DISASTER-RESISTANT CONSTRUCTION

FOR TRADITIONAL BUSH HOUSES

a handbook of guidelines

by

Charles Boyle, Dip.Arch ARIBA.

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Published by the

The Australian Overseas Disaster
Response Organisation (AODRO)

Suite 201,

2nd Floor, 381-383 Pitt Street,

Sydney, NSW, 2000,

AUSTRALIA

November 1988

ISBN = 0 9589249 8 8

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PUBLISHER'S PREFACE

The Australian Overseas Disaster Response Organisation (AODRO) is very pleased to publish this important Handbook of Guidelines on Disaster-Resistant Construction for Traditional Bush Houses. The author of the handbook is Charles Boyle, Dip.Arch, ARIBA, who is based in Honiara, Solomon Islands and who, through widespread field work, has given the Handbook a Pacific-wide perspective.

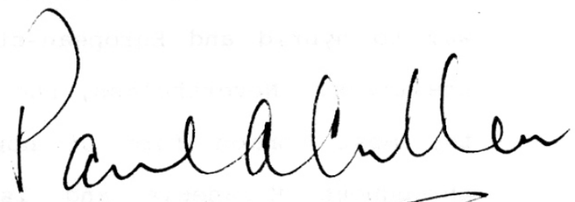
AODRO has extensive experience in disaster response operations throughout the South Pacific and is of the view that contributions towards the mitigation of disaster impact effects are worthwhile and impart long-term benefits to disaster prone communities. It is expected that this Handbook will make a useful contribution to safer living at the village level of Pacific society, and if it does so the efforts of all involved in the production of this Handbook will have been worthwhile.

It is recognised that building practices vary widely throughout the Pacific, and that the traditional bush house is slowly giving way to hybrid and European-style construction, particularly in the towns. Nevertheless, the traditional leaf building is still the most common form of house construction in the villages throughout Melanesia and is likely to remain so for the foreseeable future. AODRO is therefore making a significant contribution by devoting its first Disaster-Resistant Construction Handbook to this important type of building.

AODRO recognises that traditional leaf buildings have many advantages in respect to cost, comfort and ease of rebuilding. It also recognises that many of the 'guidelines' given in this Handbook are not new, but represent the many good practices already used by skilled builders throughout the Pacific. By bringing these practices together in one book it is hoped that this body of knowledge can be passed to future artisans in a comprehensive way.

The publishers would be delighted if interested readers would correspond with them on matters covered in this Handbook so that we can benefit from each other's experience and reflect that experience in future editions of this Handbook.

Finally, AODRO wishes to thank Mr. Charles Boyle, the author, for his dedication to the task of writing this Handbook and the sponsors, Australian Lions Foundation (Lions Multiple District 201) and Burns Philp (PNG) Limited, whose generous funding made publication possible.



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ACKNOWLEDGEMENTS

This handbook is the product of extensive original field work into traditional housing technology particularly in Solomon Islands, as well as a review of background material (see list of useful publications), and interviews and discussions with those actively involved in the construction, maintenance and preservation of traditional buildings. We would particularly like to acknowledge the contributions of the following people and organisations who have helped in one way or another to make this handbook possible.

Mr Max Gaylard, Australian High Commission, Honiara, Solomon Islands

Mr John Baea, East Kwaio, Malaita, Solomon Islands

Mr Bruce Saunders, B.J.S. Agencies, Honiara, Solomon Islands

Dr Neil Britton, Cumberland College of Health Sciences, Australia

Mr Michael Collins, Ponape, Eastern Caroline Islands

Mr Willis Eschenbach and Mrs Sholeh Todd Boyle, Foundation for the Peoples of the South Pacific, Honiara, Solomon Islands

Mr Richard Pessulo, International Human Assistance Programme, Honiara, Solomon Islands

Mr Kayhan Khadem, Islands Architecture Limited, Honiara, Solomon Islands

Board of Trustees, Hybrid Technology Inc., Honiara, Solomon Islands

National Spiritual Assembly of the Baha'is of Solomon Islands

Mr Alan Kitchener, Solomon Islands Rural Housing Reconstruction Programme

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USEFUL PUBLICATIONS

INTERTECT How to strengthen a Solomon Islands house Honolulu, Hawaii: PIDP, 1984.

INTERTECT Minimum structural standards for low-cost resistant housing in Solomon Islands Honolulu, Hawaii: PIDP, 1984.

LOUPIS, George Traditional architecture of the Central Highlands of Papua New Guinea Lae: Appropriate Technology Development Institute, 1984.

SCHRECKENBACH, Hannah and ABANKIRA, Jackson Construction technology for a developing countryS.L.: Deutsche Gesellschaft fur Technische Zsammenarbeit, 1983.

EATON, D.K. How to make your building withstand strong winds Watford, Eng.: Building Research Establishment, 1979.

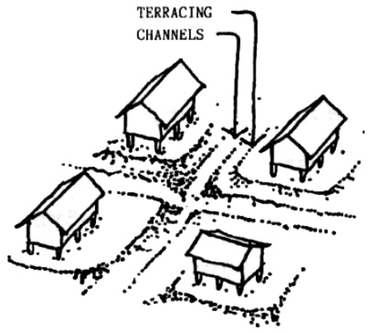
KHAN, Lloyd Shelter S.L.: Shelter Publications, 1978.

LATTEY, Peter Pole buildings in Papua New Guinea Lae: Forest Products Research Centre, 1974.

INTERECT Minimum standards for cyclone resistant housing utilising traditional materials Honolulu, Hawaii: PIDP, 1981.

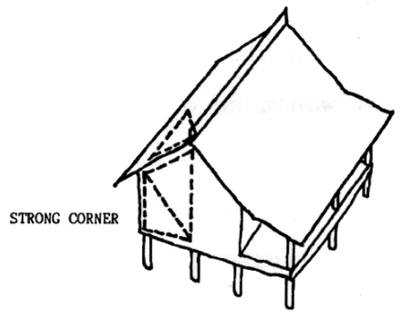
Terracing:

Build up terraces to make steps at ground level. This will reduce the effects of flood waters and rain by controlling them through watercourse channels.



Strong heart:

Make one part of the house particularly strong so that you may shelter there during a storm, comforted by a greater sense of protection. This may be an extra-strongly braced and built corner of the house.



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FOREWORD

Pacific profile

The Pacific Ocean is an area of vast seas dotted with tiny islands that covers nearly half the earth's surface. Its population is tiny - about one-thousandth of the entire population of the world, and there is a great diversity of culture amongst its scattered inhabitants.

Tropical cyclones are a natural part of life for most Pacific Island nations because of the huge areas of sea and their proximity to the equator. The nature of the earth's surface means that many of these islands are prone to earthquakes and are at risk from the sudden movement of the sea that these earthquakes can cause.

Over the centuries, the people of the Pacific Islands have learned to cope with such hazards. They build in ways best suited to resist these forces, given that the normal life of such buildings is 10 to 15 years and that they use local materials.

However, the life of the Pacific Islander is changing. An ever-growing population and an emphasis on economic growth means that there is less time available to spend on re-building houses destroyed by natural disasters or to maintain them for their useful life.

The Pacific Islands have relatively small populations, modest resources and difficulties in transport and communication.
There is, consequently, less money available for resources to

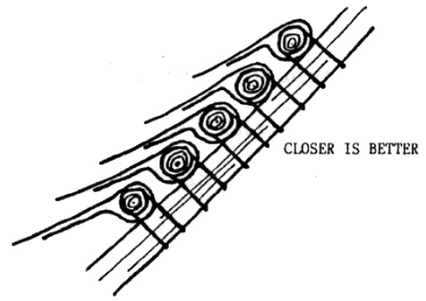
Leaf panels:

The close the leaf panels are to each other, the longer they last:

6" (150mm) apart-5yrs on average

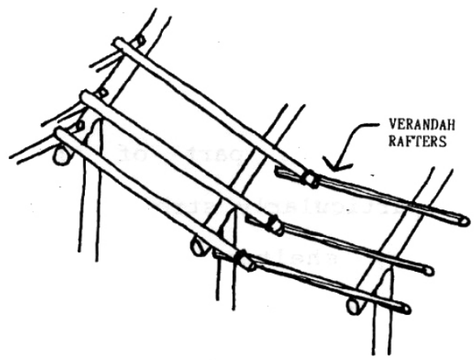
4" (100mm) apart-10yrs on average

2" (50mm) apart-20yrs on average



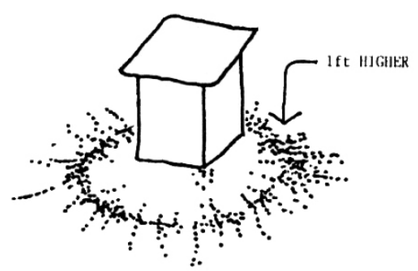
Verandah roofs:

Build a verandah roof separately from the main roof so that if the wind blows it away, the main roof won't be damaged.



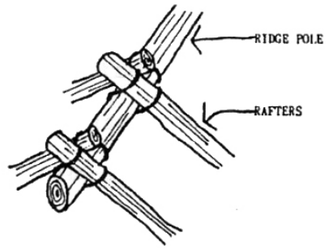
Siting of services:

Locate all toilets downhill of any water supplies and houses unless they are well protected by banks or hills. Elevate them at least one foot (300mm) above the ground to reduce the chance of flood waters washing out the toilet.



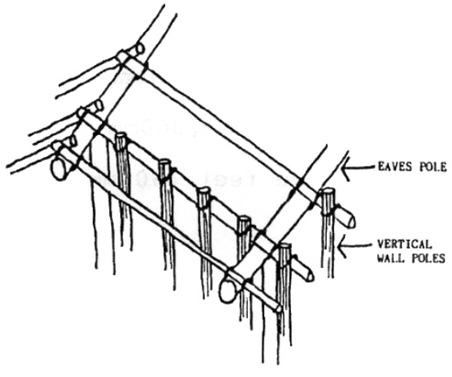
Ridge detail:

Connect all the rafters together over a strong ridge pole to help stop the wind tearing a side off.



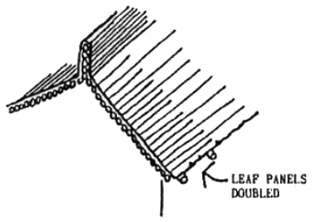
Eaves detail:

Tie down each rafter to the wall frame and to the wall poles to stop the wind tearing the roof off.



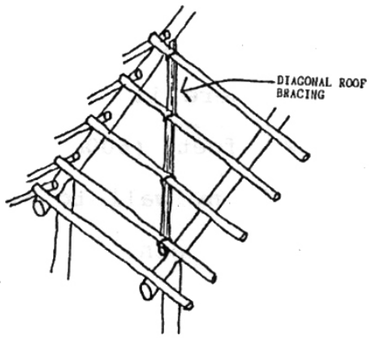
Barge detail:

Double the number of leaf panels to any gable and roof overhang to prevent the wind lifting up the edges.



Roof bracing:

Diagonally brace the underside of the rafters to help reduce raking of the roof.



improve the strength of buildings than is generally available to more prosperous countries bordering the region.

As a result, much attention has been given to ways to improve and strengthen traditional buildings in the Pacific Islands through the study of indigenous methods of construction and by devising simple cost-effective ways to improve them. The slow but steady economic growth must be supported by resilient, longer lasting buildings.

Disaster Profile

Each year, around the, about 10,000 people are killed as a result of cyclones and flooding; thousands more are killed by earthquakes and landslides and millions are made homeless. In the Pacific, the figures are far less but still, each year, millions of dollars that could be used for development are taken up rebuilding houses, schools, churches, roads and bridges damaged or destroyed by disastrous storms and earthquakes. Likewise, the energies and resources of thousands of people are taken away from agriculture, industry and commerce to help rebuild these devastated communities, slowing down economic growth and setting back the hopes and dreams of many.

Most of these problems will be reduced when sustained economic growth makes more finance available and more permanent structures affordable. But until that time, effort must be made to improve traditional buildings, particularly in rural areas where they remain practical, affordable building structures.

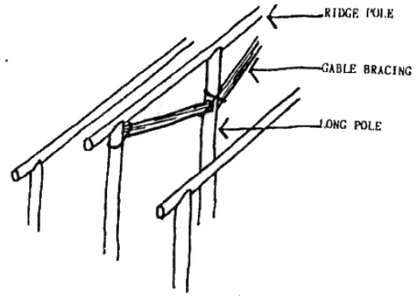
This handbook does not advocate constructing traditional

buildings in new ways, but rather remembering and using the best of traditional construction techniques to ensure that buildings have a reasonably long life, even more than the 10 or 15 years mentioned earlier.

The Pacific Islander has learned the best way to build, but many of the principles and techniques have been forgotten because there is less time to employ them, fewer people who know them and more attempts to use modern and often inappropriate methods of construction. This handbook then, is something of a voyage of rediscovery.

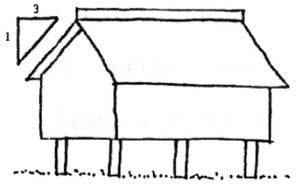
Gable roofs:

If you cannot build a hip roof, securely brace the top of the gable end to the middle of the house to stop the wind blowing it in.



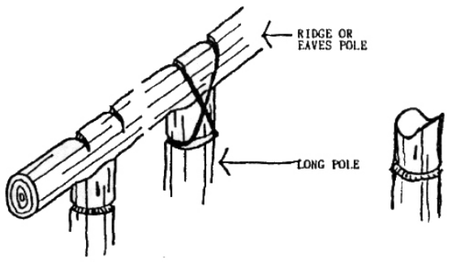
Roof pitch:

Make the slope of the roof at least one foot (300mm) rise for every three feet (900mm) it goes along.



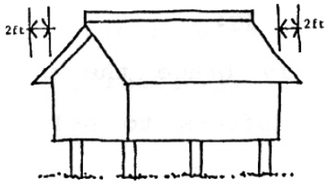
Ridge and eaves poles:

Tie ridge and eaves poles down onto the top of the long poles in 'v' shape notches making a stable frame for the rafters. This is very important. Do not cut the ridge pole or eaves poles.



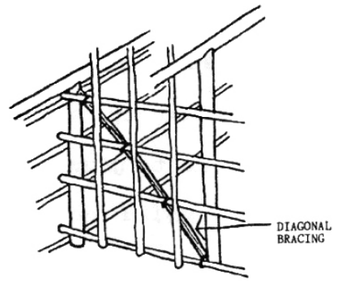
Roof overhangs:

Ensure there is a roof overhang of two feet (600mm) over the face of any wall to shield the walls from rain.



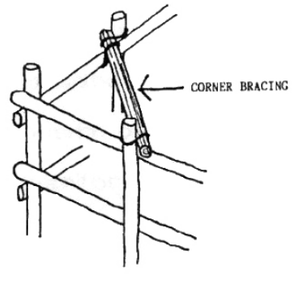
Internal walls:

Build internal walls with diagonal braces to prop up the centre of long external walls and to make it harder for the wind to blow them in.



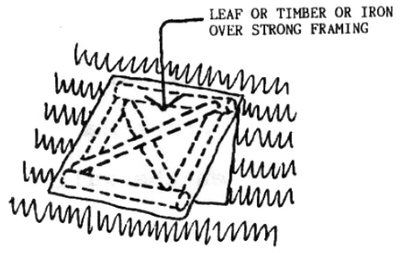
Corner bracing:

Use small braces across each corner of the house, tied to the wall poles to stop the house from twisting.



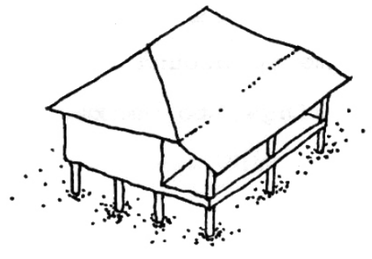
Windows and doors:

Provide some form of shuttering to cover window and door openings to stop the pressure building up inside in the event of a cyclone.



Roof shape:

Build you roof with hipped ends to allow the air to flow more easily.



INTRODUCTION

Social change and modernisation

The economic strength of the Pacific Islands has grown and so too has the need for more dependable settlements. In times past, a village founded on a suitable water supply or adjacent to arable land might have remained while the water and soil were good, but would relocate when circumstances changed. The need for buildings to stand for more than ten years was not essential. However, with increases in population and the size and number of settlements, relocating a village is no longer an easy matter. And with an increasing number of piped water supplies and a movement away from subsistence gardening to cash crops and other forms of income production, a more permanent settlement is possible and preferable. This in turn allows for a more concentrated effort in agriculture. The security of a home base is becoming more essential as economic benefits may not appear until several years after crop establishment.

New demands on housing resources

Proper building methods must be employed in order to secure a more permanent home that will last a reasonable length of time, allow for less maintenance and survive relatively strong storms and earthquakes. It is a price that must be paid for greater security and the chance to continue to develop economically, thereby earning sufficient money to provide schools and hospitals, transport and communications. It is an effort that must be made even if it means taking time out from work. When the wind blows, the rain falls or the ground shakes, much effort will have been wasted if it was not properly directed initially.

Indeed, repeated reconstruction of buildings mean that there is less and less building material readily available in the bush.

Reassessment of the value of traditional housing

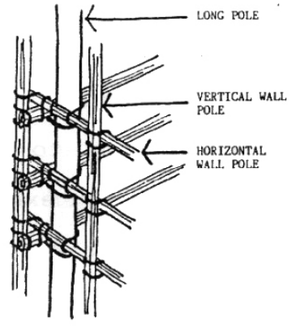
Following recent cyclones in Vanuatu, Solomon Islands and Fiji, much investigation took place as to why some traditional structures were able to withstand strong winds and rain, and some were not. One of the results of these studies was the recognition that traditional buildings using locally available materials such as bush poles, leaves and vine bindings could withstand storms of reasonable severity, provided good building practices were used. It became clear that where such practices had been neglected, a significantly higher number of houses had been seriously damaged or destroyed. The reasons why those techniques had been neglected are to some extend a reflection of the economic growth and the slow change in the structure of traditional society.

Traditional building methods are, for the most part, hard work. Building materials must be gathered, prepared and assembled by hand and properly maintained. The high cost and low availability of a wood preservative treatment for timber poles, for example, means that a type of timber that naturally resists insects and rot must be sought. Since there may be little time to find the right material in the bush, a less suitable material may be used which will make the structure a little weaker or reduce its life expectancy.

With increased interest in new forms of economic activity there has been a reduction in readily available manpower which has led

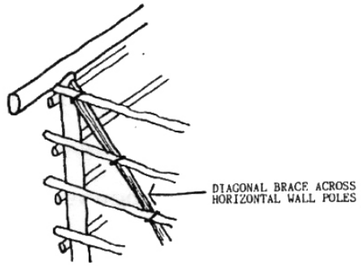
Walls:

Build the walls with poles connected to the long poles at the corners to stop wind blowing the walls in.



Wall bracing:

Brace the top corner of each wall to the bottom with a strong pole tied to the long poles and to the wall poles.

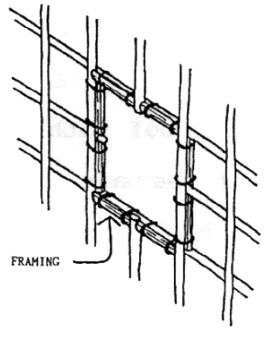


Window and door openings:

Place any window and door openings at least three feet (900mm) from any corner to strengthen the walls.

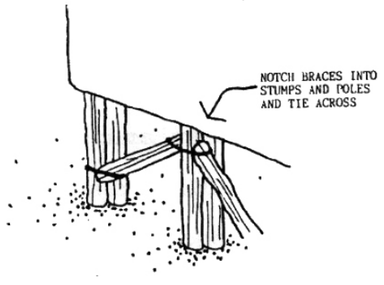
Window and door framing:

Frame up around window and door openings to make the walls stronger.



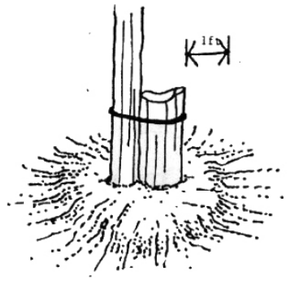
Foundation braces:

To stop tall stumps raking, brace all stumps more than an arm's length above the ground from the top of one to the bottom of the next one.



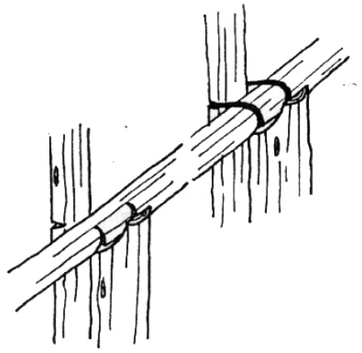
Ground around foundations:

Dig out the ground starting one foot (300mm) from the stumps to allow rain and flood waters to drain away from the stumps and so reduce the chance of rot.



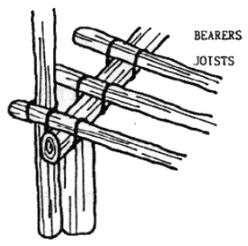
Bearers:

Tie the bearers to the side of the long poles and prop them in notches between the stumps and the long poles.



Floor joists:

Tie the floor joists onto the bearers and onto the side of the long poles. This will make it hard for the wind to blow the house off its foundations.



to shortcuts in house building. Population increases have led to extra demands on available materials making economy a necessity. Equally, builders experienced in housing construction using, for example, sawn timber posts and nail connections now seek further ways to simplify construction.

The introduction of different and apparently easier forms of construction is not necessarily the answer. More modern techniques such as timber framed construction with nailed connections, concrete stumps, galvanised steel roofs and timber walls require different knowledge to be built safely and well. The use of modern technologies applied to traditional structures can make them more dangerous if improperly applied. Galvanised roof sheeting nailed over a pole framed roof structure is weakened with nail holes, or if it is not held down properly, or if it is set at the wrong angle. Pole framed houses set over short stumps in the ground can be blown over if not properly connected - a difficult task at the best of times. These shortcomings become apparent when disaster strikes. As a further result there is, to a varying degree, a loss of faith in development.

The process of improving housing construction is slow and must be accomplished step by step. The traditional ways of building were learned from our forefathers through experience and trial and error. Since error is to be avoided, a slow process of learning and using thoroughly understood technology is a necessity.

Since cyclones, for example, although a regular event in the Pacific area, are generally localised in effect, those areas not

affected are often lulled into a false sense of security. Priorities are switched from safe house building to other areas of development. A major effort must be made to maintain high standards of housing construction. This requires a study of those methods and constant reminders of their value to sustain the knowledge and efforts of builders between cyclones.

Much of the criticism levelled against traditional housing construction is unfounded. It is not so much the quality of the materials employed but the method of their employment which is at fault. Properly executed and maintained, a leaf roofed and walled house built over raw timber poles, properly braced and intelligently located is perfectly capable of withstanding reasonably severe cyclones. Overcoming the belief that modern construction is the only way to resist any cyclone is a challenge to be met. The following principles should be borne in mind:

1. Traditional houses are capable of withstanding cyclones of reasonable severity if properly built and maintained.

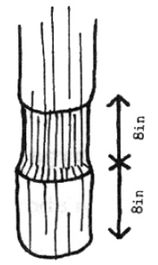
2. Modern building technology is capable of withstanding cyclones of a more severe nature, but is far more costly.

3. Traditional housing techniques, if not properly applied, will not stand up well.

4. Modern housing techniques, if not properly applied, will not stand up well and carry the added burden

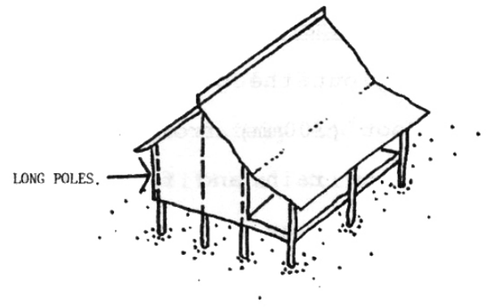
Notch stumps:

Notch stumps before placing them in the ground so you can wedge them with rocks and sand.



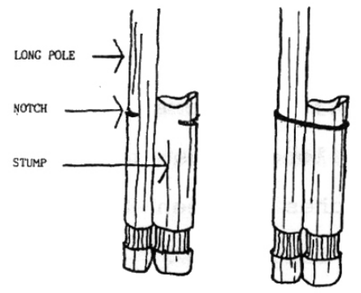
Long pole tie-downs:

Provide long poles to connect the ridge, the corners of all walls and the corners of the verandah to the side of the stumps in the ground thus making a direct connection between roof and ground.



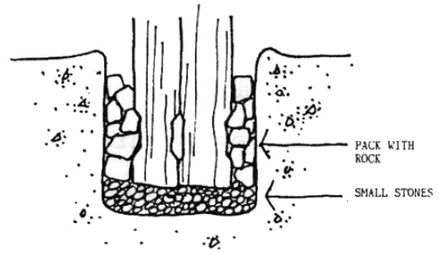
Stumps:

Place stumps in the ground, tied to the long poles to make a firm support for the bearers.



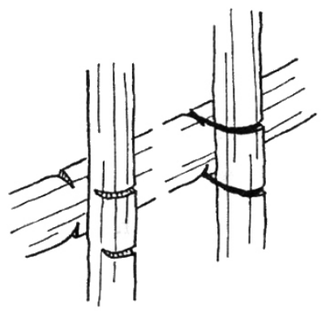
Back filling:

Pack broken rocks or river stones and fine gravel around each stump. They should be rammed in and compacted. Top the hole off with soil to ground level.



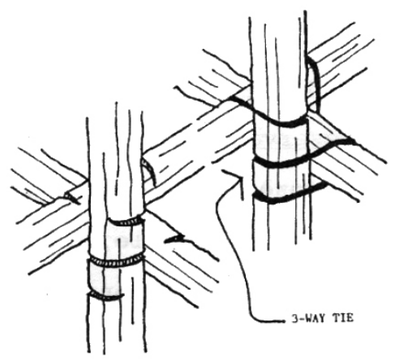
Notch connections:

Notch out vertical members passing over horizontal members before tying them all together to make stronger connections.



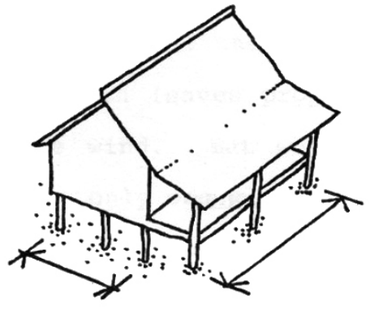
Separate ties:

Tie each connection separately so that if one tie breaks, the others will remain.



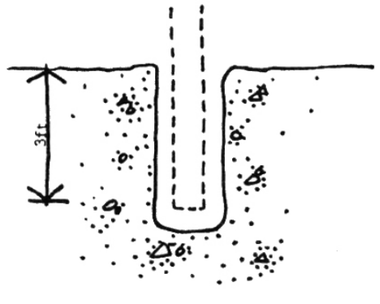
Shape:

Use a simple plan shape - square or rectangular - as this is the strongest configuration (unless you build a circular house).



Foundations:

Dig holes at least an arm's length into the ground to secure the stumps. Place a layer of compacted sand below the stumps to absorb any water that may seep into the foundation holes.



of high maintenance costs.

5. Modern technology is dependant upon economic growth and education in the use of new techniques.

6. A process of re-education in traditional skills is required in order to make the choice between modern and traditional housing.

Although it may not, through pressure of space or lack of available materials, be possible to implement all the principles outlined in this handbook, the more that can be incorporated the better.

Examples of resistant construction

Cyclones, earthquakes, floods and tidal surges are not new phenomena. The Pacific has always been subject to these natural forces and it is valuable to look at the ways both manmade and natural objects have withstood the test of time and the elements.

A coconut tree, for example, although often growing in weak soil, spreads its roots widely and ties them to the ground. The trunk of the tree grows directly from the roots and its fronds from the trunk. In strong winds, the trunk of the tree sways and the fronds, although offering little resistance to the wind and rain, are often torn because they have no shelter. They are twisted and torn away from their single point of contact with the trunk. However, the trunk usually remains standing, still tied to the roots. Likewise, a leaf house needs its roof tied at the correct angle to the ground through the walls, and with leaves properly tied down offering least resistance to the wind. But whereas each palm frond was connected to the trunk in only one place, the roof of a house is tied together and to the walls of the house in many places.

In an earthquake, the coconut tree sways while the ground below shakes, but because it is flexible, the tree remains intact. In the same way a leaf house will be flexible - its walls and floor, its roof and posts all bending slightly as the earthquake rolls by; and as long as it is properly jointed together, it remains in one piece.

During flooding, the ground around the base of a coconut tree,

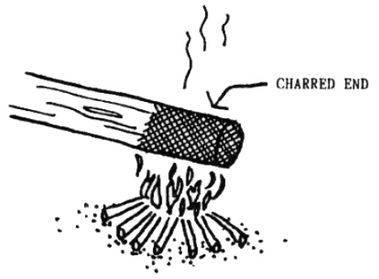
Bearers - Insect resistant, hard, heavy.

Joists - Insect resistant, hard, heavy.

Wall poles - Insect resistant, hard, light.

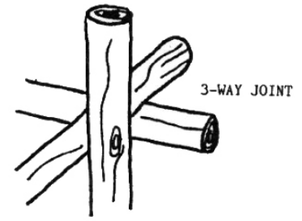
<u>Stump and long pole preservation</u>:

If insect resistant hard timber is not available, char the ends of stumps and long poles over a fire to one foot (300mm) above the ground as a simple form of preservation.



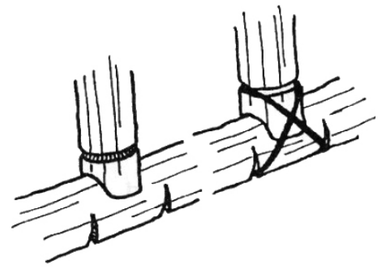
<u>Connections</u>:

Tie all members together three ways to make the joints stronger and more stable.



<u>Tie downs</u>:

Notch out vertical members so you can diagonally strap across horizontal members to make strong connections.



SUMMARY OF CONSTRUCTION DETAILS

The basic principle in building a strong, safe, traditional house is to build a strong frame over which the walls and roof are built. The walls and roof are usually in the form of sewn leaf panels tied to rafters or wall poles behind. Since the availability of materials and methods of construction for wall and roof panels vary greatly, the following construction techniques refer mainly to the frame.

None of the ideas or principles are new - all are traditional or are adapted from traditional construction techniques and are the result of consultation with local builders throughout the region.

There is room for the cultural expression of the different island nations within these guidelines, the principles being merely the basic minimum requirement to attain safe traditional housing.

Choice of material:

Spend time selecting the right timber from the stumps, the long poles, the wall poles and the roof. As a guide:

Stumps - Heartwood, insect resistant, rot resistant.

Long Poles - as for stumps.

particularly near the seashore, is often washed away. However, because the roots have spread and become attached to the ground, the water cannot wash away all the particles of soil and rock holding it up. The foundations of a house must go deep into the ground so that they will not be disturbed when flood waters wash by them.

The coconut tree that collapses under the forces of nature will do so because it is either too old or too rotten to maintain the connection between the fronds and the ground, or because the ground has become so weak that it can no longer stand up. Similarly, a house whose roof is not connected to the walls, the floor, the stumps and the foundations will not stand up; and if the ground is too weak or breaks apart in a landslide or is otherwise broken up, it too will fail to support the house.

Damage

To understand how to resist the forces of cyclones, earthquakes, landslides and tidal surges, it is necessary to know what type of damage can be caused. For convenience, damage is divided into four simple types.

a. Direct assault

This is damage caused directly by the forces themselves - the wind, the rain, the movement of the ground or flood-waters battering the building, tearing at its walls and roof, twisting and breaking its structure and shaking its joints.

This type of damage must be countered by good building techniques and intelligent siting.

b. Objects in collision

This is damage caused by objects, such as trees or loose items like iron sheets or cans, flying through the air or falling onto buildings. Likewise, other structures, uprooted by the wind, carried along by flood waters or demolished in an earthquake may crash into a building, knocking holes in its roof and walls and pushing it over.

This type of damage must be countered by good siting, by clearing away loose objects before the cyclone season, and by good building techniques preventing other buildings or parts of them from breaking free.

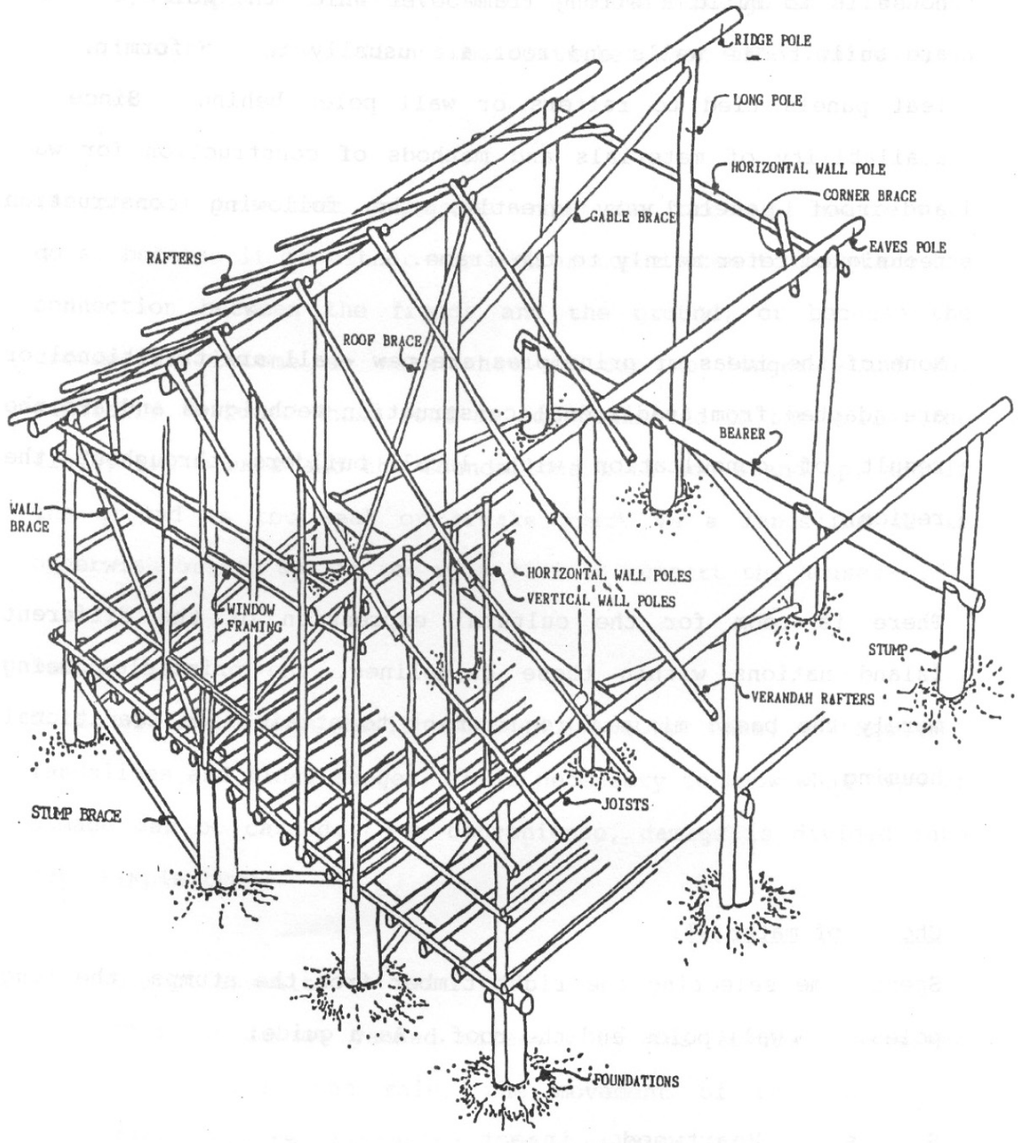
c. Service failures

This is damage caused to water supplies, drainage and electricity lines by such means as: objects falling on them; the movement of the ground fracturing pipes; the pollution of water supplies by flooding of toilet pits and infiltration by sea-water from tidal surges.

This type of damage must be countered by sensible planning of toilet pits and water supplies, by properly burying pipes and by careful location of services away from tree roots which might rip them up if the tree falls.

d. Residual effects

This is the long-term damage caused by occurrences such as: the weakening and breaking of joints and structural members; the subsidence of foundations and the general



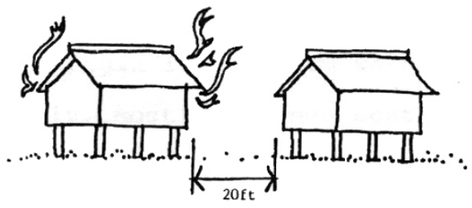
Look for signs of borers and if spotted, spray with 'Actellic' or other suitable poisons. If necessary remove the infected timber from the house.

Fire protection

It is not possible to make a leaf house fire resistant. During storms and earthquakes roofs can collapse onto kitchen fires, lamps can be overturned and wind can spread embers. Leaf houses burn very easily because they are light, flammable, airy and therefore keep the fire going. When a fire burns a leaf house, usually the leaf walls and roof burn quickly, especially if it is dry. Generally the fire does not get hot enough to burn the frame of the house however, although the vine ties may burn through causing the structure to collapse. The best defence against fire is to avoid all risks.

<u>Siting</u>:

To help prevent fire spreading from one house to another, keep all houses at least 20 feet (6m) apart from edge of roof to edge of roof.



Before a cyclone hits, extinguish all kitchen fires and tie down all kerosene lamps.

weakening of the building making it less able to resist forces in the future and allowing rot, fungus and insect attacks to damage it further.

This type of damage must be countered by good building techniques initially and close inspection and immediate repair to damaged parts after the cyclone or other event to prevent further problems from occurring.

It is not possible to construct a building to withstand all the forces of nature. Materials grow old and buildings weaken - dust to dust, ashes to ashes, bush to bush. However, buildings can be strengthened to withstand stronger cyclones and earthquakes that may occur in their lifetime. A weak building can only stand up to a weak cyclone but a strong building can stand up to a strong cyclone.

STORMS

Definitions

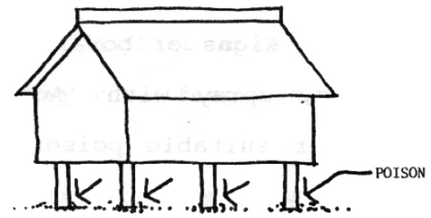
Cyclones are often called hurricanes, typhoons or tempests, but all generally mean the same thing - a storm with strong winds of over 73mph (118km/h). They usually carry heavy rains and cause rough seas. Cyclones rotate like water down a sink. This means the winds change direction during the storm and therefore all sides of a building must be equally strong. The rain is usually very heavy, falling in large drops and is driven in the direction of the wind.

The sea becomes very rough and the wind pushes the waves higher and higher before driving them ashore causing damage. The rain swells rivers to overflowing causing flooding and landslides where the ground is too weak to absorb the water.

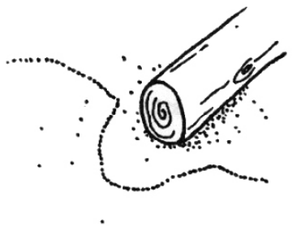
Predictability

Weather records provide a history of cyclones which helps us learn how often, how strong and where we might expect a cyclone to occur. In the South Pacific, the cyclone season is generally between October and May. Most cyclones begin in the warm waters below the Equator and then move randomly, mostly between south-west and south-east. Papua New Guinea is little affected by cyclones but to the east they become more frequent and stronger, particularly in the region of Fiji where they are often most damaging. They are generally less frequent and weaker further east over Tonga, Kiribati, Tuvalu and Samoa. This is only a general pattern for all of the Pacific is affected by cyclones to a varying degree. On average, Solomon Islands experiences a

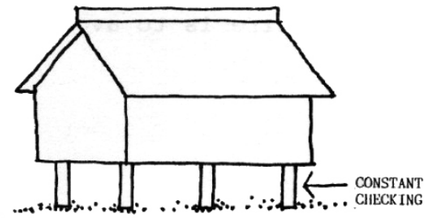
Poison the ground around the stumps with a chemical recommended by an agricultural officer.



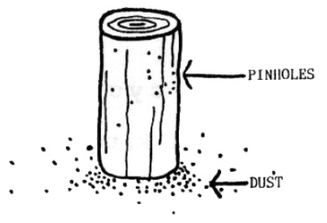
Use only termite resistant timbers for stumps and long poles.



Check all timber for borers before using it. Tap it to see if any dust falls from the holes. If so, remove the timber immediately so the borers won't infest other timber.



Regularly check stumps and long poles for termite tunnels and brush off and poison the ground around the stumps, the long poles and the backfill.



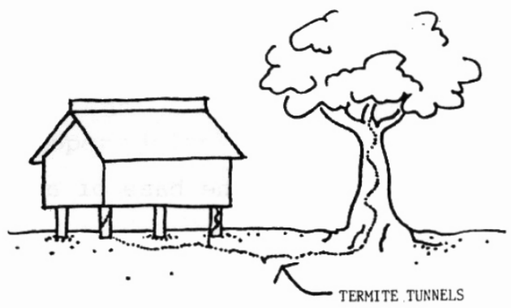
Insect resistance

Wood can be a source of food to many insects including termites and borers who would enjoy making a meal of your house if you let them. Termites live in the ground and build tunnels to connect their home to a source of food - usually a tree, bush or house. It is important to understand this because it helps us protect houses against their effects. Termites enter the timber and eat their way through its softer parts, making the timber weaker. When a cyclone or an earthquake comes, the house may collapse. Tell-tale signs of termites are little brown tunnels running up the stumps and poles and small pieces of brown termite waste that fall to the ground.

Borers are small beetles that can live inside timber without the need for underground nests. They eat the timber, weakening it with the same consequences as a termite attack.

Unfortunately there is no simple protection against insect attack, and once it has begun, only suitable poisons can be used to combat it. The best defence against termites and borers is to never allow them access to the house in the first place. There are several ways of doing this.

Check the ground around the house before you build for termites. Look at nearby trees, houses or fence posts for termite tunnels. If you find any evidence of termites avoid building there.



cyclone of moderate severity every two years; in Fiji there is often more than one a year; in Vanuatu, at least one every two years on average; and in other countries they may occur less often.

Cyclones have the strongest impact at the centerline of their path but can seriously affect an area 100 miles (160km) wide. A cyclone will affect some parts of a country more severely than others and it is only by studying the records that one can predict approximately how often a cyclone may be expected to hit and damage a particular area.

This is important to understand because a cyclone which might be expected to seriously affect a particular area once every ten years may strike twice in two years and then not strike again for twenty years. This twenty year gap could lead to a false sense of security and to a neglect of proper building standards.

Nevertheless, cyclones are relatively predictable. Meteorologists can spot a cyclone even while it is small and undeveloped. It is generally possible, therefore, to give at least several hours notice to a threatened area.

It is also possible to sense a cyclone - the clouds become blurred and visibility becomes hazy. The sky can take on a strange yellowish colour and the sea begins to grow choppy. As it approaches, the sea gradually becomes rougher and the wind stronger.

Effects

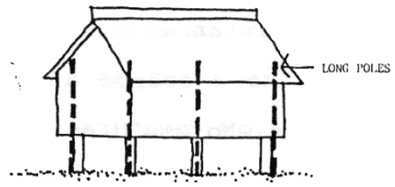
The wind is the main aggressor in a cyclone. It is important to understand how the wind affects a building so as to learn why particular construction techniques are necessary.

The walls and roof of a house are designed to keep the wind and rain out, so when the wind blows against the house it is slowed down but increases its pressure in the same way as a wave is created at the front of a rock in a stream. In order to escape, the wind slides around and over the top of the house at an increased speed, just as the speed of the stream increases when it flows around the side of the rock causing a reduction in pressure or a suction to occur. This suction increases correspondingly with the wind speed over the roof and around the walls. As it passes over the house it also causes turbulence and further suction on the rear wall, just like the movement of the small stones behind the rock in the stream.

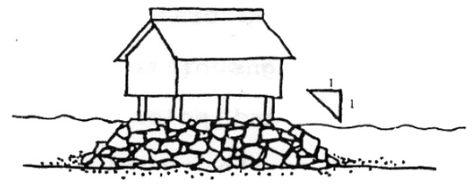
The effect of this pressure and suction is to blow the windward walls in and to suck the roof off. As the wind speed and direction is often changing, it causes strain on all the joints by twisting and stretching them, shaking them and pulling at them. If they are not properly made they will loosen as they stretch slightly and may finally become too weak to hold the roof and walls together. The pressure and suction on the walls and roof cause great strain along the edges, ridge and corners and so special attention must be given to proper jointing, in these locations.

The pressure on the walls increases during the storm, so walls

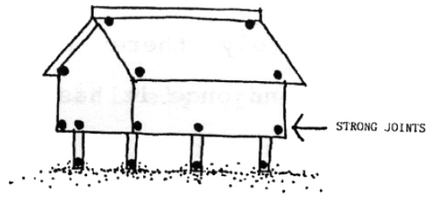
Drive long poles alongside all stumps around the outer edges of the building and tie them firmly to the stumps.



Build up around stumps and poles with rock to form a platform under the house to a height of at least four feet (1.2m) and for a radius of at least four feet (1.2m) around the outside of the stumps.

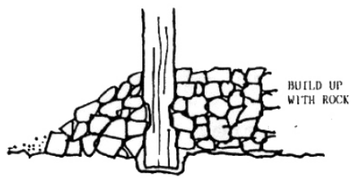


Rigidly brace every wall in the house (refer diagrams pp.61 and 62).



Provide shutters to seal windows and doors.

Notch out the base of all stumps to anchor them (refer diagrams p.59).

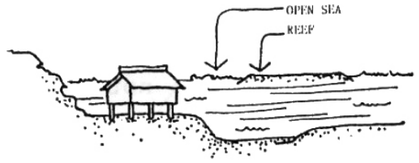


SPECIAL CONSIDERATIONS

Structures over water

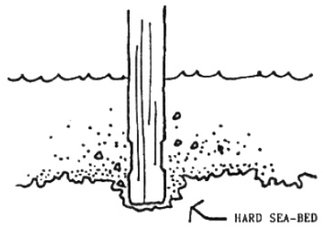
In some places, people build their houses over water. Sometimes they are built over rivers, which should be avoided at all times, but more often over the sea on artificial islands. There is a higher risk of damage because there is no natural shelter from winds and sudden increases in water level. However, such houses are usually built to free as much land as possible for gardening, for protection against mosquitoes and animals and because they are cooler. These buildings can be strengthened using the guidelines, but special attention must be paid to the following:

Take advantage of any natural sea defence such as reefs, islands and harbours.



Select the right insect and water resistant timber.

Dig the foundations into the sea bed, through the sand and onto solid rock, to ensure a solid base.



must be made to resist the bending and ballooning that occurs. If they bend too much, the joints and fabric can give way allowing the wind to suddenly enter the house and, coupled with the suction on the roof, cause it to be blown apart. Bracing and framing of walls, particularly around weak spots such as windows and doors, is most important.

Likewise, if the stumps are not secured, the pressure on the walls and suction on the roof can cause the entire building to be lifted up. Good connections must be made to the ground foundations so that the stumps work like the roots of the coconut tree and tie the house to the ground.

Indeed, even if the roof is tied to the walls and the walls to the floor and to the stumps, but the foundations are poor or the stumps weak, the wind might blow the house sideways onto the ground. Strong foundations are therefore essential.

Resistant construction principles

The principle method in building cyclone resistant houses is to tie down the roof to the walls, the walls to the floor, the floor to the stumps and the stumps to the foundations. Also, the walls must be strong enough to prevent the wind blowing them in, and the joints must be strong enough in order that the wind cannot lift off part or all of the roof or knock the house over.

Since local topography can cause wind speeds to increase greatly by concentrating the wind in valleys, or since exposure on hillsides or the effects of buildings close by can also increase the threat to houses, the following guidelines should be adopted

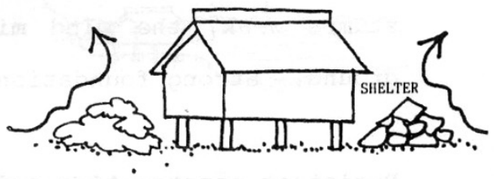
where possible. Otherwise the house will need to be strengthened to survive the strong wind speeds.

Siting:

Do not build at the head of a valley or on the side of an exposed hill where the wind speed can be much stronger.

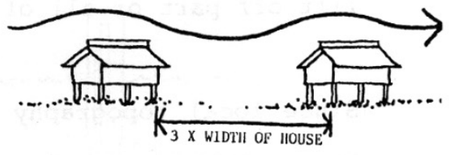
Location:

Take advantage of natural protection such as rocks, banks and strong bushes or plant strong bushes nearby the house.



Planning:

Build a short distance away from other houses and never directly next to them as this can cause destructive wind turbulence.

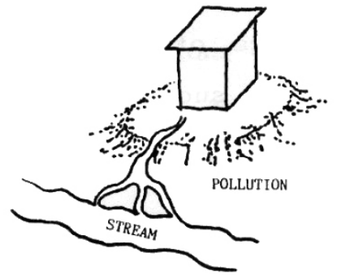


Ground checks:

Inspect the ground around stumps and fill up any areas where water is ponding. The ground may have become covered with mud from the flood waters and should be cleared away to allow natural drainage away from the base of the stumps.

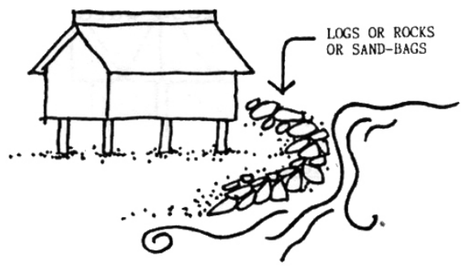
Service check:

Inspect all water supplies to ensure they are not polluted by water-logged toilet pits. Test by smell and secure alternate water supplies if necessary.



Deflection:

Large rocks, tree trunks and copra sacks filled with earth placed at the front of a house can deflect water. Tree trunks must be braced against poles dug into the ground behind them. Waters of up to one foot (300mm) in depth can be deflected by this means.

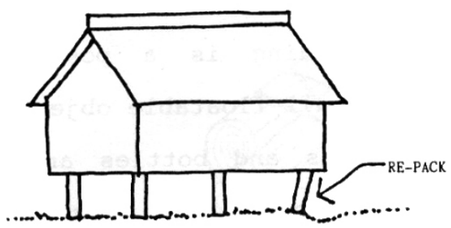


Repairs Afterwards

If your building has been affected by floods it is vital to inspect its underside and any services as soon as possible.

Foundations:

Check whether foundations and back-filling around stumps are still strong. If they have sunk, dig them out a little and re-pack the top with small stones and soil. If stumps are leaning, they must be dug out and replaced, even if it means cutting out a part of the floor to slide them in.

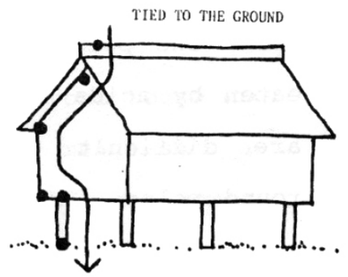


The Frame

Although there are several different shapes and ways of building traditional houses throughout the Pacific, all generally rely on a strong timber frame with leaf panels or mats on the roof and walls. The key to a strong house is a strong frame and the following points should be borne in mind:

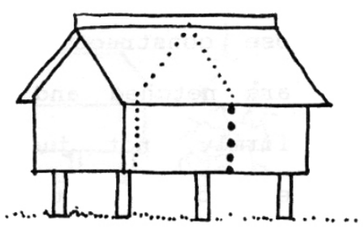
Tie the structure down to the ground:

Connect the roof to the walls, the walls to the floor, the floor to the stumps, and the stumps to the ground, creating a chain of anchorage.



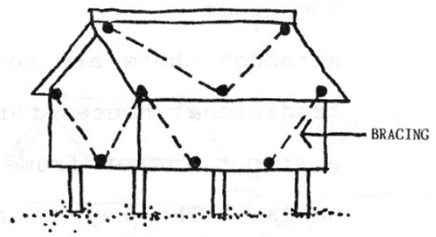
Support all walls where possible:

Build internal walls to brace the outside walls and prevent them from caving in.



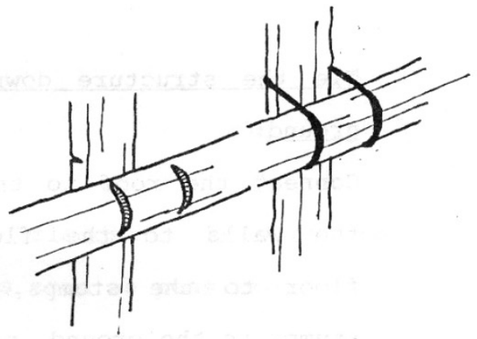
Brace all walls and roof:

Brace all the walls, and across the corners of the walls and diagonally across the underside of the roof with timber braces to make the walls stiff.



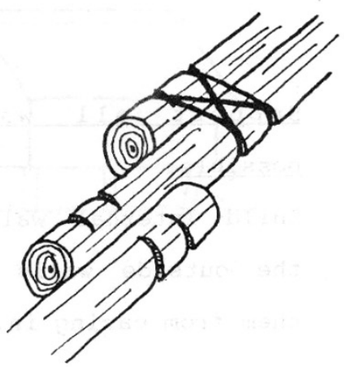
Make strong connections:

Ensure that all structural members are securely connected with vine. Nails are not good connectors because they can split the poles, rust away, be eaten by acids in the wood and are difficult to drive into round poles. Nailed timber is very difficult to replace without damaging the timber to which it is nailed.



Join the parts together securely:

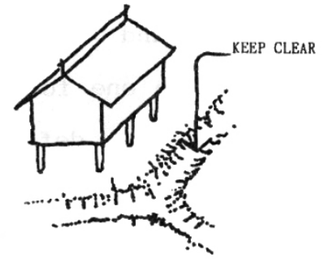
Use construction joints which are notched and tied together firmly, not just tied across each other so that the wind can loosen them.



immediately around the house is clear of logs and the like that can throw flood water upward.

Maintenance:

Always keep natural streams and man-made drainage channels clear and clean to allow swift and uninterrupted passage of rain and flood waters.

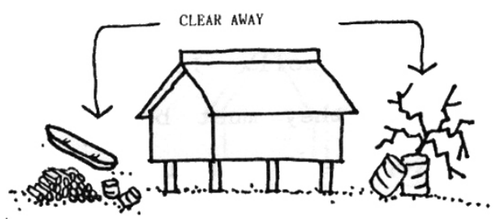


Precautions

It is possible to give some added protection to your house and community from river flooding and saturation by means such as sandbagging. Tidal surges and tsunamis are usually too powerful however, to be resisted by any means other than good siting. Temporary barrier measures should not be used to defend against waves as they can be turned into missiles by the waters.

Clearing away:

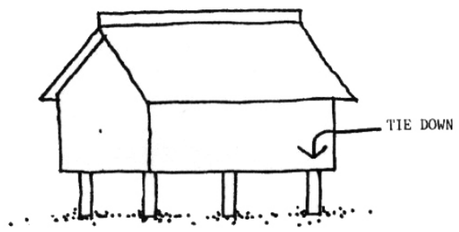
If flooding is a possibility, secure all floatable objects such as drums and bottles and clear away anything that might hinder the flow of the flood waters such as stacks of firewood or random piles of stones.



might otherwise knock the house off its stumps.

Tie down:

Remember that because leaf houses are made of materials which can float, it is essential to tie the house down to the stumps to prevent it floating away. This starts with the fixing of the bearers to the stumps and then tying the joists to the bearers and so on (refer diagrams p.60). It is not enough to rely on the weight of a house to hold it down.



Elevation of structure:

Depending on the likely depth, always aim to place the floor of the house above the level of anticipated flood waters. The water should never reach the floor. As a rule, build your stumps at least an arm's length above the ground.

Minimise resistance:

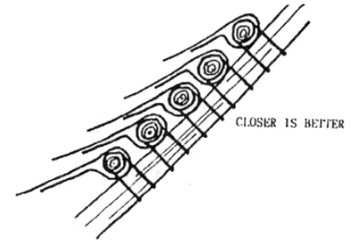
Ensure the area under and

The Cladding

Leaf is an excellent material for housing because it is light, waterproof, cheap and can allow a certain amount of air to pass through which helps to reduce pressure differences inside a house. However, it must be used properly.

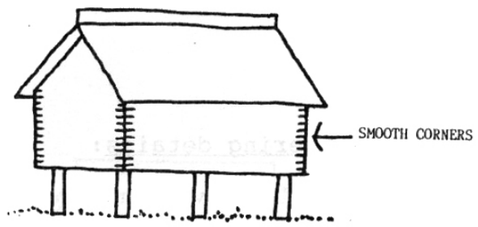
Roof fabric:

Use more leaf on your roof so that each panel can reinforce the next.



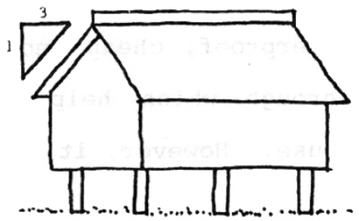
Walls:

Use properly woven and tied leaf walling or wall panels that the wind cannot pull away. This is especially important at the corners to allow the wind to slide around.



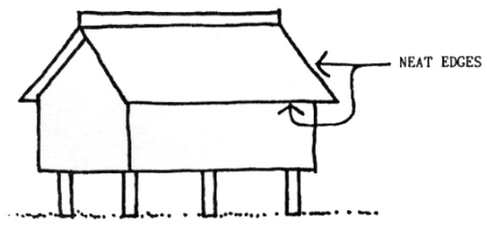
Roof pitch:

Pitch your roof to rise one foot (300mm) or more for every three feet (900mm) along as this reinforces the leaves and reduces the chance of rain being driven underneath. The leaf panels must always slope away from the house.



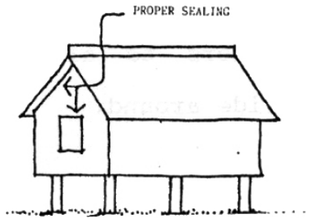
Loose edges:

Tie down the edges and corners of the roof securely so that the wind cannot attack one part and slowly tear it away. Trim back all roof edges evenly - give your house a good haircut.



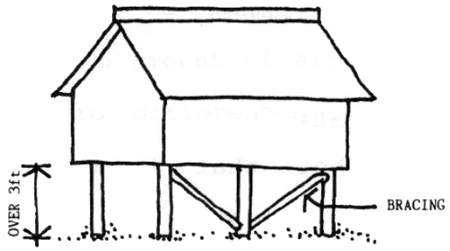
Weathering details:

Seal leaf walling over window openings and where the roof meets the walls to prevent rain and wind from entering.



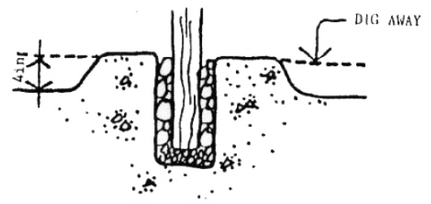
Bracing:

Brace all stumps more than an arm's length above the ground from the top of one to the bottom of the adjacent one, preferably in two directions.(refer diagram p.60).



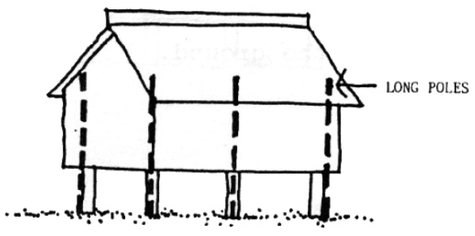
Ground treatment:

Dig away the ground one foot (300mm) from the edge of any stump hole to allow for drainage.



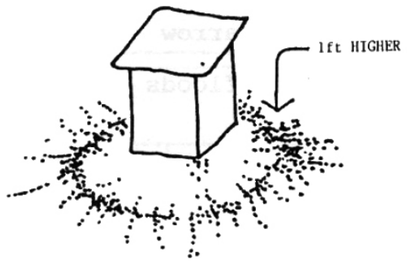
Structural continuity:

Drive long poles into the ground tied to each stump along the edges of the building. This will strengthen the connection between walls, floor and stumps and resist flood waters which



Siting of services:

Elevate the edge of toilet pits at least one foot (300mm) above the ground to deflect flood waters.

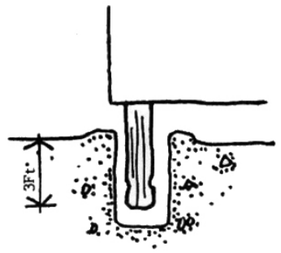


Foundations and Frames

Strong foundations and frames are again the key to building strong houses. Where there is a risk of flooding, it is vital to adopt the following measures.

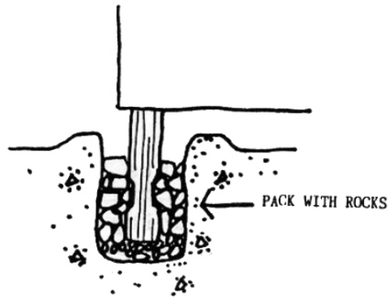
Stumps:

Ensure stumps are at least an arm's length into the ground.



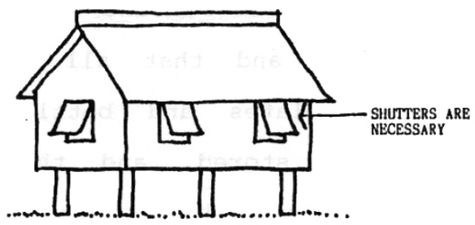
Back filling:

Notch stump bases and use rocks and stones to fill in most of the hole. If river stones are used, pack fine gravel between them. This will make a solid grip on the stump that will not soften during flooding. Top the hole off with soil to ground level.



Closing off windows and doors:

Close off window and door openings with firm shutters of wood, iron or well-woven leaf in strong frames, firmly fixed into the openings. If the wind is blowing strongly from only one side, open the windows on the other side to let the pressure difference equalise, but make sure you close them again if the wind changes direction.

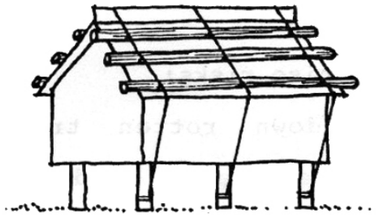


Precautions

When you hear a cyclone warning, there are several things you can do to help preserve your house and keep you safe.

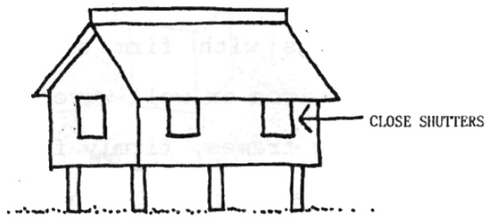
Holding down:

If you feel your roof is unsafe, place long pieces of timber along each side of the ridge and at the eaves and tie ropes from these down to the stumps to help secure the roof when the wind blows.



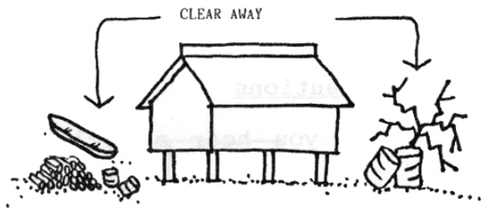
Closing off:

Ensure all window shutters are properly secured and doors shut tightly and that all objects like plates and bottles are safely stored, and that all lamps and other loose objects are tied down.



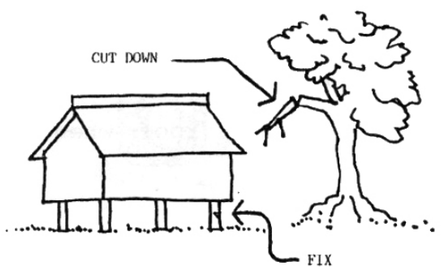
Clearing away:

Move loose objects such as canoes, oil drums, loose branches and other items the wind could blow around away from your house or into your house.

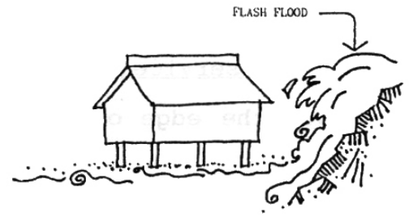


Recognise risks:

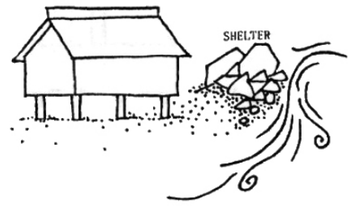
Cut down rotten trees and branches nearby and fix any loose parts of your house, such as foundation stumps that are rotten or posts that are cracked.



Avoid building at the bottom or mouth of narrow rock valleys where flash floods can occur.



Take advantage of any natural outcrops of rock, banks and strong trees to deflect water-borne debris.

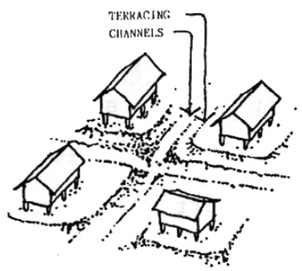


Always build on slightly sloping ground to allow natural run-off.

Avoid building on unprotected seashores.

Planning:

Plan settlements so that the entire community collectively channels and disposes of flood and rain water and terraces the ground.



Fallen trees, other houses and stones bowled along by the weight of water are unpredictable allies to flood water as they seek to demolish buildings. Only defensive siting such as where buildings are protected by natural outcrops of rock or well-rooted trees and elevated positions can protect against this form of attack.

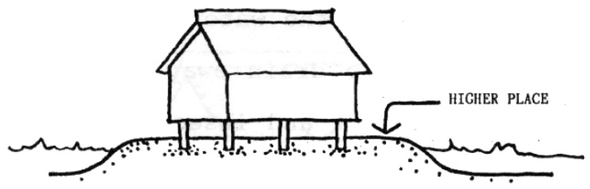
Local topography can turn minor flooding into serious disaster by channelling and compressing the flood waters where they enter, for example, a valley or a river. The flood waters can become much deeper and stronger and sweep by much faster.

Resistant construction principles

Leaf houses are able to stand up to fairly fast moving flood waters because the size of stumps commonly used is quite thick. However, the main defence against flooding is the use of local knowledge and commonsense in selecting a safe location.

Siting

Commonly, flood plains are inhabited because of their good soil and close proximity to water. It is necessary, because of their exposure, to take advantage of hills or rises in the land.



Laying in supplies:

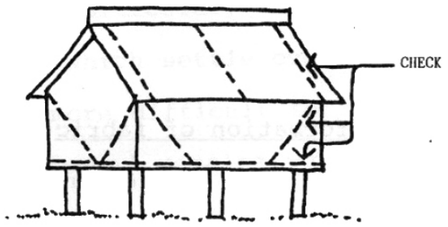
Lay in supplies such as clean drinking water, matches, some food and dry clothes. Wrap them in a waterproof sheet.

Repairs Afterwards

A cyclone will probably cause some damage to your house, but hopefully it will be small. In order that it doesn't become a more serious problem through subsidence, rotting or insect attack, it is important to inspect your house carefully after the cyclone has passed.

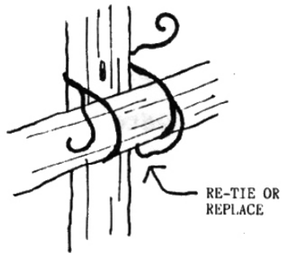
Dislocations:

Examine the bearers and joists, the bracing and the main frame structure to see whether any part has become loose from its seating. If so, put it back in place and fix it down again as soon as possible, otherwise added strain is placed on the house.



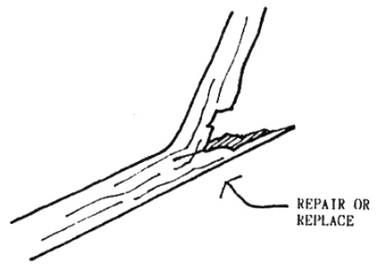
Joint fractures:

Inspect all the joints in the building to see if any are broken or loose. If so, they should be repaired as soon as possible before the wind weakens them further.



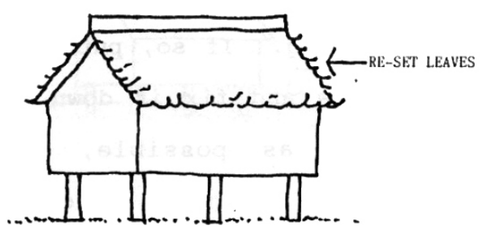
Structural failure:

Check to see whether any of the frame members, rafters, joists or bearers are broken and then take steps to repair them as soon as possible. The house will be weakened by any broken members.



Deformation of fabric:

Check the walls and roof and repair any damaged leaves. Straighten out any that are bent to prevent rain and rot from damaging them further.



Effects

All floods act in several ways to damage buildings. Firstly, because foundations are holes in which the ground has been replaced around the stumps, they are weaker than the ground around them and therefore more easily washed away. By pressing on the stumps and, if the water is deep enough, on the walls and floor, the sheer weight of water can knock over a house, particularly if the stumps are tall and not braced, and the foundations have been washed out. Firm, well-packed foundations are therefore essential.

Flooding also can fill toilet pits and wash out their contents, polluting water sources and carrying disease. Proper siting of services is the best protection from this form of attack. Saltwater is another pollutant which can ruin crops and poison the soil for a long period, resulting in food shortages and malnutrition.

Often large areas of land remain flooded for several days after rains have ceased or the sea waters have subsided. This is because the waters can alter the shape of the land, building up banks and forming ponds and lakes. In particular, rain and river flood waters carry particles of soil which settle over the land when the waters slow down, making it more difficult for the waters to drain away. As a result, the ground remains wet and allows rot and insects that thrive in the flood waters to attack the stumps of a house and its walls and floor. The faster the waters can be drained away the better.

earthquakes cause this pressure on the water, but when they do, the waves move quickly away from the centre, gradually slowing down and growing in height as the sea becomes shallower. Although they can be detected following an earthquake, often they can move too quickly to warn people who might be affected. As the sea bed rises up sharply near the shoreline, these waves called 'tsunamis', give little warning. The only defence against their power is to build behind sheltering reefs on which such waves can break.

Another type of flooding is that which occurs when rain falls so heavily that rivers overflow. Water spills over the surrounding low-lying land sometimes referred to as the flood plain. Rather like spilling a glass of water over a table, the water spreads out very quickly though it may not be very deep. This type of flooding is very difficult to predict, except by local knowledge, and lasts as long as it takes the rivers to carry the water away. It is the most common type of flooding.

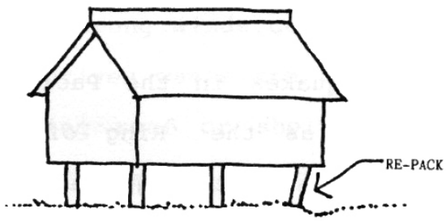
Flooding can be caused also by rain falling so heavily or for such a long time that the ground, which usually absorbs much of the rain and spills what it cannot hold into the rivers, becomes so wet that it cannot absorb any more. This type of flooding can be extremely dangerous because where the soil is very thin or weak, it can soften the surface of an entire hillside and causes the rocks, soil, trees and bushes to slide down **suddenly** and often catastrophically. This type of flooding is usually characterised by the slow appearance of water on the land. Local knowledge being a necessary guide here, good siting is the best defence.

<u>Loss of weather tightness</u>:

Check the walls and roof for leaks. Repair them as soon as possible before they allow rot to attack the frames, joints and other parts of the house.

<u>Uprooting of fixings</u>:

Inspect your foundations to ensure they are still strong. If they are loose, repack them with sand and stones to make them firm again as loose foundations place added strain on the rest of the house.



<u>Deformation of bracing</u>:

Check all bracings to ensure they are still tightly connected at both ends. Fix them as soon as possible as loose bracing will allow the house to move in the wind causing further damage.

EARTHQUAKES

Definitions

The world can be likened to a boiled egg whose shell, though still attached to the egg inside, is cracked in many places. When the egg is squeezed slightly, the pieces of eggshell move against each other. In the same way the surface of the earth, although made of hard rock, is broken up into large pieces which, though still stuck to the soft centre of the earth, are forced to move and rub against each other, causing earthquakes. For this reason, places near where the pieces of the earth's surface rub against each other experience the worst earthquakes.

Earthquakes in the Pacific are confined to its rim, sometimes known as the 'Ring of Fire', which runs from Japan through Micronesia, through parts of Papua New Guinea, Solomon Islands, Vanuatu and New Zealand, along the west coast of South and North America to Alaska from where it finally circles back to Japan. There is also a hot spot right in the middle of the circle, around the Hawaiian Islands. It is called the 'Ring of Fire' because where you find earthquakes, you usually find volcanoes.

Predictability

The limited land masses of the Pacific Islands prevent the prediction of the occurrence or severity of an earthquake in the way for example that the Chinese do. They are able to do so by observing the wildlife and other natural phenomena in their country.

Earthquakes vary in strength and this is measured by scientists

FLOODS

Definitions

Flooding is a general term used to describe the overflowing of water into an area that is normally dry. It is usually caused by one or a combination of events that either provide an excess of water or reduce the ability of the land to naturally absorb that water. It is important to understand that it is the combination of the two that influences flooding and its effects, the normal causes of which are discussed below.

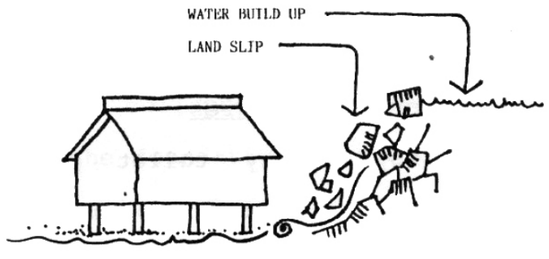
Predictability

Cyclones can make the sea very rough and strong winds can drive water ashore. These high seas and wind-driven waves are called 'storm surge'. If there is no protecting reef or sheltering islands, the waves can do great damage to the coast, houses, trees and land. The sea is pushed over the land, often made worse by high tides, and remains as long as the wind continues to blow it there. The huge volume of water makes the land very wet and often it takes days for it to return to the sea, leaving behind its salt and other debris which can ruin gardens and destroy crops. Sea insects can be carried ashore to attack certain timbers and crops. This type of flooding is predictable because it occurs during a cyclone but mitigated only through intelligent siting away from obvious dangers.

A second cause of flooding by the sea is the disturbance of the sea bed during an earthquake. The pressure of this movement of the earth's crust can cause shock waves to radiate from the epicentre like waves from a pebble dropped in a pool. Not all

Landslip:

Inspect the ground and area around and away from the house for previous landslides and indications that the ground might collapse during rains. Any changes to the amount of water in nearby streams may indicate a blockage higher up a valley which might later burst and flood the area. Clear away small blockages and loose stones in nearby creeks and contact appropriate authorities if a serious problem has occurred.



who can tell how strong an earthquake was and where it was. This is important because sometimes earthquakes can cause the bottom of the sea to move and create waves. Earthquakes are commonly centred around a small area where the forces are greatest. This point is called the epicentre. Generally the closer to the epicentre, the stronger the earthquake feels. However, because of the nature of the forces, sometimes areas some distance away can be affected more. This is because the shock waves travel through the earth's rock crust and severely shake weak areas.

It is probably fortunate that earthquakes occur frequently in the Pacific and tend to keep the ground broken up. This is helped further by the type of ground that makes up the islands- often a solid core of volcanic rock overlaid with coral and clay. This means that an earthquake that has been measured as very strong, often does less damage than expected. Instead of the whole ground shaking, the surface of the ground rolls in little pieces. This is rather like the waves of the sea which, instead of carrying a large tree trunk that slaps up and down, carries small pieces of timber that float with the waves.

Effects

Landslides can be the main cause of damage when an earthquake strikes. They are capable of burying entire villages. Earthquakes are unpredictable, therefore their effects can be sudden and catastrophic.

The main forces in an earthquake move like waves in the sea

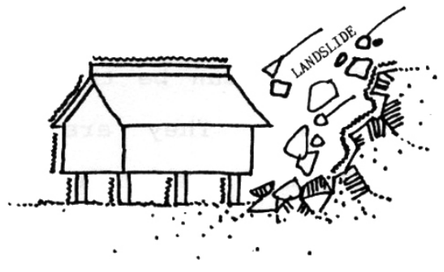
radiating from the epicentre. This is important to understand because buildings, trees and other objects all rise up and down on these waves producing the characteristic swaying feeling. This swaying effect may cause part of a house to rise up while part of it sinks down. As a result, the earthquake's forces cause twisting and rolling of a building and if the connections are not strong, a house may be thrown off its stumps, or parts not properly connected may break away and collapse. Likewise, the movement of the ground can disturb the foundations, causing the ground to subside, particularly if there is weak ground under the topsoil such as loose stone.

Resistant construction principles

The following principles should be followed to avoid undue damage to property:

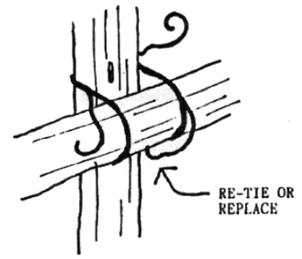
Siting:

Avoid building your house at the foot of a steep hill if you can see that rocks and trees have fallen down earlier. There is a good chance it may happen again.



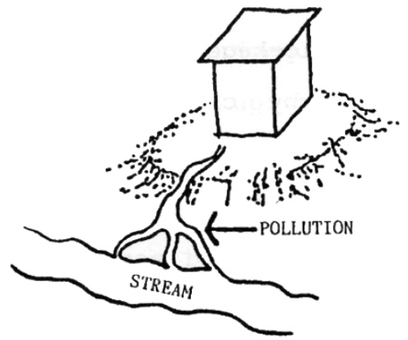
Joint fractures:

Ensure that all connections are still intact by checking the strength of the ties and replacing any bindings that have broken or come loose.



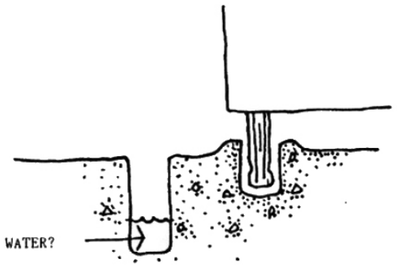
Service failures:

Inspect any toilet pits and water supplies to ensure that they have not been broken or damaged. Make any necessary repairs as soon as possible before disease-bearing bacteria enter the water supply or the ground is polluted. Digging the ground over any toilet pipes and smelling the air is a simple test. Any change in the colour of the water supply is another test, although sometimes a spring or stream becomes cloudy with mud from the shake up.



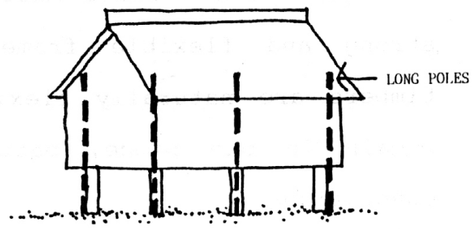
Ground water changes:

Check on the level of any ground water to see if it has risen. It could seep into the foundations or sink down causing the ground under the house to sink.



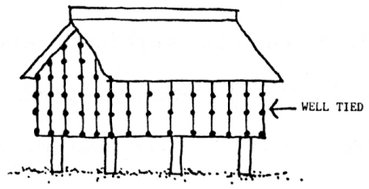
Tie the structure down to the ground:

Connect all walls to the stumps below with long poles and bury them in the ground to ensure that the house is not twisted or shaken off its stumps.



Fix the fabric securely:

Tie all wall panels and roof panels to the wall poles and rafters to help stiffen them.

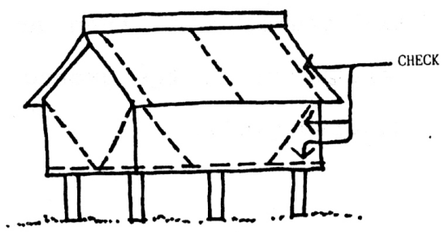


Repairs Afterwards

You can expect some damage to have occurred to your house during an earthquake although it may not appear so at first. Your house may have been weakened and it is important to check all parts after any earthquake or tremor.

Dislocations:

Check to see whether the floor and walls remain firmly fixed to the stumps. Reseat and refix any parts of the frame and roof structure that have come adrift.

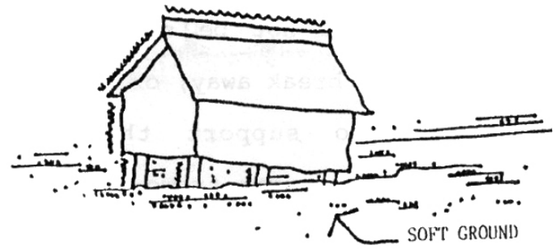


Planning considerations:

Avoid building near tall coconut trees which can sway allowing the nuts to break free or the tree to break in half and fall onto your house.

Local topography:

A study of the ground will indicate whether landslides have occurred before and if the ground is soft on top and liable to move when it becomes very wet and an earthquake occurs. Avoid building on loose ground that can be dug out very easily (the exception being sand and finger coral) because it can subside and settle in an earthquake. Local knowledge is vital.



The Foundations and Frames

Traditional houses, properly built, are usually very resistant to earthquakes. They are flexible and can accept bending and twisting during an earthquake. Again, the key to a strong house is a strong frame and the following principles should be adopted:

Foundations:

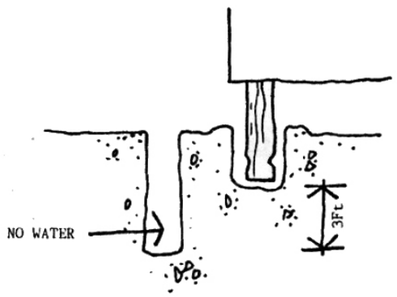
Ensure that the stumps are solidly packed when buried in the ground so that they remain rigid.

Ground conditions:

Ensure that the ground around the foundations will be strong enough to keep the stumps rigid. It should not be so soft that it will break away, or yield and fail to support the stumps during an earth tremor.

Water table:

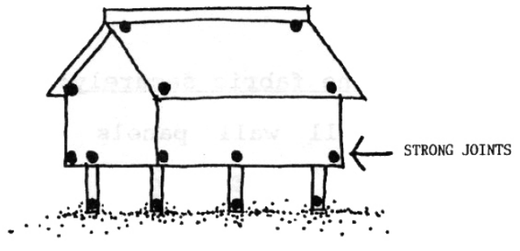
Find out at what depth there may be water by digging a hole at least three feet (900mm) deeper than the bottom of the lowest stump. The water could cause the ground above to break up in an earthquake and may rise like a spring into the foundation if it is under pressure.



The ground usually returns to its normal condition after an earthquake and a house must be built to do the same. Hence, a strong and flexible frame is necessary. Fortunately most timbers are naturally flexible but in order for the house to remain in one piece, particular attention must be given to connections.

Make strong connections:

Securely tie together all pieces of the structure in order to maintain its strength and flexibility. Otherwise parts of the house may simply break away or collapse.



Brace all walls and roof:

Brace all walls and the roof diagonally and brace across the top of all wall corners (refer diagram p.62) to prevent the earthquake twisting the house into a pile of sticks. Brace all stumps more than an arm's length out of the ground (refer diagram p.60).