards, like earthquakes, landslides and flooding due to storms and sudden downpours of rain, volcanic eruption. The principles of this book are designed to minimize vulnerability to natural hazards, so that houses will safeguard occupants and their assets.

In an area that is prone to earthquakes and other significant natural hazards, 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.

Another important element in sustainable housing is spatial planning, building houses in places that are less vulnerable, like away from river beds and sea shores and steep cliffs. Where houses have to be built in these locations, design must incorporate resistance to locally experienced hazards.

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.

Robin D Willison

Forewords

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

Good Building Design and Construction: the Experience of the Philippines is the second in a series of publications dealing with the same topic. The first one was based from the experience in Aceh and Nias, Sumatra, Indonesia during the rehabilitation and reconstruction process from the destruction wrought by the tsunami of December 2004. Here, we focus on the experience of the Philippines in the course of rebuilding and recovering from the devastation caused by severe flooding and landslides in the past three years.

As recent events have continued to confirm, disasters upset and negate hard-won development gains. Disaster risks are increasing and, as awareness grows, these risks have become a major cause for concern worldwide. The fact that disasters are often the results of multiple, interrelated causes, means that societies have difficulties in addressing this global issue. As a result, disasters can have enormous, far-reaching consequences, impacting the survival, livelihoods and dignity of communities, particularly the poor and the deprived, which are located mostly in developing countries.

A wealth of experience and capacity in disaster-risk reduction exists all over the world and needs to be shared with others. The Philippines is one source of such knowledge and information. This publication is a practical guide to the design and construction of houses during the reconstruction phase in the aftermath of a disaster as well as during normal times.

The Special Unit for South-South Cooperation (SU/SSC) supports the sharing of knowledge, expertise and lessons learned concerning the enhancement of growth and development as well as the management of disasters that derail development efforts. In particular, we emphasize South-to-South exchanges and strategic partnerships to address the risk of vulnerability of poor and developing countries, which often are the most affected by disasters and the adverse effects of climate change. In 2005 at the United Nations High-level Committee on South-South Cooperation, delegates from the Asia and Pacific region requested SU/SSC to support developing countries that are vulnerable to disasters, especially the small island developing States. For this reason, SU/SSC has been working to support the implementation of the Hyogo Framework of Action through collaboration with the International Strategy for Disaster Reduction (ISDR) and with other organizations through the development and publication of knowledge products on disaster reduction and management.

We in the Special Unit are proud to have a role in this publication along with ISDR and the German Agency for Technical Cooperation (GTZ). The importance of safe shelter cannot be overemphasized. Hence, commitment to quality design and construction should be one of the prerequisites in reconstruction efforts. The children are the hope and future of the world and it is unthinkable for them to continue to live and learn in unsafe, poorly built houses and schools. The past tragedies hold lessons from which we can all learn and it is our hope that this publication will help us to build better, safer places in pre- as well as post-disaster environments.

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

Sálvano Briceño
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Strategy for Disaster Reduction

Climate change, environmental degradation, and unchecked urban growth, are increasing the severity and frequency of disasters. This is a growing threat to lives and livelihoods, and a serious challenge for socioeconomic development in many countries. Against the backdrop of these global trends, the secretariat of the International Strategy for Disaster Reduction (UN/ISDR) seeks to strengthen the exchange of concrete experience and knowledge of community-based risk reduction. Practical, simple steps like this publication, which shares clear, useful examples on how to decrease disaster risk at the grassroots, are vital to strengthening the disaster resilience of not only houses, but entire communities and nations.

The Philippines is regularly exposed to climate-related hazards such as intensifying typhoons and floods, as well as seismic and volcanic events that have affected whole regions of the country. In 2006 the Philippines experienced a devastating typhoon season which damaged and destroyed hundreds of thousands of homes, and affected eight million people. However, the experiences of the Philippines, as a disaster-prone country, can serve not just as a warning of the damage that is done by vulnerability to hazards, but as a showcase of the opportunities for integrating disaster risk reduction into the recovery process.

This handbook on 'Good Building Design and Construction in the Philippines' does exactly that, capturing the potential of increased resilience through good construction. The UN/ISDR secretariat is supporting the development and distribution of tools like this handbook, as a part of its mandate for coordinating the implementation of the Hyogo Framework for Action. In 2005, just after the Indian Ocean Tsunami, 168 governments adopted the Hyogo Framework for Action, in an acknowledgement of the need to build back better, to increase disaster resilience by mainstreaming disaster risk reduction into development, and to avoid the recreation of past mistakes.

At the international level, UN/ISDR secretariat, in partnership with the UNDP, ILO, World Bank, and the governments of Italy, Japan and Switzerland, have established the International Recovery Platform, which provides guidance for building back better from disasters. At the community level, UN/ISDR secretariat is also actively engaged in supporting partners, particularly NGOs and local authorities, in reconstruction processes, to ensure the integration of risk reduction into the rebuilding of houses, schools, and health facilities.

Complementing our work, this handbook explains basic but vital principles of design and construction that can withstand natural hazards, in clear, easy to understand language, and with photographic examples of good and bad practices. For communities that are building back from disaster, or committed to building resilience in these times of increasing disaster risk, this handbook should be the one of the first tools out of the box. To make this happen, the handbook, and tools like it, should be widely translated and made available to UN country offices, and national and local governments to learn from, in order to make disaster recovery efforts more effective and sustainable.

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

Jochem Lange
German Technical Cooperation (GTZ)
Country Director for the Philippines and the Pacific

Some areas of the world are especially exposed to natural hazards. One such location is the Philippines as part of the Pacific "Ring of Fire" and a major recipient of tropical storms hitting the country from the Pacific Ocean. The vulnerability of the country was demonstrated repeatedly by volcano eruptions like that of the Pinatubo in 1991, the flashflood in Ormoc the same year, many land- and mudslides in the western part of the country and the big earthquake in Baguio (magnitude 7.7) in 1990. Thousands died or were injured due, in part, to limited understanding of prevention, mitigation and preparedness for disasters. Had people known more about risk reduction, large numbers of injuries, death and damage to assets could have been avoided.

The importance of analyzing hazards carefully and integrating measures to reduce their impact in land use planning and in building codes cannot be overemphasized. Taking the risks of landslides, floods and tsunamis into account, spatial planning of human settlements, both, residential and commercial, is the key to taking people out of harm's way. In some cases resettlement might be the only option for homes in extreme hazard areas. It is simply not acceptable to continue living under the constant threat of a major disaster.

Shelter is a basic human need. A house protects from the climate and animals, and it also has a socio-cultural role as the centre of the family life and as a manifestation of self-identity. A well designed and built house is a house that supports the lifestyle of the dweller, and a well-constructed house protects the lives of the residents.

Many of the existing houses in the Philippines are still not safe enough to withstand the recurring forces of nature and GTZ is pleased to publish this Handbook as an aid to assist local communities to design and build stronger houses in safe locations. This will help them to withstand extreme weather and geological events. It is written with the aim of making technical information simple and understandable for those who build so many of the homes: the homeowners themselves.

Jochem Lange
Country Director for the Philippines and the Pacific
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Acknowledgements

Mr. Robin Willison, Disaster Risk Reduction Consultant and a Civil Engineer, researched and wrote the text and took the photographs for this Handbook, developed through experience in recovery from tragedy caused by impacts of hazards from nature in Indonesia and the Philippines.

The development and publishing of this Handbook to promote better practice in building houses in the Philippines was the initiative of the Environment and Rural Development program of GTZ, supported by UNISDR and the Special Unit for South-South Cooperation of UNDP. Mr. Olaf Neussner, disaster risk consultant to GTZ provided support for assessing the building culture in Leyte and Samar and study of the effect of local catastrophes.

Contents

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 this 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 to resist lateral movement.

Drainage plans are essential to good house design. The design should carefully consider whether the house needs to be elevated to safeguard it and 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 a 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? Design foundations appropriately.

- 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. This house is being built in a swampy, waterlogged area. As the foundations and the foundation trench was dug, it filled with water so the builders dropped dry sand and cement into it and then the first row of blocks were located on top of this mixture. These foundations in permanently wet soil are inadequate and will also be weak when impacted by any external hazard.

Example of bad location. This house is located on a river bed, close to running water, where it is very vulnerable to flooding. Not only the house, but also its contents are vulnerable to destruction due to heavy rains. Houses should not be built in such obviously vulnerable locations, or if they are, they should be designed to resist the hazards of their location.

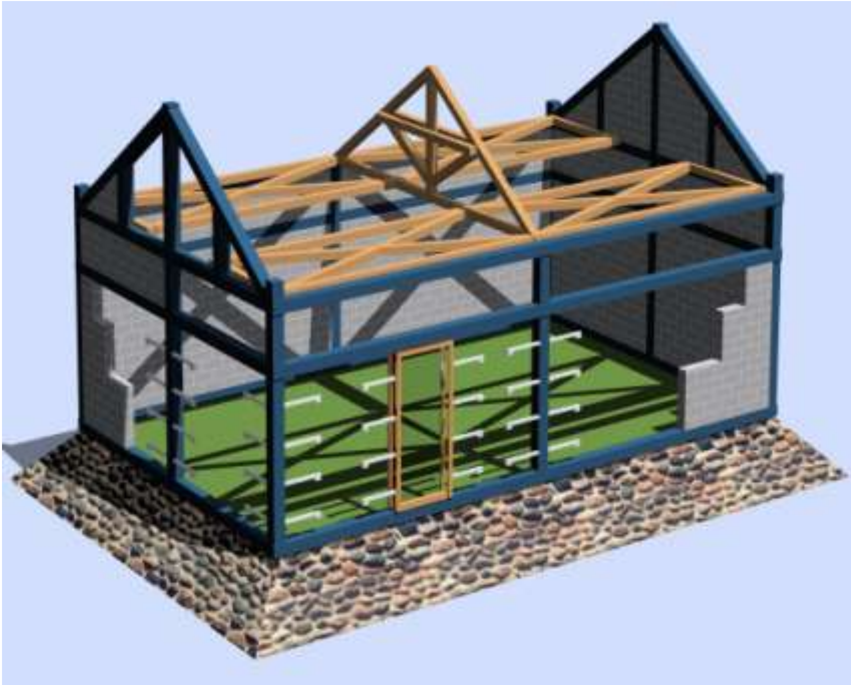
Liquefaction. Example of a well built and well structured house that was not quite finished when a major hazard struck. The house was structurally good but the foundations were poor for this location. Due to a major earthquake the foundations suffered from liquefaction of the ground, and due to the weight 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 **regularly structured building** is able to withstand the impact of hazards. 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 continuous columns to the foundations.



This illustrates **good structural design** principles for a hollow block or brick wall building with a reinforced concrete structure. 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 2 ring beams connecting all the building elements at the top of doors and windows and at the top of the walls. Gable end walls are also strengthened with reinforced concrete.

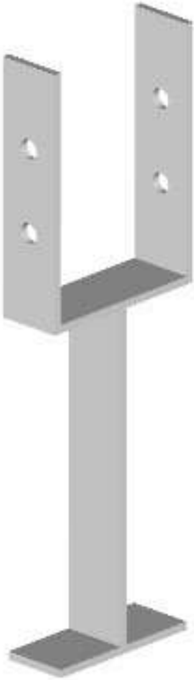
This is an example of **bad structural practice**. This house has no structural columns and no ring beams to hold the structure together. There are no columns at the corners, or within the walls, and there are no ring beams at the top of doors and windows or at the top of the walls. This building will have little resistance to being destroyed by any impact from nature, like an earthquake or a storm.

An example of **poor structuring of a house**. The columns are very poor, with concrete poured in stages after the walls were built up, and the concrete has not fully covered the steel so that the reinforcing will rust. The columns are too small and the steel is too close together. The concrete was not tamped to ensure good compaction. Columns should not be made to fit within the thickness of the wall because there is not enough room to properly cover the column reinforcement with concrete. This kind of column does little to give a house structural strength. It would have been better to have a proper column at the end of the wall on the right.

Not good structure. Another example of a house which has too little structure to brace the walls against lateral forces. This is a common construction fault with hollow blocks. Columns are inadequate, too small, and poorly constructed, and there should be a reinforced column between the door and the window. The window and the door have inadequate structural support. When the forces of nature strike this house, it will progressively deteriorate and be hard to repair.

Good structural practice. A good pattern of reinforced concrete columns and beams to strengthen all aspects of the building including support to strengthen the triangular gable end wall so that it will not fall when a lateral force strikes the building. All end walls of this nature need a reinforced column to strengthen them, or they are liable to fall when the building is subjected to a major lateral force. It also has a reinforced concrete beam to top to all walls.

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



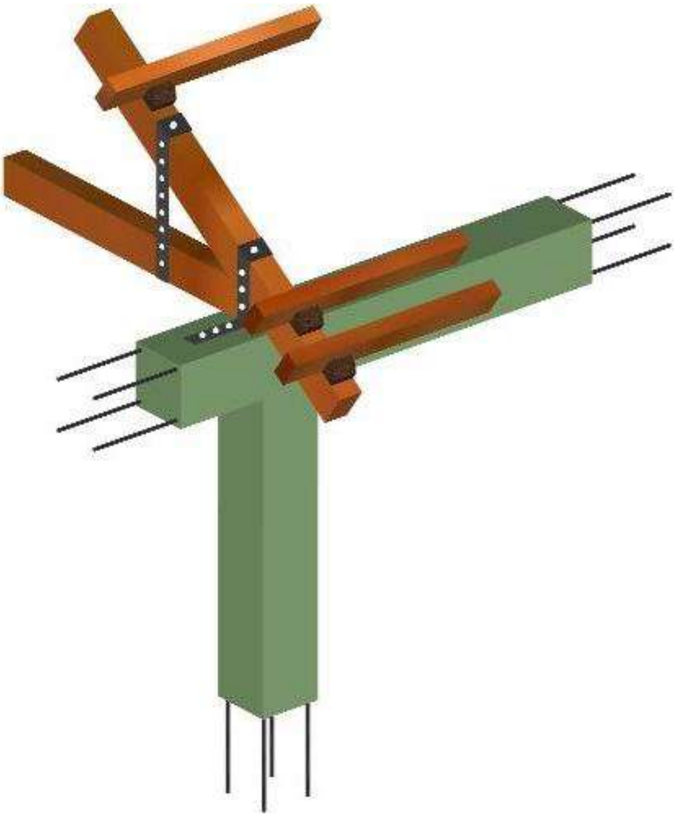
It is essential that a wood frame structure mounted on a concrete frame/brick stub wall must be fully anchored together. A bracket, as shown above left, made of non-corrodible metal, must be cast into the bearing structure to provide a structural connection for the whole wall through to the foundation.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

- Exposed metal should be painted with rust proof paint to prevent corrosion.



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 or plates can be used for this role, particularly where the building structure is made of wood.

A **good roofing 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 keep the roof on the house when a natural hazard strikes the structure. Such exposed steel should be painted with rust-proof paint to minimize corrosion.

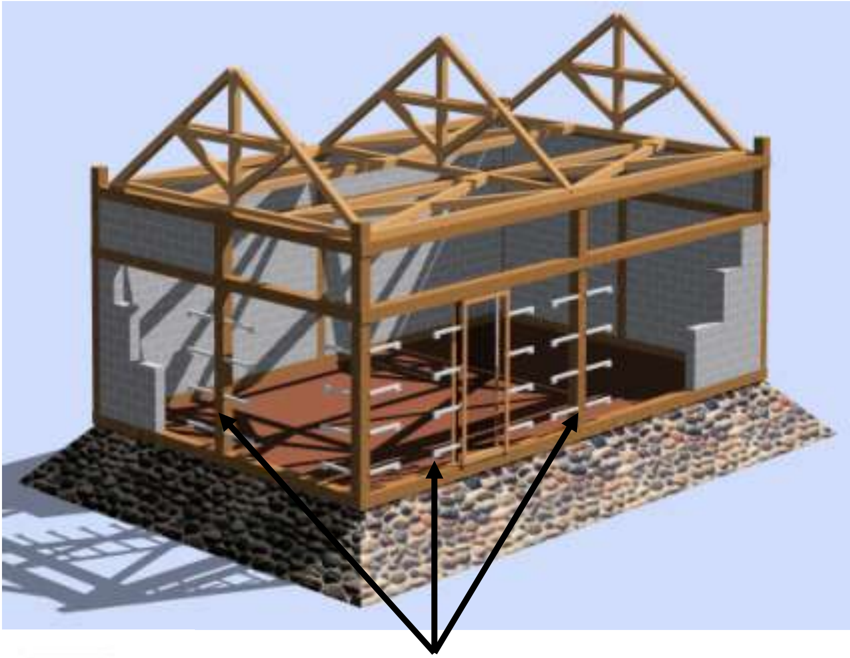
Example of **good roofing practice.** Steel roof trusses are connected to columns through welding of truss members to column reinforcing steel and purlins are welded with ties to roof trusses. This will hold the roof firmly on the house in storms or other hazards from nature.

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

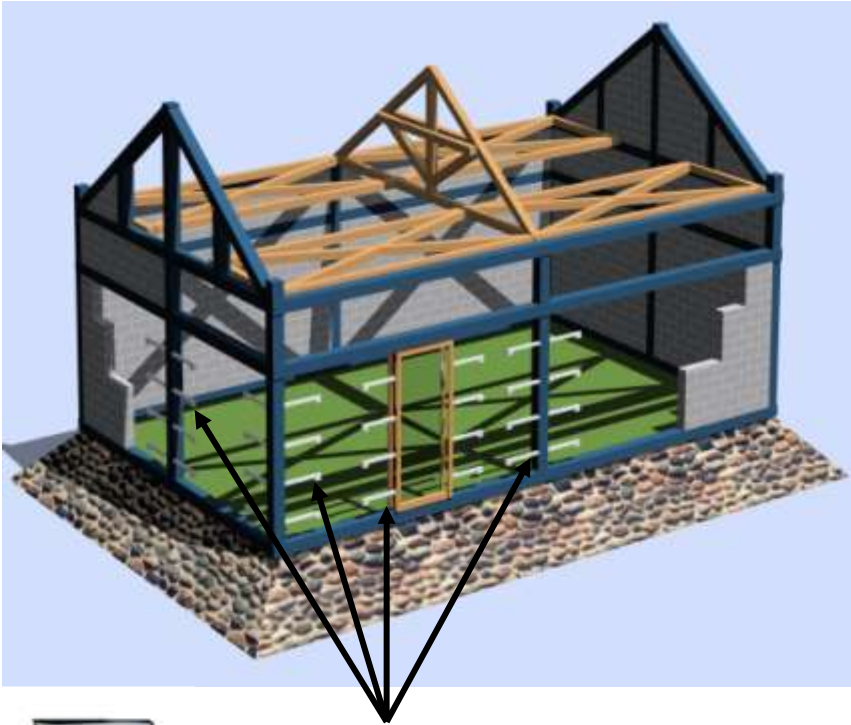
4. Tying walls to building structure

Walls tied to columns protect 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 tying practice. An illustration for a wooden 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 a maximum of 40cm spacing.



Good tying practice. An illustration for a reinforced concrete frame building, where metal ties are used to tie walls to the main building structure. Steel wall ties are to be at maximum of 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 to be at maximum 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 (2 floors on the left) withstood the forces of nature striking it, but the one floor extension collapsed. The columns could not help resist the force of nature 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 wooden roof trusses need to be bolted together and tied with metal straps to provide flexibility but not collapse under the forces of nature.

- Metal roof trusses must be welded together, welded to purlins, and welded to wall reinforcement for strength.

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

This illustration shows a strap or plate across the joint at the apex of the roof structure. This is always **good jointing practice**. Notice also that for a wooden roof structure, wooden blocks should be used for support of purlins, not a single nail through the purlin into the truss.

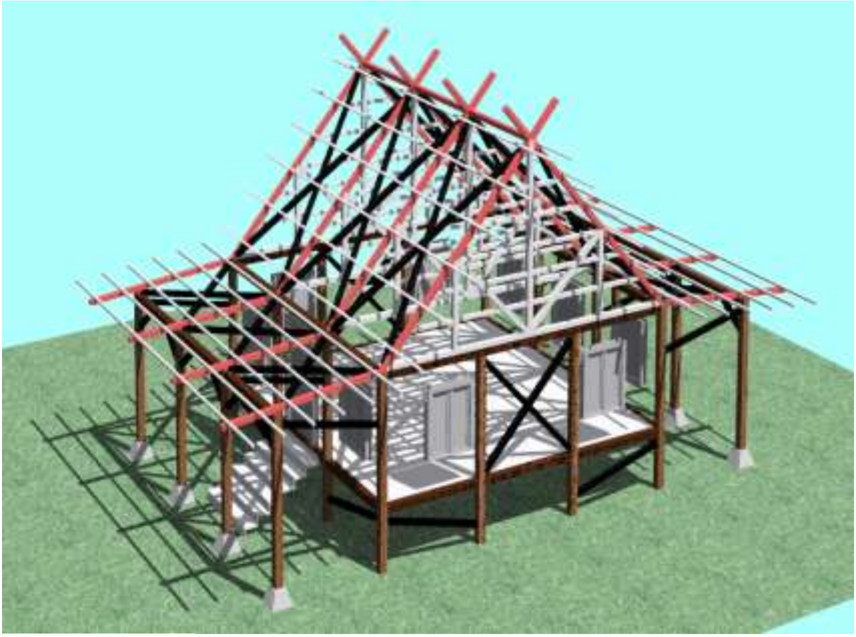
Good roofing practice with metal roof trusses, where the roof is strongly connected to the reinforcing in the wall columns by welding, and the purlins are welded to the roof trusses with small brackets to make a strong roof structure.

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.



Example of a **cross bracing system** for the walls, roof, 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.

Good Practice. Traditional Batanes houses, which have stood through many storms and earthquakes, are well structured and supported, with good corner columns, and have good arches over doors and windows to bear weight down their sides. The solid stone wall on a good foundation provides resistance to lateral movement.

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 them for people and vehicles.

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

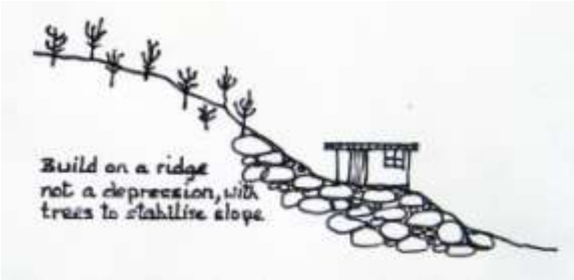
8. House elevation and location

Safeguards house and contents from flooding, landslides, flashfloods.

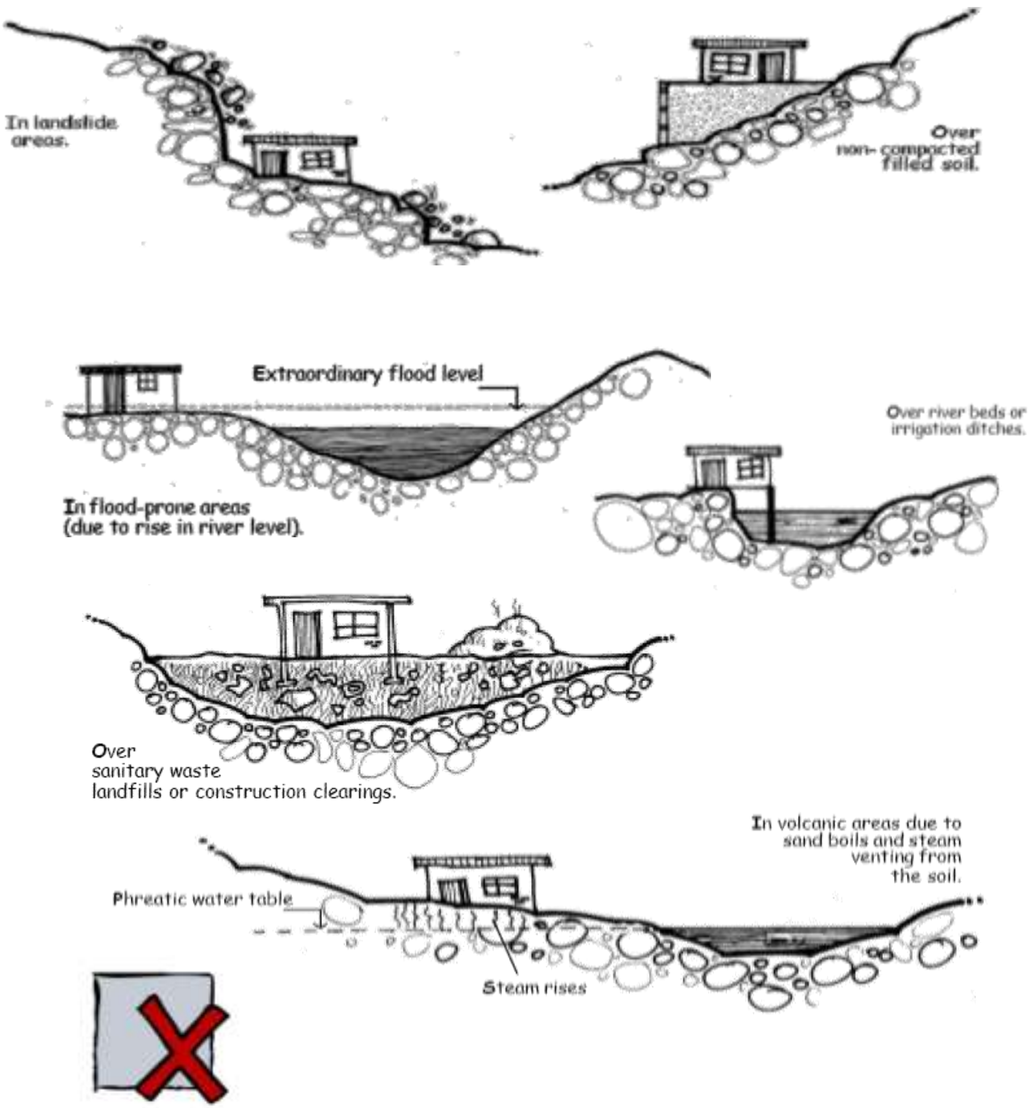
- The house floor should be elevated above the surrounding ground level, and extra height is needed in vulnerable situations such as locations close to a floodable waterway or a swampy area, or in a tsunami or wave prone area near the sea. Extra height is best provided through stilts.

- Houses must be located away from places subject to landslides where soil may move down a steep slope, debris flows where soil gravel and rocks may be washed rapidly down by heavy rainfall, and flashfloods.

Good house elevation. This house is being built in a low lying area vulnerable to flooding. Concrete stilts are being cast on pad footings to raise the floor level of the house so that it will not be flooded or subject to dampness.



Guidelines on where to build. These illustrate principles for locating houses in safer places so that house and contents will be less likely to suffer disaster.



Where not to build. Examples of places where it is dangerous to build and where houses may easily be destroyed.

Construction and Materials Principles

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 to it. This section explains 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 may injure or kill people when outside forces impact it.

In constructing a house the first and foremost principle is to follow the design and not to cut corners by reducing design requirements. 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 keep everything and everyone 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 to be built on.

- 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 used in the foundation into one solid foundation that will not subside unequally.

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

Good material for foundations—broken rock. This material is of a harder rock, of sufficiently large size so that rocks will not slip between each other. If it is properly laid and properly cemented, with column starters concreted into it, 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. Too many rounded stones, not properly laid and are not adequately bonded together with cement, give a weak foundation. 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 in a dry trench using good materials, and the first row of blocks was laid while the concrete was still wet. Starter bars to reinforce the hollow block walls are inserted while concrete is wet.

2. Sand and Gravel

Choice of materials affects 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 larger 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 is mixed with larger stones so that 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 for materials. 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, roots, shells 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 and have few smaller stones.

3. Mixing of concrete

Good clean ingredients with limited 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 building.

- 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 135° into the center of the column.

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

- Do not put pipes down the centre of columns.

Columns being constructed before walls on a base to raise the house above surrounding low lying land. Reinforcement of columns continues from the footings through the floor to provide structural strength.

Poor concreting of corner column in a particularly important area. It will gradually rust and deteriorate even when covered over with mortar.
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.

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 of wood should be made with a triangular frame, placed over columns and tied to them.

- Roofing supports for wooden trusses 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 45° 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.

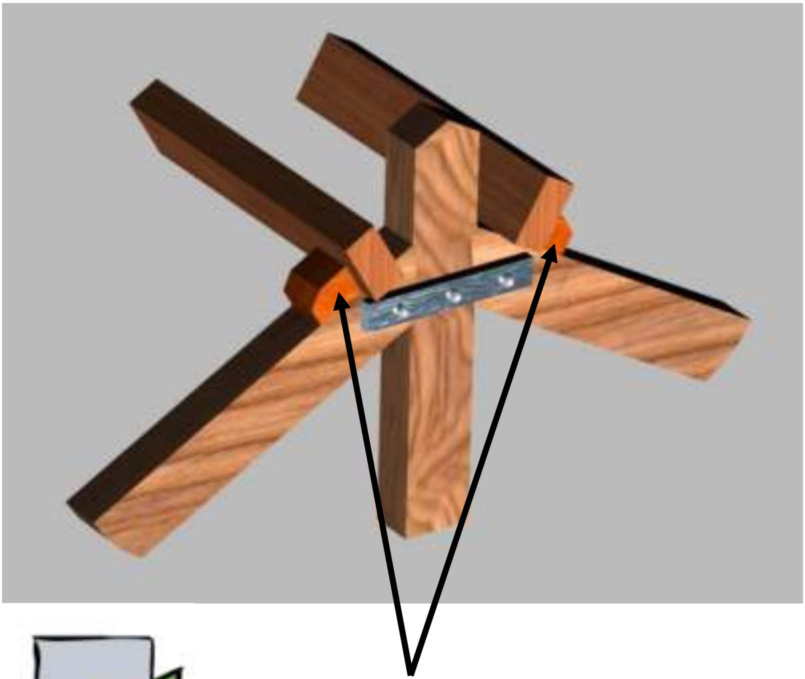


Illustration of wood blocks for securing roof structure. Do not use a single nail, which is a weak support, and may corrode and cease its function quickly in the Philippines climate. Nails through the wood structure itself also are a weak support.

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.
- Hollow block walls should be reinforced.

A **good example of how to insert wall ties** into columns before they were constructed, so that walls will be well tied in to the structural columns.

Hollow block walls should have a reinforcing bar every 80cm which is concreted into the blocks throughout the height of the wall and is inserted into the floor or foundation when it is cast. It is good practice to fill all holes in hollow blocks to provide further strengthening to the walls.

8. Wells, septic tanks, plumbing

These are essential health-supporting systems to a house.

- A well should not be located closer than 30 meters to the nearest septic tank (Sphere Standard). 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.

- Bathrooms and toilets need to be well ventilated and to have a window.

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.

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. Houses must be located away from places subject to landslides where soil may move down a steep slope, debris flows where soil gravel and rocks may be washed rapidly down by heavy rainfall, and flashfloods.

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 and 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 3 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 45° 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 □
Depth of foundations: Insufficient □ Sufficient □
Shape of stones: Round □ Broken □
Material: River stone □ Sea rock □ Limestone □

2. Walls

Columns were made before walls: Yes □ No □
Column steel was covered with a minimum of 2cm of concrete all around: Yes □ No □
Wall ties to the columns at 40cm interval: Yes □ No □
Minimum size of column reinforcement steel 12mm: Yes □ No □
Interval between reinforcement rod ± 12cm: Yes □ No □
Minimum size of stirrup steel 8mm: Yes □ No □
Interval between column stirrups 10-15cm: Yes □ No □
Reinforcement rods sufficiently protruded out from the top of the column: Yes □ No □
Mortar thickness between bricks / blocks 1cm: Yes □ No □
Bricks were layered neatly: Yes □ No □
Beam on top of door and window frames: Yes □ No □
Minimum size of ring beams reinforcement steel size 12mm: Yes □ No □
Minimum size of ring beams' hoops 8mm: Yes □ No □
Interval between ring beams' hoops 10-15cm: Yes □ No □
Triangular end walls were supported: Yes □ No □

3. Roofing

Triangular roof trusses: Yes □ No □
Roof trusses joints were strapped and bolted: Yes □ No □
Roof trusses were placed on the columns: Yes □ No □
Roof trusses were tied to the columns: Yes □ No □

Woodblocks were used for fixing purlins to the trusses:
Yes □ No □
Cross bracing in between trusses: Yes □ No □
Cross bracing on the roof frame: Yes □ No □
Roof cover: Zinc □ Asbestos □ Roof tile □

4. Door and Window Frames

Wood frames were of dry condition: Yes □ No □
Frames tied to the walls and columns: Yes □ No □

5. Building Materials

Sand from the sea: Yes □ No □
Sand was coarse, no gravel or stone: Yes □ No □
Minimum size of gravel 2cm: Yes □ No □
Concrete mix: Watery □ Quite stiff □
Water quality: Clean □ Dirty/salty □

6. Other Aspects

Site drainage plan: Available □ Unavailable □
Adequate elevation: Yes □ No □
Located close to a floodable waterway, swampy area, or in a tsunami or wave prone area near the sea: Yes □ No □
Located clear of landslides, debris flows, and flashfloods:
Yes □ No □
Well situated more than 30m from the nearest septic tank:
Yes □ No □

7. 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.