IMPROVEMENT OF HOUSING IN TUVALU TO WITHSTAND HURRICANES

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Study and recommendations prepared for

the Office of U.S. Foreign Disaster Assistance,

Agency for International Development

Washington, D.C. 20523

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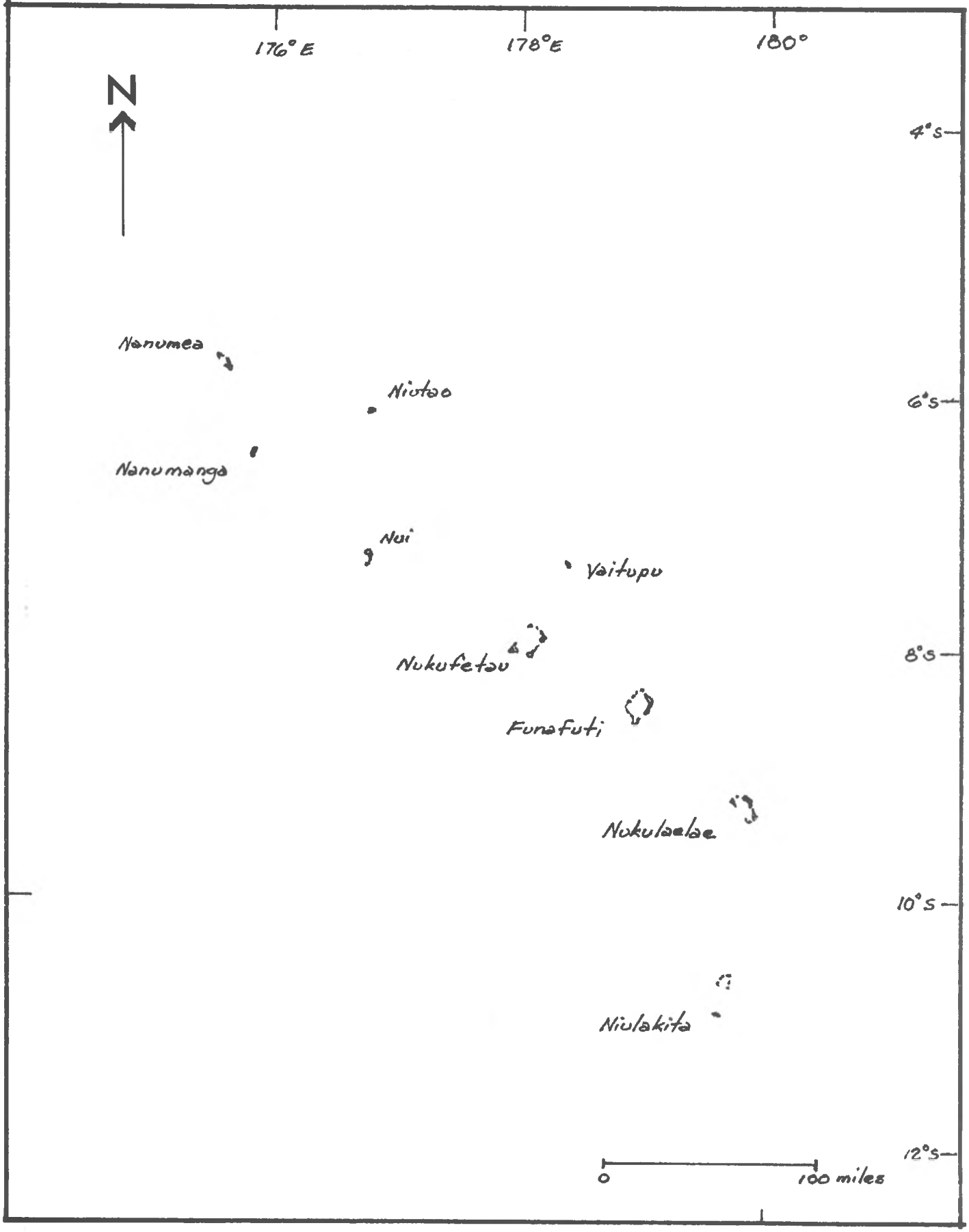


IMPROVEMENT OF HOUSING IN TUVALU

TO WITHSTAND HURRICANES

I. INTRODUCTION

BACKGROUND

As Hurricane Bebe demonstrated in 1972, the majority of Tuvaluans reside in houses vulnerable to damage from hurricanes. The majority of the people on the outer islands reside in traditional fales -- houses which are built without extensive architectural or engineering input and with only limited use of disaster resistant construction techniques.

A devastating hurricane could place an enormous financial burden on the country. Even with extensive foreign aid, reconstruction costs could require a sizable portion of the annual budget for several years. A reconstruction program represents valuable resources that must be diverted from development schemes. Furthermore, housing styles on all the islands are changing, and newer buildings using more modern designs and relying on imported materials are increasing in number. As the investment in housing increases, the potential costs of reconstruction grow proportionally.

In 1979 the South Pacific Bureau for Economic Cooperation (SPEC), in response to the disaster threats in the region, called for the establishment of disaster preparedness measures. At a Disaster Preparedness Planning Conference in Suva in 1979, the housing sector was identified as a priority area for action.

In support of these objectives, INTERTECT was retained by the Office of U.S. Foreign Disaster Assistance, Agency for International Development, to conduct a survey of low-cost housing in Tuvalu and three other countries to determine its vulnerability to hurricanes and earthquakes. The objectives of the Tuvalu study were:

A. To survey the housing of Tuvalu and the construction techniques used in order to:

   1. Classify the various building types, and

   2. Analyze the relative vulnerability of each type of building to hurricanes.

B. To determine design changes, improvements in the construction process, and improvements in the use of local building materials that can make the housing more wind resistant, yet remain affordable to the majority of people residing in these buildings.

C. To make recommendations for dissemination of information about construction methods to protect buildings, including:

1. Short-notice or emergency actions that can be taken to protect existing buildings (including instructions that can be disseminated when a hurricane threatens describing methods for improving safety, and techniques for reducing damage and strengthening buildings to better withstand hurricane forces);

2. Self-help actions for upgrading existing buildings through low-cost modification or retrofitting measures; and

3. Recommendations on how to influence the design and construction of new houses.

DEFINITION OF TERMS

The following are brief definitions of the terms used in this report:

A. Design Changes: the process of altering the design of a structure before it is erected to make it more disaster resistant.

B. Disaster Resistant Construction: a term used to denote the degree to which a structure can be made more resistant to (or safe from) certain natural phenomena. The term recognizes that no building can be considered totally safe, but that certain steps can be taken to improve performance or survivability.

C. Housing Education: instruction for homeowners or builders on how to build a safer or more disaster resistant house.

D. Housing Modification: changes in the configuration of an existing building to make it stronger. Modifications might include changing the pitch of the roof, adding a room, etc.

E. Non-Engineered Buildings: those structures built either by homeowners or by local building tradesmen such as carpenters and masons without formal architectural or engineering input into the design or construction process.

F. Progressive Upgrading: systematic improvements to existing buildings to increase disaster resistance. Measures may include modifications and/or retrofitting.

G. Retrofitting: the process of installing additional supports or altering components of an existing building in order to make it more disaster resistant.

H. Risk: the relative degree of probability that a hazardous event will occur. Tuvalu is situated in a zone of moderate risk to hurricanes and low risk to earthquakes.

I. Traditional Housing: indigenous modes and styles of housing using local traditions, skills and techniques. Traditional housing can be identified by a particular style, design or construction, by popular features, and/or by the building methods used.

J. Transitional Housing: structures that use a combination of traditional and manufactured materials in a modern house form.

K. Vulnerability: a condition wherein human settlements or buildings are exposed to a disaster by virtue of their construction. Buildings are considered vulnerable if they cannot withstand the forces of high winds. Communities on unprotected, lowlying islands threatened by hurricanes are considered "vulnerable communities".

II. RISK IN TUVALU

HURRICANE RISK

Tuvalu is situated on the edge of one of the most active hurricane regions in the world. Within the last decade one major hurricane has struck the islands and several others have passed close by. The damage caused by Hurricane Bebe underscored the vulnerability of the population and showed that a majority of housing cannot withstand the forces of high winds.

Hurricanes threaten housing in Tuvalu in two ways:

--- Damage or collapse resulting from the forces of high winds; and

--- Inundation from storm surges (popularly known as tidal waves) affecting lowlying islands.

Figure 2 depicts the tracks of hurricanes that have struck Tuvalu in the last 50 years. Figure 3 depicts a cross-section of a typical hurricane, showing the sector of the storm system which produces the most damage. It can be seen from this drawing that the band of destruction can be fairly wide, often spanning a diameter of up to 100 miles. Because of the relatively small size of the island group, as well as the small size of the islands themselves, no areas are completely safe from high winds or storm surges.

High winds can cause extensive damage to any type of structure, but generally lightweight buildings, especially those made of traditional materials, are more susceptible to damage if basic hurricane resistant building features are not incorporated into the design and construction. Because the majority of buildings on the outer islands are open structures built with lightweight indigenous materials, they do not have adequate resistance to high winds.

EARTHQUAKE RISK

Tuvalu is situated far to the north of the fault system that generates the earthquakes which periodically affect Fiji and other countries in the region. For this reason, earthquake risk is low.

Damage from tsunamis (seismically-generated sea waves) is a small concern to the islands due to the small, narrow land area where the communities are located. However, as a general rule, atolls are not as vulnerable to tsunamis as other islands or coastal areas, and a re-

FIGURE 2 The Tuvalu Islands – Hurricanes

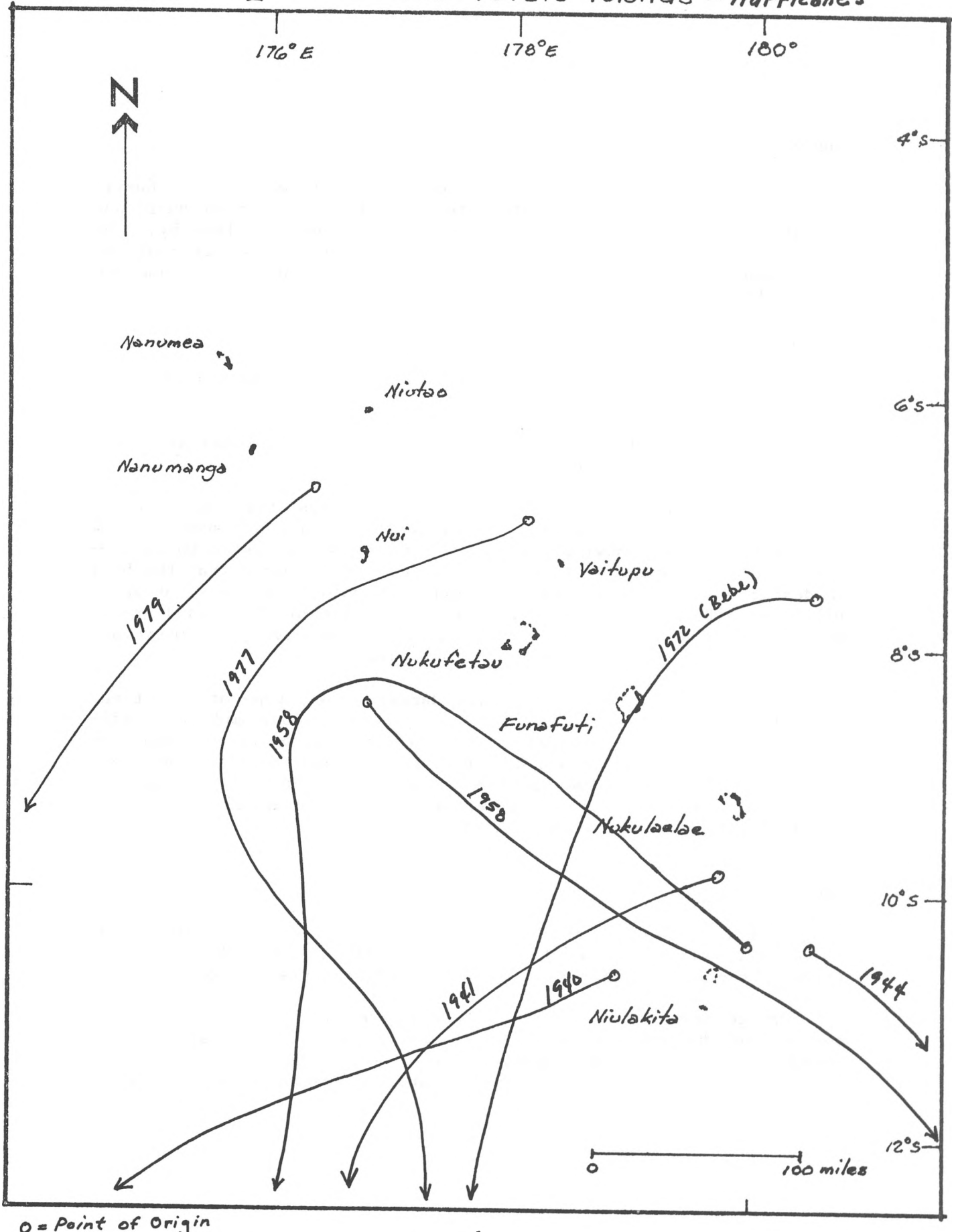
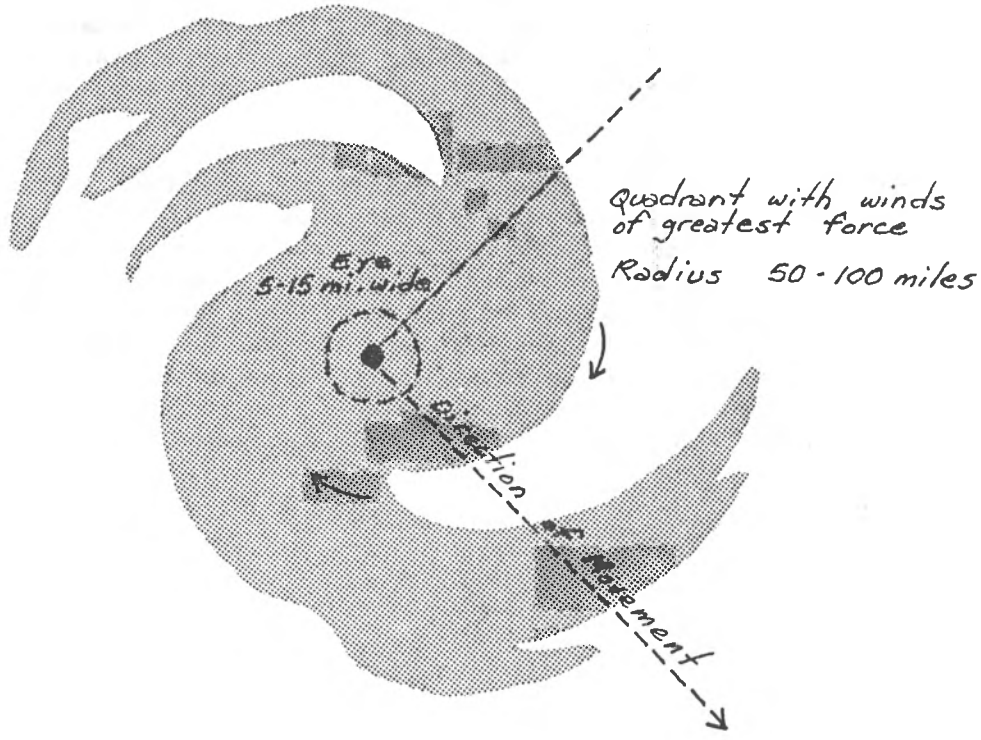
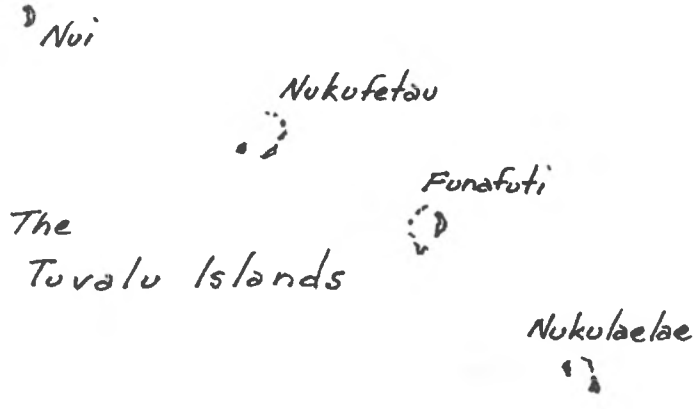


FIGURE 3 Cross Section of a Typical Hurricane





view of historical records* shows no further cause for concern. In any event, little could be done to protect communities in Tuvalu from tsunamis, other than to provide warning and notice of evacuation.

ESTABLISHING PRIORITY AREAS FOR VULNERABILITY REDUCTION

Vulnerability reduction efforts should be initiated in areas at greatest risk, in areas where reconstruction would be most difficult or costly, or in areas that would be difficult to reach or supply. Also efforts will be most successful in areas where new housing is being built.

In Tuvalu, there are several factors to consider. First, hurricanes frequently originate in latitudes below 10^{o}; thus hurricane risk increases the more southerly an island's position in the group. Second, most of the new construction is taking place in the central islands (Funafuti, Vaitupu, Nukulaelae). Third, transport of building materials to all the outer islands is difficult and only Funafuti has an adequate airstrip. Therefore, it is recommended that priority in vulnerability reduction efforts be given first to Nukulaelae, then to Funafuti, Vaitupu, Nukufetau, and finally the remaining more northern islands.

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*Iida, Kumizi, Doak C. Cox and George Pararas-Carayannis, Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean, Hawaii Institute of Geophysics, 1967.

III. CONTEMPORARY HOUSING AND HOUSING TRENDS

CONTEMPORARY LOW-COST HOUSING

Housing in Tuvalu can be classified into one of three categories: traditional, transitional or formal housing.

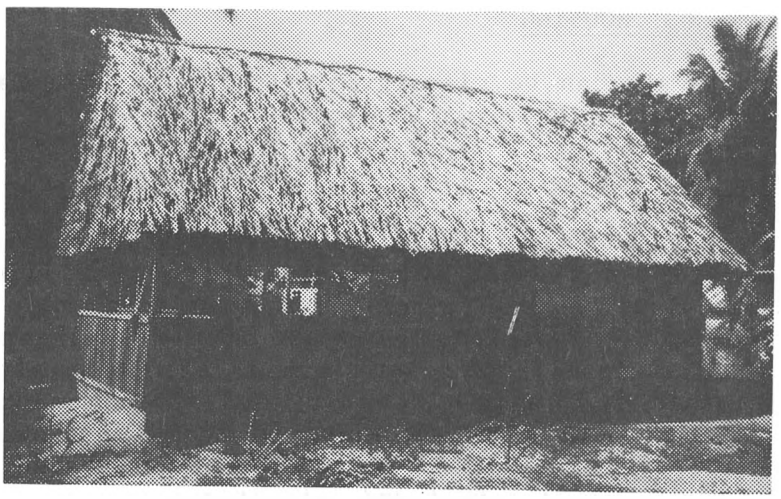
A. Traditional Housing

The traditional house or fale is a beautiful housing form, well-suited to the climate and traditional way of life in Tuvalu. Each island has a distinctive style of fale, many with intricate structural features. Usually only a small section of the house is enclosed; the remainder is left open, although it can be screened in rough weather or when the occupants desire privacy. Unfortunately, fales built in the traditional manner are very susceptible to damage from windstorms because wind can easily get underneath the roof and lift it off.

B. Transitional Housing

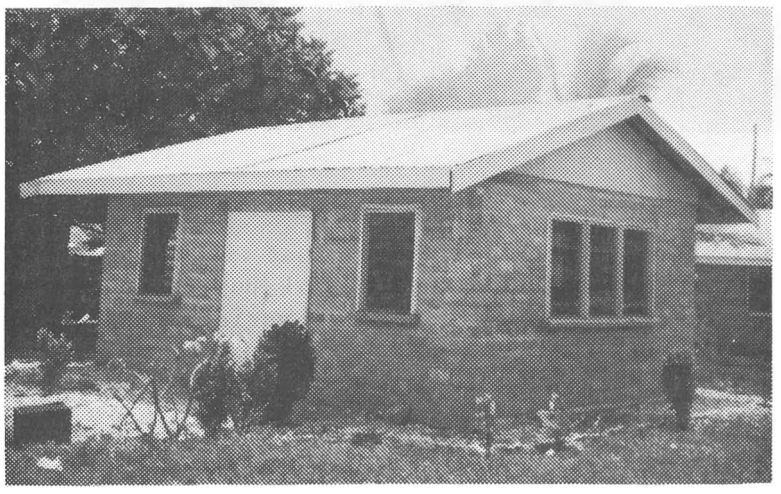
Transitional houses are buildings that illustrate the architectural transition between traditional buildings and more modern forms. There are several popular variations seen in Tuvalu including buildings that use concrete posts to support the roof, fales with corrugated iron (C.I.) sheets on the roof, and build-

ings that use concrete block for the enclosed sections of the house.



C. Modern Low-Cost Housing

Modern housing can be divided into contractor-built housing, government-built housing, and houses rebuilt with foreign aid after Hurricane Bebe. Contractor-built housing consists of a few concrete block designs and some wood frame houses. Government-built housing is provided by the Public Works Department for government employees. No government programs provide housing either directly or indirectly to the public. The Public Works Dept. does provide design assistance to prospective home-builders if requested.



In the aftermath of Hurricane Bebe in 1972, the British government provided housing and building materials for reconstruction to persons living in Funafuti and Nukulaelae. The houses provided (known locally as "hurricane houses") were prefabricated panel-type buildings that were transported to the country and erected on-site. The houses were provided free of charge. Many of the houses are poorly designed, poorly built, and inadequately braced. Now ten years old, many are showing signs of deterioration. The designs are not hurricane resistant and many are as vulnerable as the houses they replaced.

HOUSING TRENDS

There are a number of housing trends that affect vulnerability reduction efforts. They are:

A. Building Trends

Throughout the islands, there is a gradual change from traditional buildings to more modern building styles and materials. This changeover in building styles has several implications for vulnerability reduction efforts. Because the changeover is gradual, there is only limited opportunity to affect the design and construction of new buildings to ensure that they are built safely. It also means that large numbers of people will continue to live in vulnerable structures which they will be reluctant to improve, beyond taking basic emergency measures for personal safety.

The second implication is that, unless vulnerability reduction efforts are begun now, not only will people living in tradi-

tional buildings be vulnerable, but those building more formal houses are also likely to build vulnerable structures.

B. Material Preferences

Persons building new homes prefer to use concrete block. At present, block is cheaper than wood imported from Fiji, New Zealand or Australia. If costs of wood were comparable or even slightly less, concrete block would still be preferred because many families consider it more durable than wood. Most believe that concrete block houses better resist hurricanes.

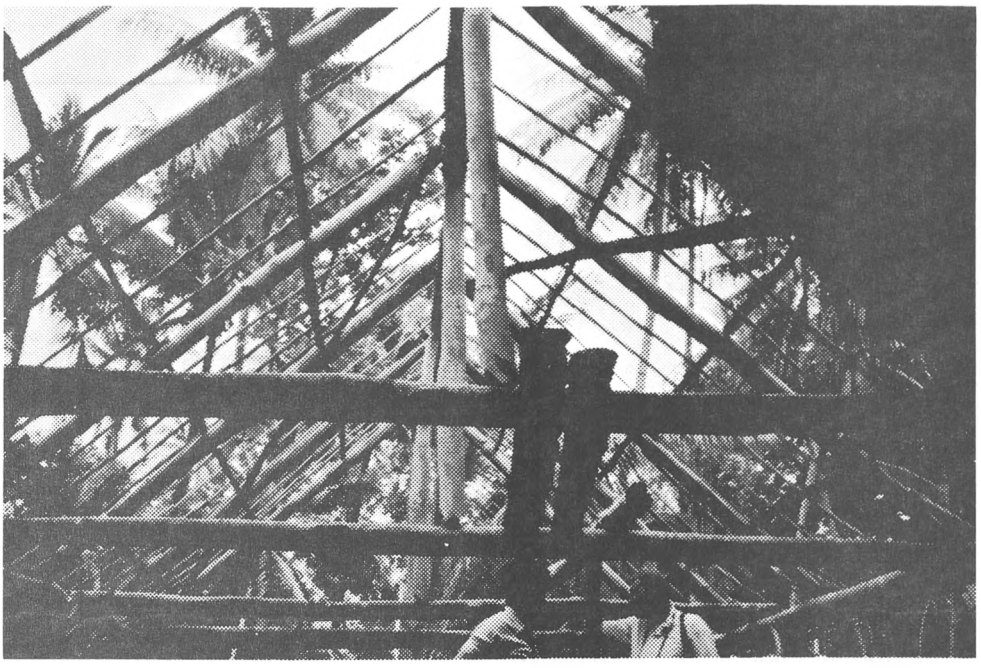
Due to the demand for concrete block, a number of small cottage block-making industries have been established on many of the outer islands. Unfortunately, the quality of the blocks made in these establishments is fairly poor. The government helps subsidize block-making by paying transport costs for cement and in some cases for the actual blocks. Houses made of block are often inadequately reinforced, roofs improperly attached, and the quality of the masonry work is marginal unless supervised by the Public Works Dept. or a contractor. Thus vulnerability is not decreasing and the occupants are actually less safe than if they were in traditional buildings where the collapse of a wood and thatch fale would pose little threat of injury.

When a disaster occurs, the cost of reconstruction will be many time higher than reconstruction of traditional buildings which rely on indigenous materials. Should the disaster occur in the outer islands, costs will be further increased if it is necessary to transport large quantities of manufactured building materials from the larger islands to the more remote areas. This also means that the total time for recovery would be increased due to transport delays and the time required to build more formal buildings.

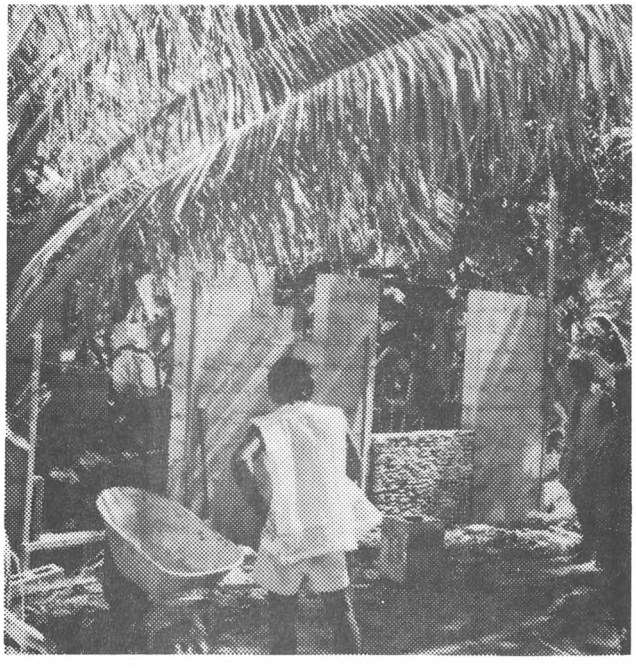
C. Use of Indigenous Materials

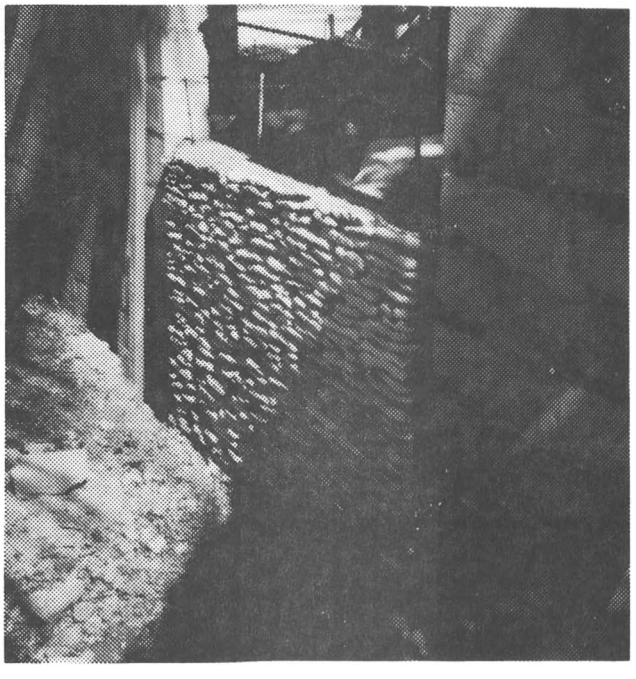
In the past, most fales were built of hardwoods found on the islands. With the growth of the population and the clearing of large portions of the islands for replanting with coconut palms, most of the trees are gone. Most fales now use pandanus or, in some cases, concrete posts for the main frame. Save the Children Foundation has asked a consultant in Fiji to undertake a coconut stem utilization study, a part of which is to determine the potential for using coconut wood in housing. (Stems are now used in the roof frame and in the non-load-bearing parts of some houses.) If coconut palms can be used, this would

provide a much-needed source to keep building costs down.



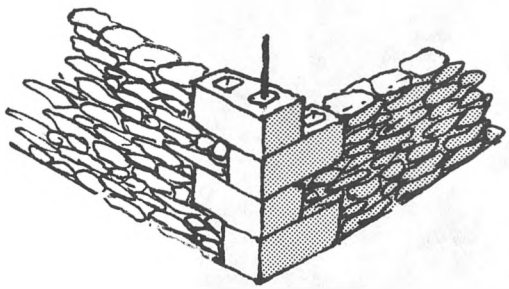
Another way of reducing building costs is the substitution of coral rocks for concrete blocks in some buildings.

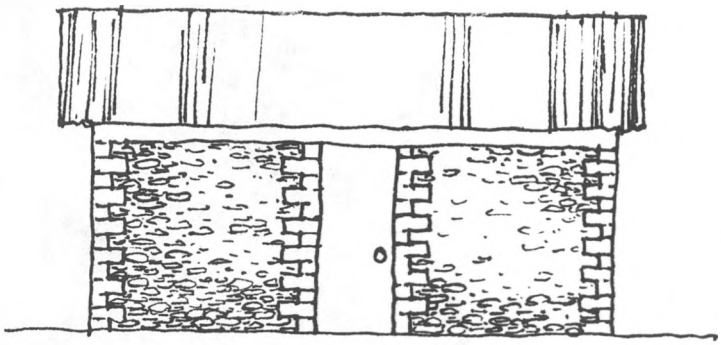




If adequate reinforcement is used, there is no reason why this type of construction would not be safe. In fact, even more

coral could be employed safely as shown below.





D. Increased Use of Contractors

In recent years there has been a trend toward increased use of contractors to build or supervise construction. This is due in part to the demand for more modern buildings made possible by Tuvaluan workers abroad sending money home or bringing their savings when they return. The majority of concrete block housing in both Funafuti and the outer islands is built with at least some input from a tradesman. The number of contractors is very small but growing, and many men are receiving training and experience overseas. A contractor may be asked to build the complete house and provide all the labor. In other cases he may only be hired to provide periodic advice or to build critical components.

The increased use of contractors is an important consideration for housing vulnerability reduction since they build the heavier and more costly structures. Efforts should focus on upgrading contractors' skills and capabilities. Without full participation by contractors, vulnerability reduction will be difficult to achieve.

IV. VULNERABILITY ANALYSIS OF HOUSES IN TUVALU

The purpose of this chapter is to identify the most common types of low-cost houses, to identify the structural problems of each type, and to determine their relative vulnerability to high winds. Options for improving the structural performance of each building type are then considered.

DETERMINANTS OF VULNERABILITY

The extent to which a house is vulnerable to a disaster is a function of four factors: the design and configuration of a house; the quality of workmanship; the strength of the materials used; and the relative safety of the site. In general, buildings made of lightweight materials are fairly susceptible to damage from high winds, but buildings made of heavier materials, such as block or concrete panels, are also vulnerable unless properly reinforced.

Vulnerability to hurricanes is determined by:

--- configuration of the building;

--- configuration of the roof;

--- angle of the roof (a 30-45^{o} angle is best);

--- how well the building is tied together;

--- how securely the roof is tied to the walls;

--- how well the building is anchored to the ground.

Roof configuration and construction are very important considerations for all types of housing. If the roof is not adequately attached and braced, if it has a large overhanging eave, or if wind can easily pass under the roof, it will be lifted off the walls, usually severely damaging the rest of the house.

POPULAR BUILDING FEATURES

A. Features and Practices Which Reduce Vulnerability

1. Hurricane Straps: In some buildings, metal straps and other devices are used to fasten the roof trusses to the building. Planners should encourage increased use of these measures.

2. Small Eaves: The roofs of some houses project only one foot to 18 inches over the sides of the walls. This reduces uplift under the eaves and damage to the roof. Where shading is required for windows, shutters hinged at the top can be used, as is the practice in many of the houses already.

NO YES

3. Steep Roof Pitch: Most traditional buildings have roof pitches of 30-45°. This is to provide better drainage for thatched roofs and to let the heat rise well above the heads of the occupants. This is also an excellent pitch for wind resistance as it helps break up the upward suction as fast-moving winds pass over the building.

NO YES

4. Hurricane Fences: A traditional means of protecting a house is the erection of a hurricane fence several feet away to protect the building from flying debris. The fence is made of coconut fronds lashed together as shown below.

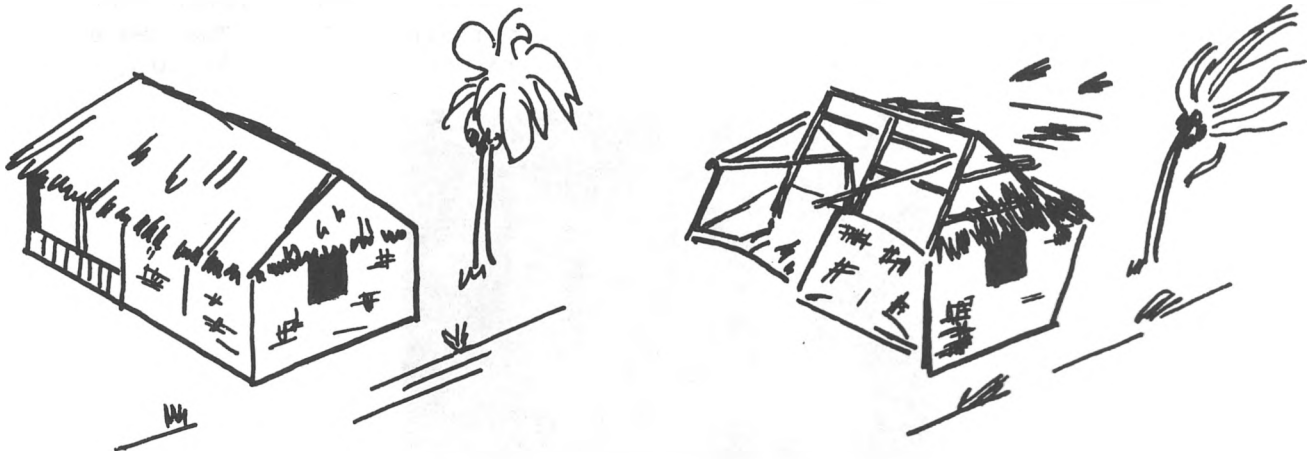
The fences may also cause turbulence in the wind, reducing its speed and its ability to create suction on the outside of the house (but in strong hurricanes, the fence will soon blow away).

B. Features and Practices Increasing Vulnerability

1. Flat or Slightly Pitched Roofs: In recent years flat or "shed" roofs have become popular. Many of the "hurricane houses" use this type of roof. This configuration is especially vulnerable to damage in hurricanes. The low pitch increases suction and uplifting forces.

2. Open Sides: Unfortunately the most distinctive feature of traditional Tuvaluan homes makes them almost totally vulnerable to high winds. Fales with open sides permit the

wind to enter the house and push upward on the roof, usually destroying the entire structure.



Buildings with open sides cannot resist high winds, but safe areas can be constructed inside a building to provide protection, as will be explained later in this chapter.

3. Verandas: Verandas or open porches are a popular feature on many of the modern houses. Many of these verandas would contribute to wind damage, particularly if the veranda is formed by extending the main portion of the roof over the edge of the house. Breakaway verandas, such as those illustrated in other parts of this report, should be used.

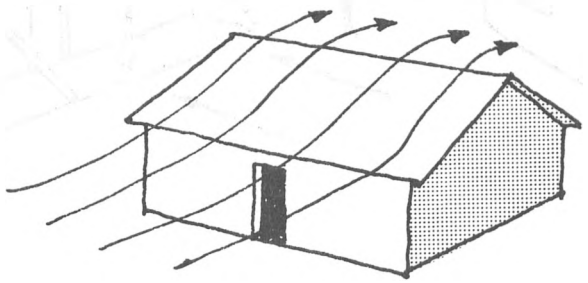
4. Louvered Windows: Louvered windows, especially those made of glass or flimsy metal, are increasing in popularity, particularly in Funafuti. They can be dangerous in hurricanes. Vibrations caused by high winds often cause metal fatigue, destroying the louvers and permitting excessive amounts of wind to enter the house. Glass louvers can be shattered by flying debris, injuring persons inside the house. If louvers are used, storm shutters should be added.

5. Concrete Piers: Many of the smaller wood frame buildings are placed on short concrete posts. In some cases there is some provision for anchoring the frame to the pier, but usually the building simply rests on the posts. In hurricanes, fast-moving turbulent air can pass under the structure, lifting it off the footings and contributing to its collapse.

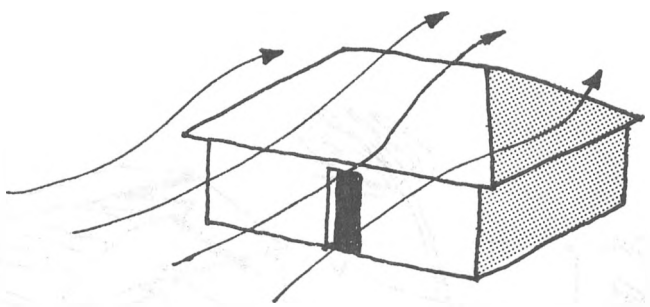
PROBLEMS COMMON TO ALL BUILDING TYPES

There are a number of problems common to all types of housing in Tuvalu. The following section describes some of the more popular styles and details that have been identified as being dangerous in hurricanes.

A. Roof Configuration: Many buildings in Tuvalu utilize a gable roof such as the one illustrated below.

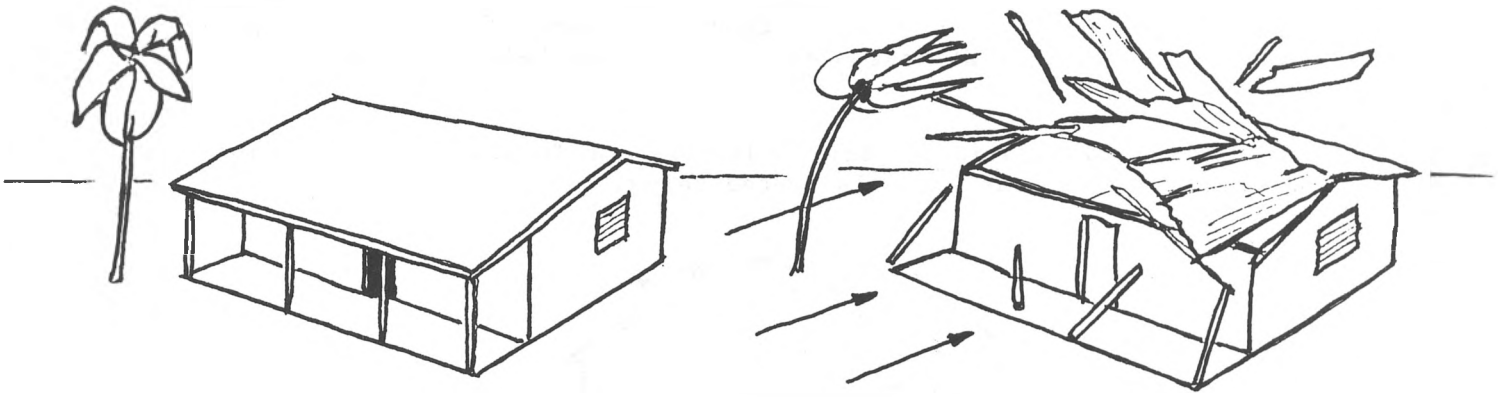


For hurricane resistance, a hipped roof configuration such as that illustrated below is preferred because there is less area directly facing the wind and thus suction will be reduced.



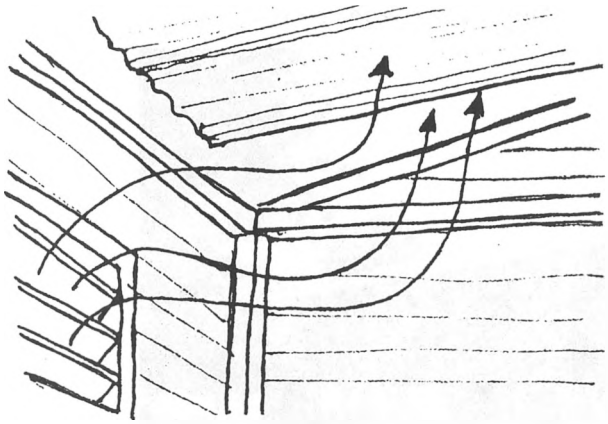
B. Verandas: The manner in which a veranda is constructed affects the vulnerability of a house. If the veranda is attached to the roof structure and traps wind underneath, the entire roof can be lifted off the house.

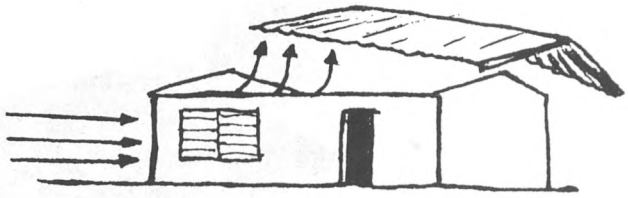
A typical veranda and its pattern of failure is illustrated below.



If a veranda is to be used, the connections between it and the walls and roof frame must be designed in such a way that the veranda can break away from the main structure of the house without severely damaging the rest of the house.

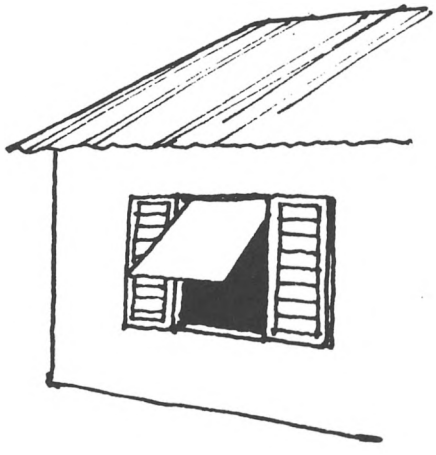
C. Louvers: Unless louvers are completely sealed off during a hurricane, excessive wind can enter the building, increasing the upward pressures on the roof.



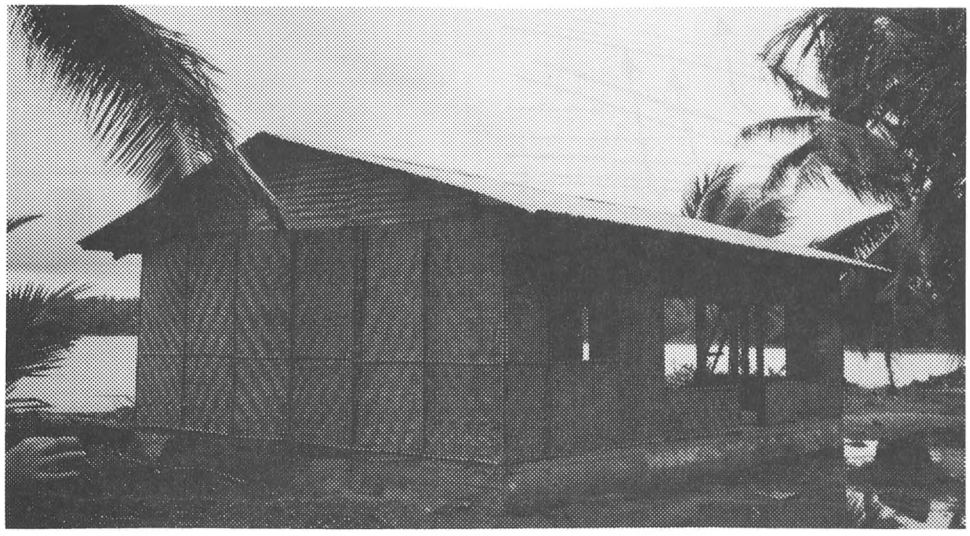


In theory, it should be possible to place boards over the windows before a hurricane, especially if adequate warning is given. In practice, however, wood is scarce and it may be difficult to obtain the materials necessary to seal the windows. The ideal solution is to install storm shutters.

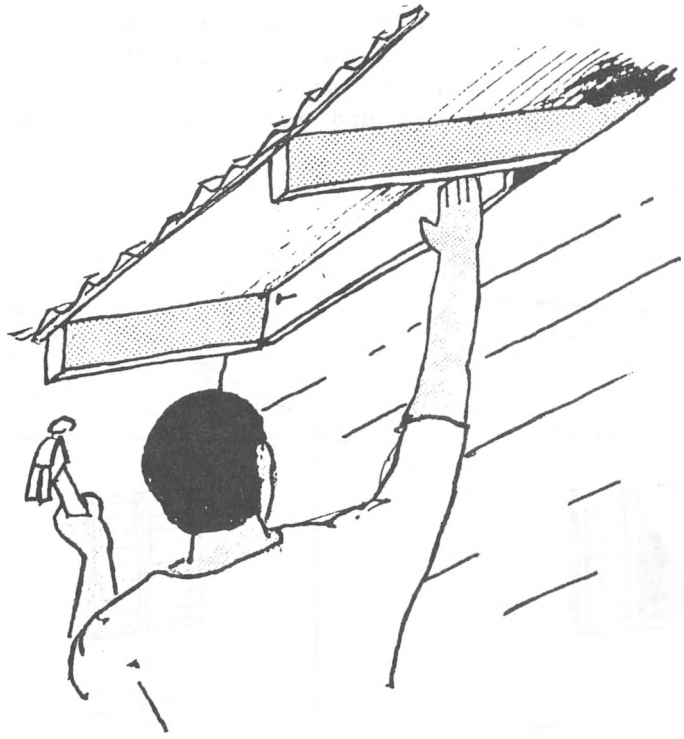
When placed over a window, storm shutters provide a good deal of protection from a hurricane. When a hurricane threatens, the storm shutter is closed over the window. The shutter protects the opening from flying debris and prevents rain from entering through the window.



D. Open Spaces: Many wood and concrete block houses leave open spaces between the roof and walls to allow air to enter the house for cooling purposes. But during high winds this space permits excessive amounts of wind to enter the house and increases the outward pressure on the walls and roof.



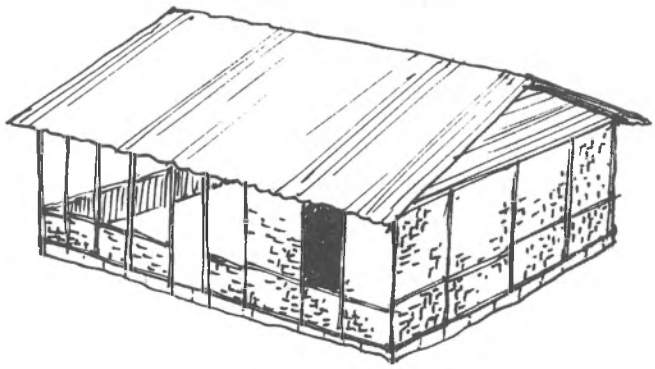
The best solution to this problem is to seal the eave as illustrated below. This will also help reduce the uplifting forces at the edges.

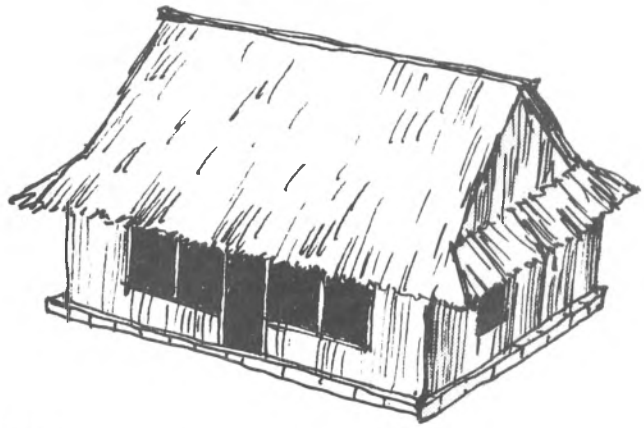


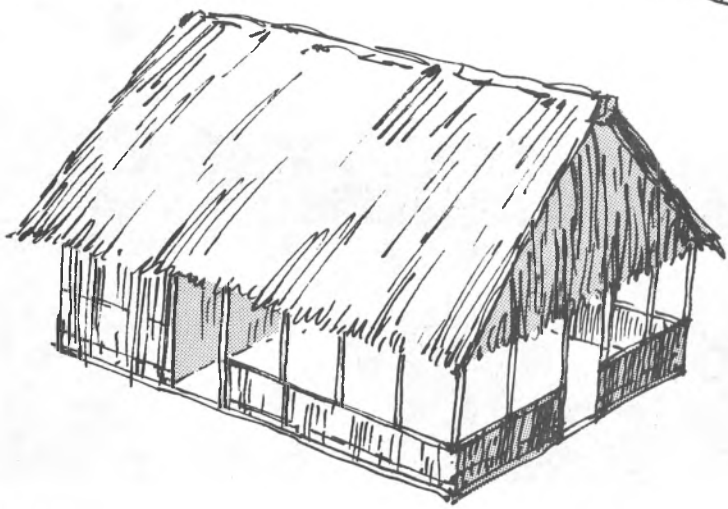
VULNERABILITY ANALYSIS OF THE BASIC CONSTRUCTION TYPES

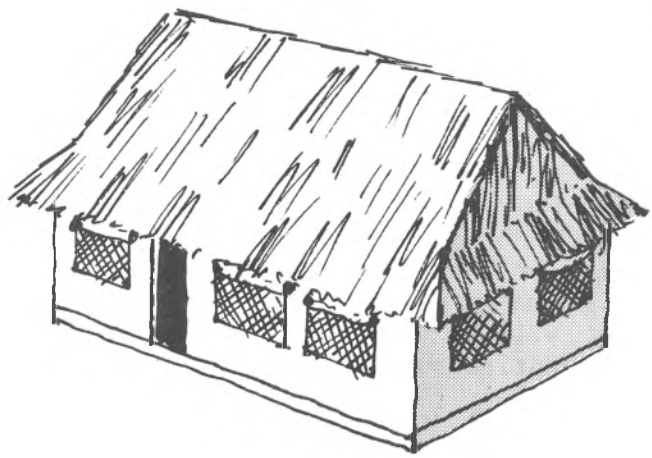
A. Traditional Fales

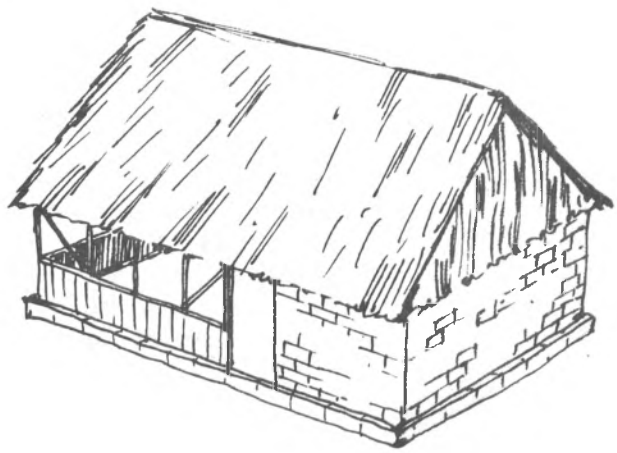
Traditional Tuvaluan houses, or fales, are found on all the islands. The architectural style and design are particularly well-adapted to the climate and environment. Unfortunately, even when properly built, it is not a hurricane resistant design.







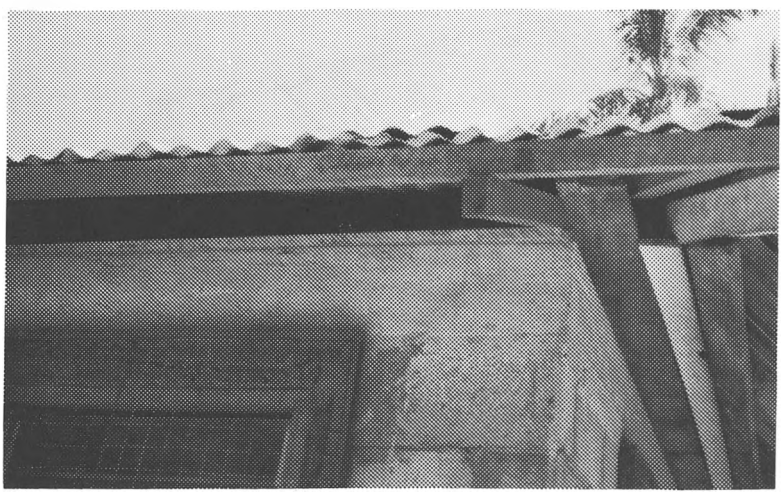




1. Construction: In traditional fales, strong wooden posts are set in the ground. Next a wooden roof frame is erected on top of the posts and covered with pandanus thatch. Typically, a small section of the house (normally an area of approximately 8 x 15 feet) is enclosed; the rest of the structure remains open.

   The walls are made of woven pandanus attached between the main posts. These are often supported by small vertical posts which help to reinforce the walls in the center. Traditionally, the house is bound together with ropes made from coconut fiber or other natural materials; but in recent years nails and sometimes construction wire have been used.

2. Roof: Fales normally have a thatched roof made from pandanus (or in a few cases, palm leaves). Almost all roofs are high and use a unique semi-gabled configuration. In recent years, some thatched roofs have been replaced by corrugated iron (C.I.) sheets.



3. Size: Fales average about 20 x 45 feet.

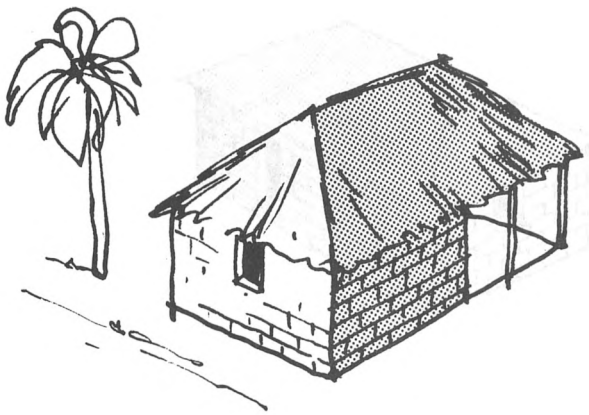
4. Vulnerability: Despite the fact that the traditional construction methods are excellent and strong, the design itself is highly susceptible to hurricane damage. The openness of the buildings is the primary problem. With that much exposure, the roof will not be able to sufficiently resist uplift, and the entire building will usually fail.

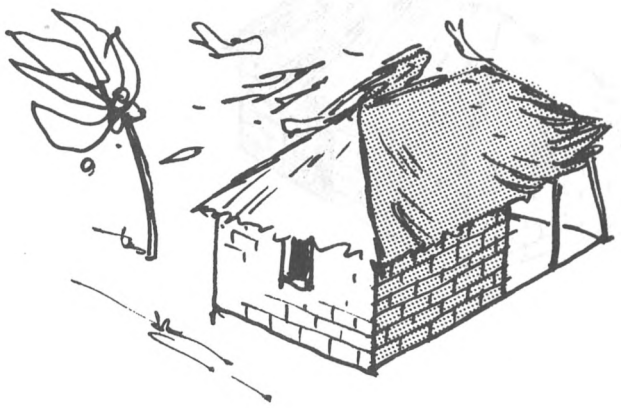
5. Considerations for Wind Resistance: Even though extensive structural damage may result from hurricanes, the potential for serious injury resulting from collapse of these buildings is relatively minor. They are lightweight structures and, because they are woven together, components will not come flying off to cause major harm to occupants.

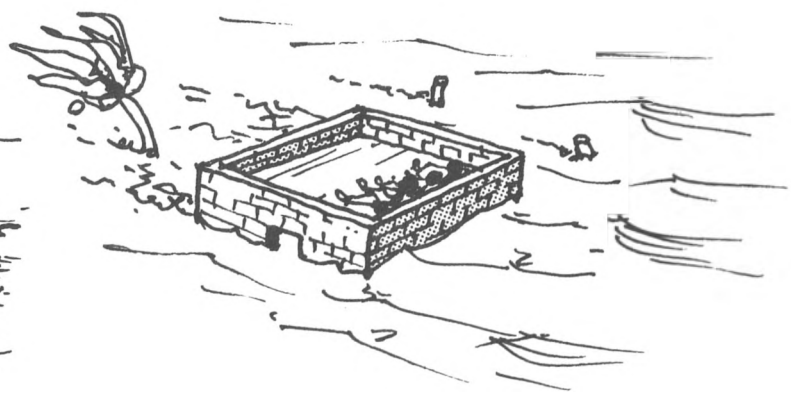
Because the risk of personal injury is so small and because hurricanes are infrequent, it would be unwise to attempt to radically alter the design or configuration of the buildings solely on the grounds of hurricane vulnerability. Furthermore, a general program of replacing the traditional dwellings with more modern structures would be difficult both economically and socially.

There is one alternative that can be recommended. The area of the fale that is enclosed could be built with concrete blocks or a combination of block and coral. The rest of the structure would be built in the traditional manner. The room would then become an in-house hurricane shelter.

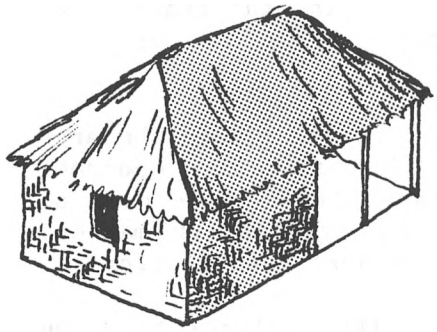
This has several advantages. First, the shelters could be designed in such a way that they would provide protection from high winds but also give some limited protection from storm surges.

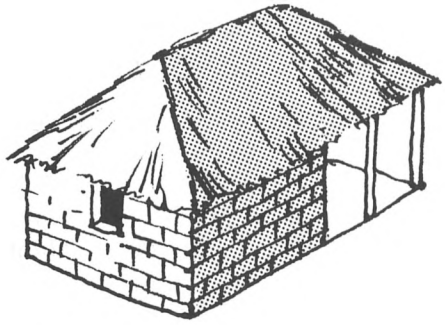


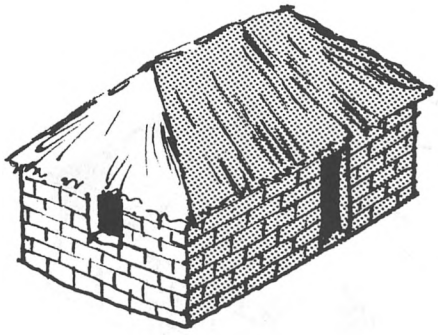


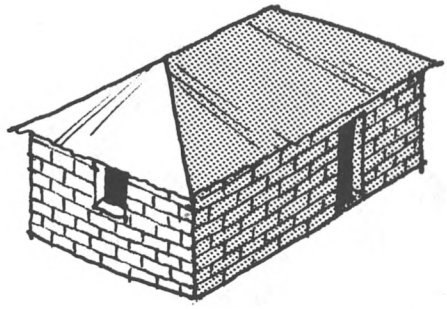


The shelters could easily be added to both new and existing buildings. The change would not be a radical one, and living styles and arrangements would not be altered. The shelters would provide a good solid area for other improvements (e.g. indoor plumbing, kitchen, etc.) and would be an excellent core for future expansion, should the owner decide to build a more modern-style house sometime in the future.





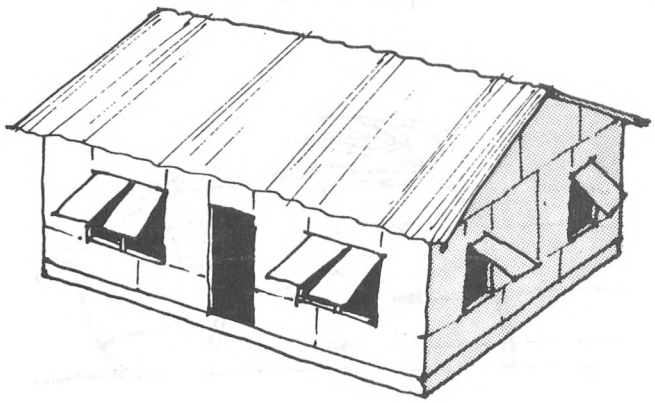


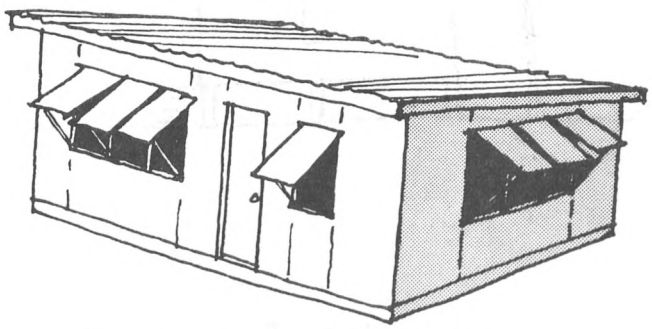


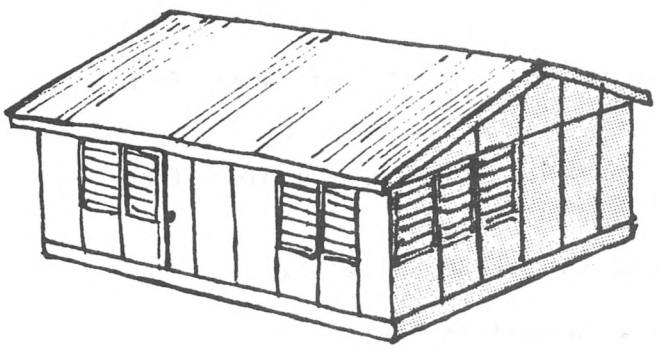
B. Wood Panel Construction

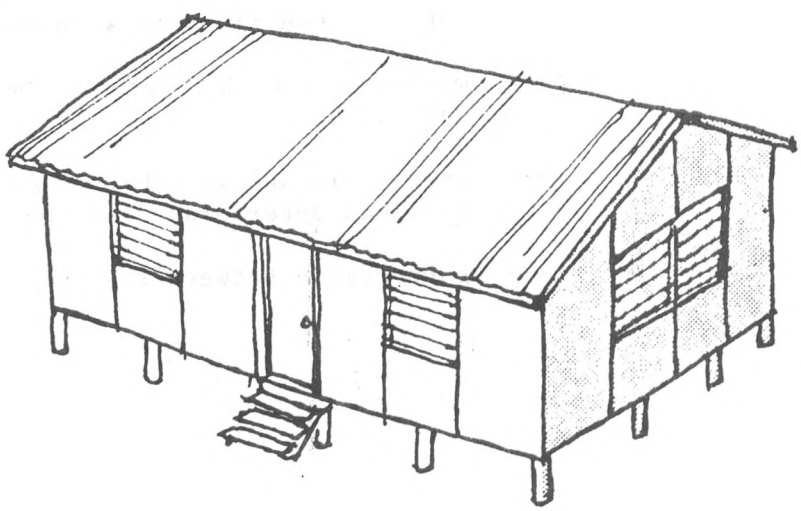
Wood panel houses were erected in large numbers in Funafuti in the aftermath of Hurricane Bebe in 1972. The houses offer the advantages of ease in building additions and suitability to the climate. If properly maintained, they will last for many years.

1. Construction: There are four variations of wood panel houses, ranging from small one-room buildings to larger two-family buildings. The various designs are shown below.







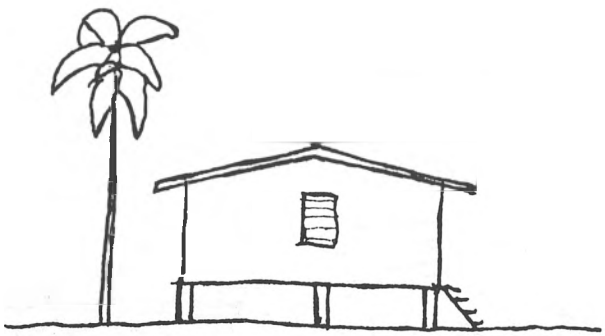


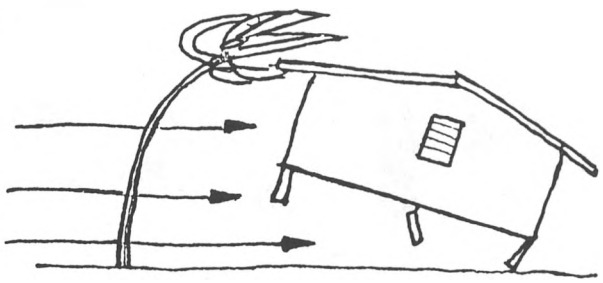
2. Roof: C.I. sheets are used to cover the roofs. Most are single-sided shed roofs, although a few use a gable or hipped configuration.

3. Size: Sizes vary from 12 x 15 feet to 20 x 50 feet.

4. Vulnerability: The most likely damage that would be caused by high winds is roof separation. Loss of the roof would probably also cause further damage to the walls, finally resulting in total collapse of the building.

   Many of the houses rest on short concrete posts or piers. This is insufficient anchorage for hurricanes, and the houses may be lifted off the ground and toppled over.





5. Other Weak Points: Typical weak points of wood frame houses are:

   --- connections between the roof sheeting and roof frame (most nails are too short);

   --- connections between the roof frame and walls;

   --- corner connections between wall panels;

   --- windows (which cannot be adequately sealed or covered);

   --- open eaves on many buildings (the plywood used to seal them has deteriorated and been removed);

   --- connections between the building and the ground.

6. Modifications for Wind Resistance: The following actions are recommended in order to improve the structural performance of wood frame houses in high winds:

a. Emergency measures

--- Use more, and longer, nails to secure the roofing sheets to the roof frame.

--- Seal the area below houses on piers with rocks and mud to prevent uplift.

--- Use metal hurricane straps to secure the roof frame to the walls.

--- Seal (or reseal) the eaves of the house to prevent wind from entering under the overhang.

--- Board up windows during periods of high wind.

b. Progressive upgrading measures

--- Change gabled roofs to a hipped roof configuration.

--- Increase the pitch of the roof, if necessary.

--- Reinforce the connections between wall panels in the corners by using angle irons and/or long wood screws.

--- Place diagonal braces on top of the frame at each corner to tie the walls together.

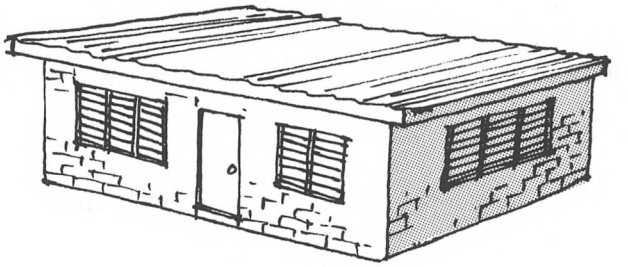
--- Anchor the structure securely. Replace existing piers with types that have anchoring devices.

If these recommendations are carried out, the wind resistance of this type of structure will be substantially increased. If properly built, wood panel buildings provide moderate safety in hurricanes.

C. Concrete Block Construction

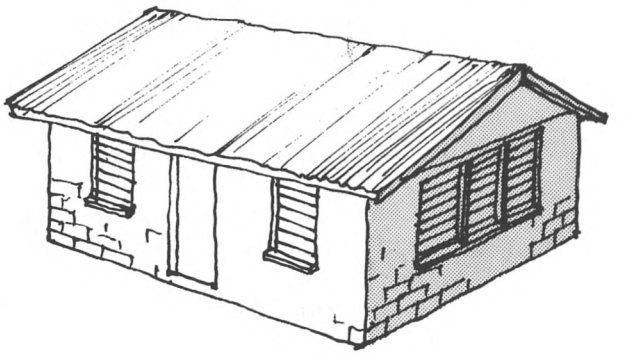
If properly built, a concrete block house can easily withstand windstorms and is a safe form of construction. If improperly built or inadequately reinforced, this type of construction is very dangerous.

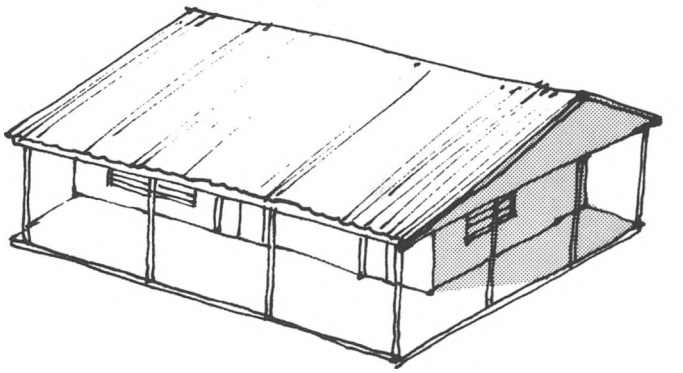
Several popular designs are illustrated below.



Owner-built

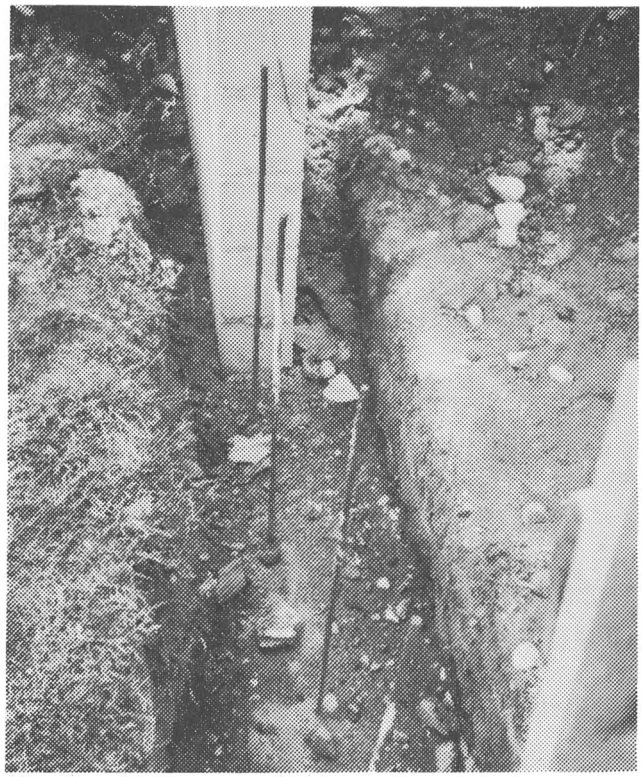
Contractor-built





Government-built

1. Construction: The strength of a block house depends on the amount of reinforcement at the corners, the amount of vertical and horizontal reinforcing in the walls, the strength of the foundation, and whether the house is properly balanced. In Tuvalu, reinforcing rods are placed vertically in the corners and in the walls at no more than 18-inch intervals. At the top of the walls, a ring beam is made of poured concrete. Foundations are made by pouring a thin layer of concrete in the trench, imbedding the steel rods, then cementing a course of blocks slightly below ground on which the walls rest.



2. Roof: The roofs of concrete block houses in Tuvalu are made with C.I. sheets. The sheets are attached to wood purlins which are fastened to trusses held on the walls in two ways. In the first, a portion of the steel rods used in the reinforcing columns is left protruding out of the ring beam. A board plate is laid on top of the beam with a hole drilled for the rod to pass through. The rod is bent over to hold the plate down. The roof trusses are then attached to the plate.

   In the second method, bolts are imbedded in the cement when the ring beam is poured. The plate is then attached by

bolting it down. Of the two methods, this latter is stronger, especially if washers are used between the wood and the nut.

Roofs use "shed" (flat, sloping roof), gabled and hipped configurations.

3. Size: Block houses vary in size. The smallest are approximately 12 x 20 feet, with the average being about 15 x 30 feet.

4. Vulnerability: The most likely damage to concrete block houses includes separation of the roof from the walls (due to a poor connection of the roof frame to the walls) and, in some cases, damage from wind pushing against an unreinforced or poorly reinforced wall, causing failure.

   In cases where houses use louvered windows, excessive pressure could build up inside the house, resulting in loss of the roof. Explosions would occur only to very poorly-built or inadequately reinforced structures.

5. Other Weak Points: Some block houses in Tuvalu have large overhanging eaves and porches. In high winds they trap excessive amounts of wind underneath, creating uplift under the roof edge and thus contributing to roof damage or loss.

6. Modifications for Wind Resistance: In order to improve the structural performance of concrete block housing in high winds, the following actions are recommended:

   a. Emergency measures

      --- Use more, and longer, nails to attach the C.I. sheets to the roof frame.

      --- Seal the eaves of the roof.

      --- Fasten the wooden roof truss more securely to the ring beam of the walls by using hurricane fasteners or straps on each connection.

   b. Progressive upgrading measures

      --- Convert shed or gabled roofs to a hipped roof configuration.

      --- Use a roof pitch between 30-40^{o}.

--- Reduce roof overhangs.

--- Install storm shutters.

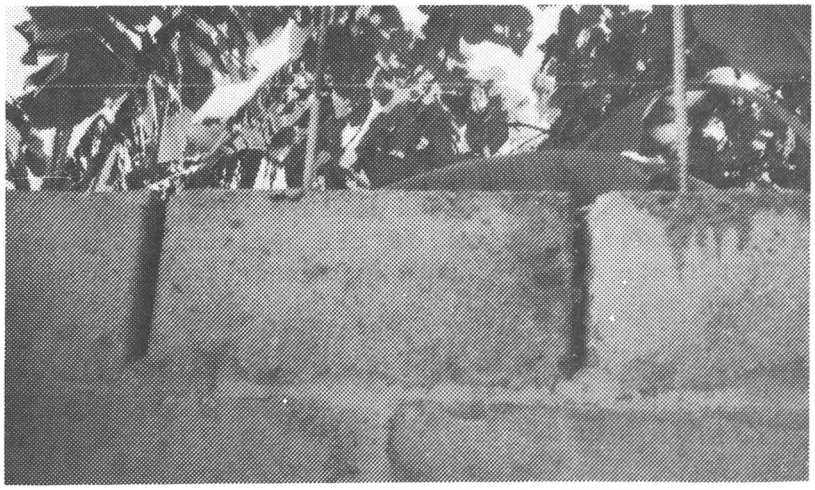
If the recommendations outlined above are incorporated into the design of concrete block houses, the wind resistance of these structures will be excellent and only minor damage should occur in windstorms.

7. Problems in Masonry Construction: The strength of masonry is a function of the alignment of the wall (both vertically and horizontally), the strength of the mortar, and the strength of the blocks. A number of faults have been noted, including:

   a. Poor-quality blocks: This is usually a result of lack of quality control in the local fabrication of blocks.

   b. Poor mortar: There is often a tendency to reduce costs of the mortar by using less cement in the mix. This reduces the strength of the bond. Likewise, there is a tendency to make the mortar too wet in order to make it more pliable and easier to work with. This too reduces the bonding strength.

   c. Insufficient mortar between blocks.



   d. Improper or insufficient foundations.

V. VULNERABILITY REDUCTION STRATEGIES

Vulnerability reduction measures include three types of activities: provision of public information about emergency measures to protect existing buildings; progressive upgrading for existing buildings; and improved design and construction of new buildings.

EMERGENCY MEASURES

Emergency measures are immediate actions taken to provide protection from an imminent danger such as a hurricane. Emergency measures focus on actions that ensure the safety of persons within a house.

Thorough planning and preparation are required to effectively disseminate the necessary information when a hurricane is forecast. Preparedness planning in the housing sector should be a part of routine government activities. Each year at the beginning of the hurricane season, government officials should review their plans and ensure that the necessary materials are prepared and on hand.

Some examples of emergency measures that can be taken to protect housing are shown in Appendix I. Government officials should be taught these measures and should demonstrate them to the islanders each year. Posters illustrating how to protect the various types of buildings should be printed and distributed, and booklets should be made for teaching school children these procedures.

PROGRESSIVE UPGRADING

The overall objective of progressive upgrading is to strengthen existing housing to withstand a hurricane. Actions focus on activities which can be carried out by the homeowner with minimal financial and technical assistance, and which do not require extensive reconstruction or modification of the building. In Tuvalu, activities should concentrate on wood panel and concrete block houses rather than traditional fales.

Examples of progressive upgrading measures are:

--- Changing the configuration of the roof

--- Reducing roof overhangs

--- Sealing the eaves

--- Adding storm shutters

--- Installing or increasing hurricane straps in the roof

--- Installing connectors in walls and corners

--- Improving foundations or footings

--- Replacing deteriorated wood

--- Increasing the number of wall-to-ground connections

--- Replacing short piers with longer piers that have anchoring devices

Progressive upgrading in Tuvalu can be accomplished through an intensive public information campaign and periodic demonstrations of the required techniques. The government should take the lead in encouraging people to upgrade their houses, and they should designate the Public Works Department to serve as coordinator. Save the Children and the Peace Corps can help by demonstrating the techniques on the outer islands.

In order to encourage people to carry out housing upgrading and modification, the following are required:

A. Information. In order to both encourage and guide progressive upgrading, a variety of information is needed including illustrated booklets that show how to do the modifications.

B. Technical Assistance. Most people upgrading their houses will do so on a self-help basis. To ensure that upgrading is carried out in a correct manner, technical assistance in the form of advice and demonstrations should be readily available on all islands.

C. Development of Local Skills. Some housing improvements may require the services of contractors. It is important that the government provide training to enable them to do the improvements correctly.

IMPROVED DESIGN AND CONSTRUCTION OF NEW BUILDINGS

Improved design and construction focuses on ensuring the safety of new housing by encouraging builders to incorporate disaster resistant features in buildings as they are erected. This requires creating an awareness of the need to add these features and development of a reservoir of talent and public information about how to build safely.

Many new houses will be constructed in the next decade as people on the outer islands build more modern houses. It is imperative that special emphasis be given to disseminating information on how to build hurricane resistant housing so that these structures will be safe and the people's investment will be protected.

The methods used to make new buildings strong are often simple and uncomplicated, and usually add little, if any, extra cost when they are routinely incorporated during construction. Design changes include:

--- Changes in building configuration

--- Changes in building layout

--- Changes in roof configuration

--- Changes in roof pitch

--- Changes in balance

--- Changes in the design or layout which increase strength and durability and/or facilitate reinforcing

-- Modifying certain details to increase strength

--- Changes in design of foundations and footings

Construction improvements include:

--- Improved quality of workmanship

--- Improved use of building materials

--- Increased use of reinforcing materials and components

--- Use of better-quality materials

A. Requirements and Information Resources. The requirements and information resources for improvement of new houses are essentially the same as for progressive upgrading, although the emphasis is on affecting construction before and during the building process.

B. Coordination. Responsibility for effecting improvements in new construction should be assigned to the Public Works Department. Personnel should be trained so that they can review plans and advise people on the correct building methods.

C. Technical Assistance. A more comprehensive range of technical assistance and information is required to effect improvement in new construction. Initial emphasis should be given to buildings made with concrete block or the block and coral method described earlier.

COST REDUCTION STRATEGIES

In order to enable some families to participate, the cost of materials may have to be reduced. The government should identify those materials that are critical, then identify methods to reduce the costs. Methods may include:

--- Payment of transportation costs

--- Local production of components

--- Subsidies

--- Cooperative activities

PUBLIC INFORMATION MATERIALS

Three separate sets of materials are required. Many of these materials are already available or can be quickly adapted from existing resources. An asterisk denotes materials that should be prepared specifically for Tuvalu.

A. Materials for Public Awareness and Promotional Activities

1. Film: "Building for Safety in Hazardous Areas": A 15-minute film explaining how the forces of hurricanes and earthquakes damage houses. This film should be shown periodically to promote public awareness. The film uses animation to show how buildings collapse and illustrates how different building features and designs affect performance.

2. *Audio-Cassettes for Radio Programs: A series of audio-cassettes for use by the radio station, describing hurricane precautions, should be prepared for broadcast at the beginning of the hurricane season and when a storm threatens.

3. *Posters Showing Emergency Measures: Posters showing simple emergency measures for protecting buildings and people from hurricanes should be printed and distributed each year at the beginning of the hurricane season.

B. Training Aids for Strengthening Existing Buildings

4. *"How to Strengthen Wood Panel Buildings": Pamphlet to illustrate reconstruction measures which can improve the strength of wooden buildings in hurricanes. Special emphasis should be placed on use of hurricane straps and the problems of piers and anchoring the buildings.

5. "How to Strengthen Houses Made of Concrete Block": Pamphlet to guide homeowners in how to evaluate and improve block houses, placing special emphasis on reinforcing the connections between the roof and walls.

C. Training Aids for Design and Construction of New Buildings

6. *Instructor's Manual: A manual including sections on construction techniques, building details, instructional techniques, and guidelines for training including how to prepare a class, how to effectively demonstrate building details, and how to prepare course outlines for topics not discussed. Suggested course outlines and checklists for each class in a training program should be included.

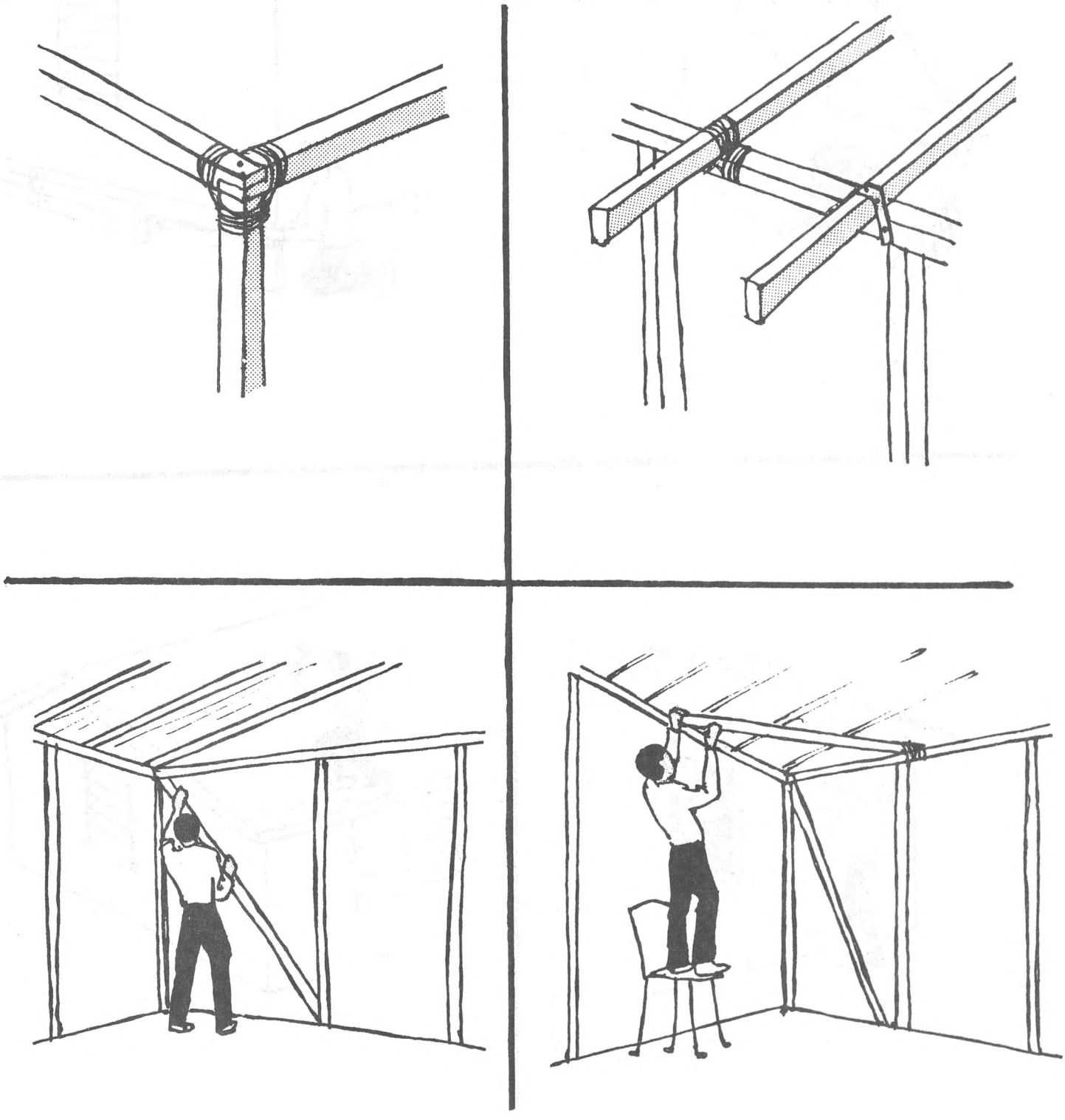
7. Introduction to Wind Resistant Construction: A Guide for Agencies in the South Pacific: Booklet to introduce the basic concepts of wind resistant construction.

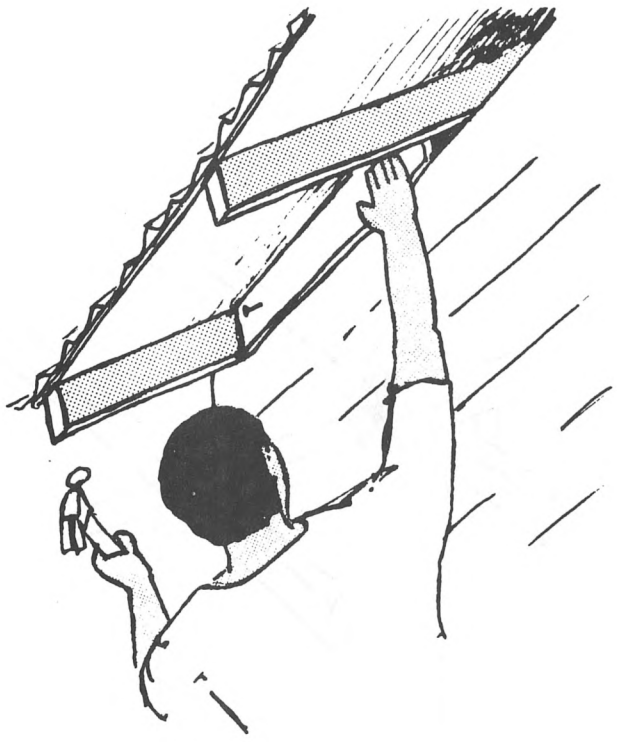
8. *"How to Build a Safe Concrete Block House": Pamphlet to serve as a guide for those building with concrete block or concrete block and coral.

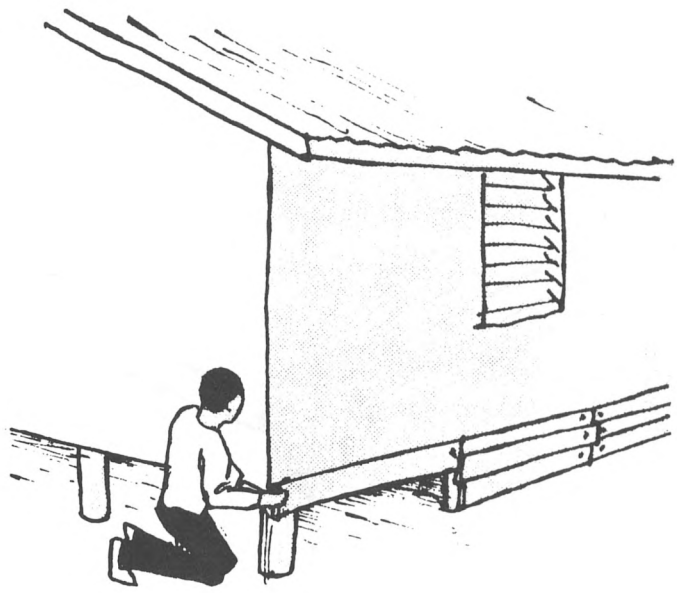
9. "Techniques of Concrete Construction": Pamphlet to demonstrate correct techniques for preparing and using cement and concrete (can be prepared from existing materials available from VITA and the Peace Corps).

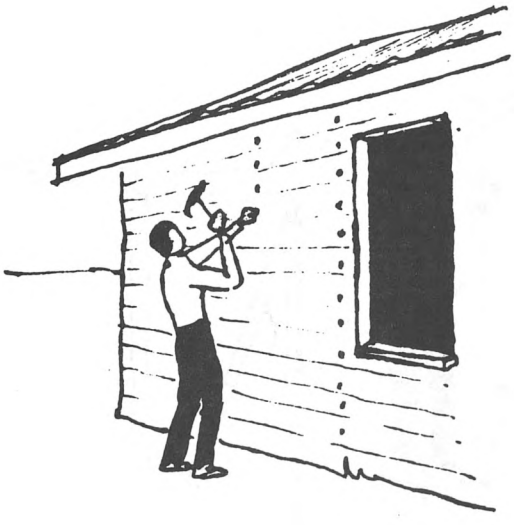
APPENDIX I:

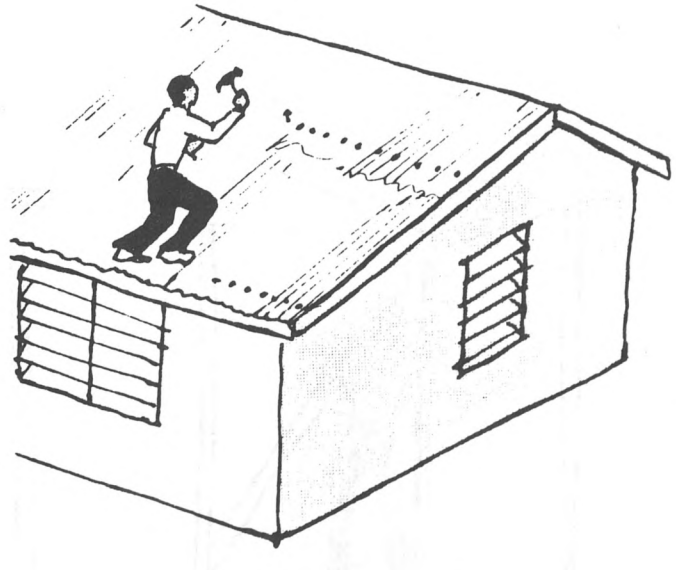
EMERGENCY MEASURES TO PROTECT SMALL BUILDINGS FROM HURRICANES

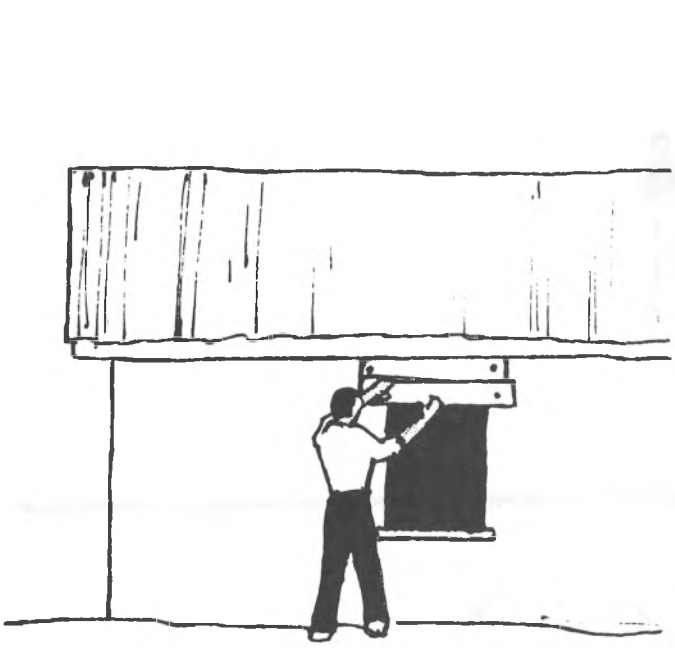


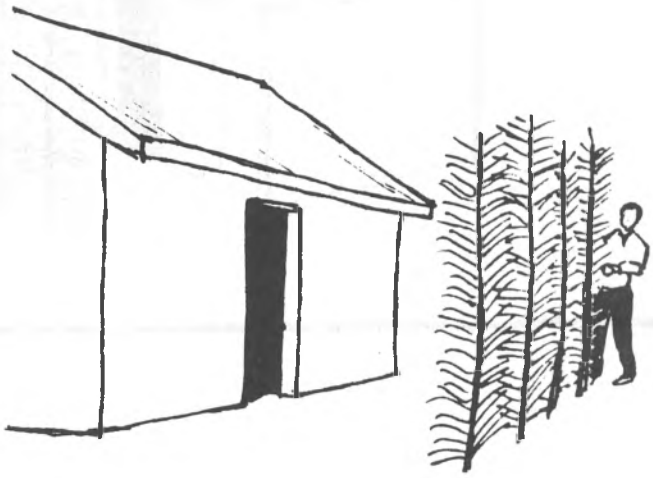


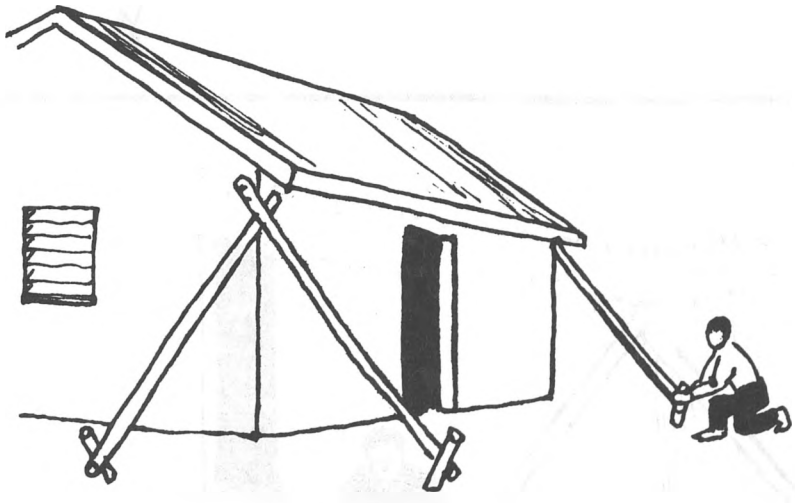


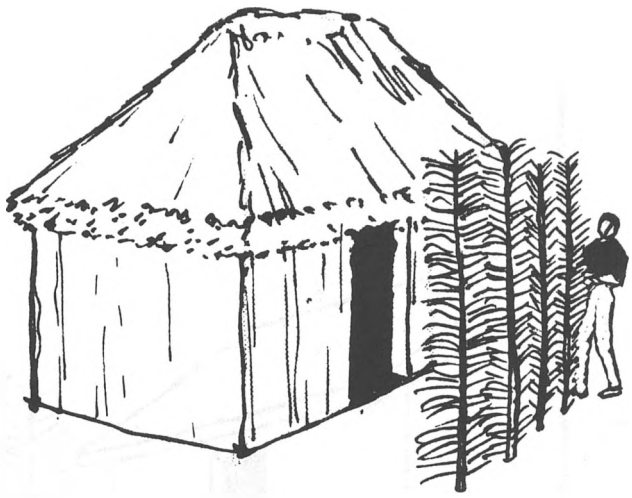


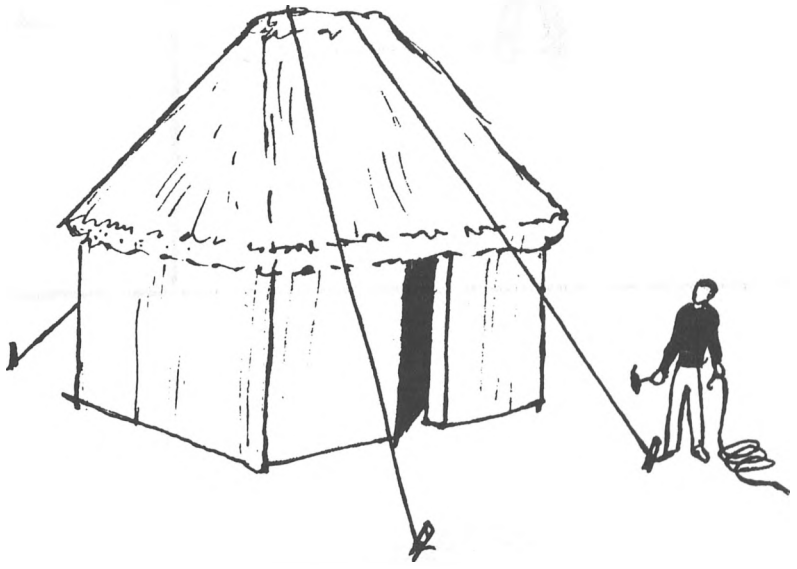


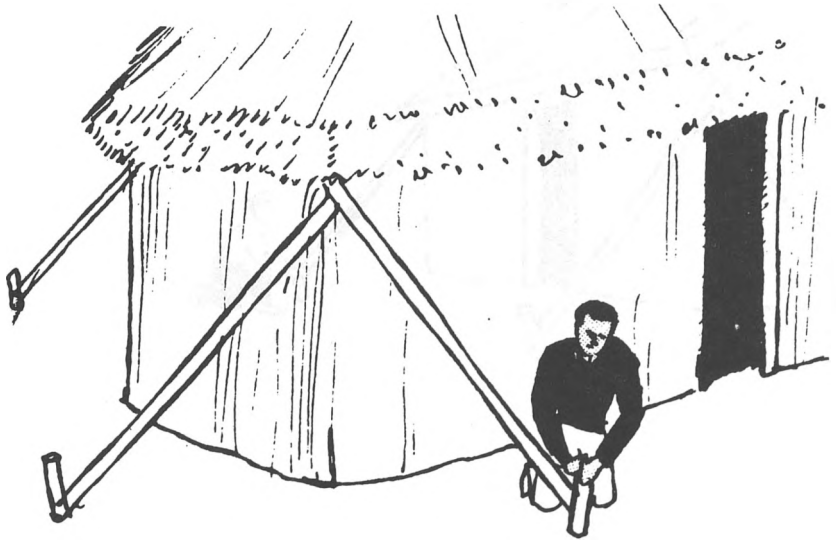












APPENDIX II:

ASSESSMENT OF THE HURRICANE HOUSE
PROPOSED BY MINISTRY OF WORKS & LOCAL GOVERNMENT

In general, the in-house shelter concept proposed by the Ministry of Works & Local Government is appropriate for Tuvalu. The house as designed provides significant protection from hurricanes and some limited protection from floods. The houses are feasible to construct and are relatively inexpensive compared to houses made totally of imported building materials. Specific comments are listed below.

Good Features

A. Excellent roof pitch for wind resistance;

B. Good roof configuration (hipped);

C. Use of reinforced blockwork for a small hurricane resistant shelter is an excellent way of increasing personal safety at a relatively minor cost;

D. Good balance in building configuration and layout.

Weak Features

A. Eaves appear to be too large and may create excessive uplift pressure on roof during high winds;

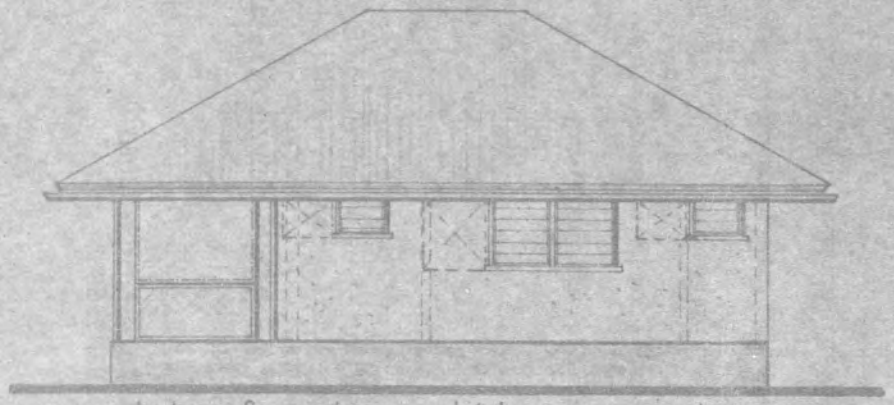
B. Southeast corner of reinforced hurricane shelter has too many door openings close together, making that corner extremely vulnerable. It is recommended that the doors of the south and east walls be moved toward the center of the walls.

Other Comments

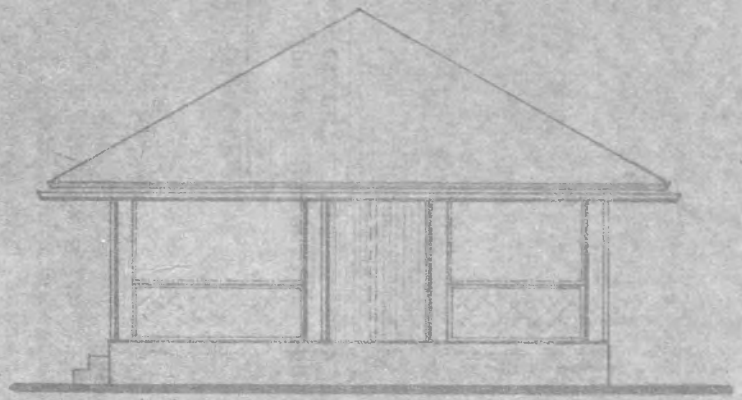
Special attention should be given to all roof-to-wall-to-floor connections.

ELEVATION OF HURRICANE SHELTERED ISLAND HOUSE PLAN.

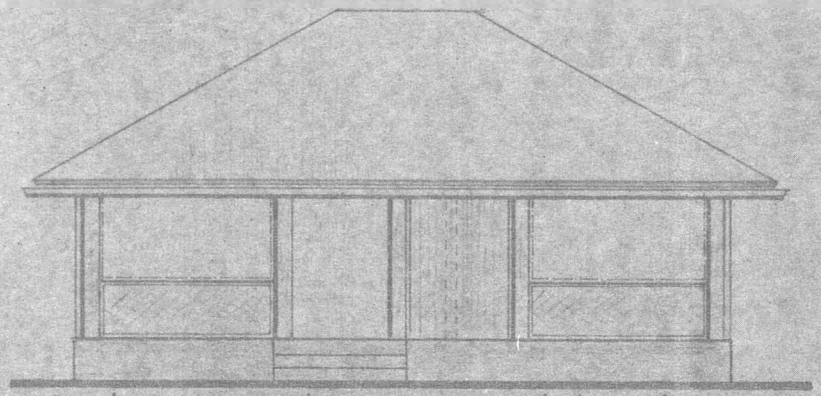
- of composite island & imported material construction.



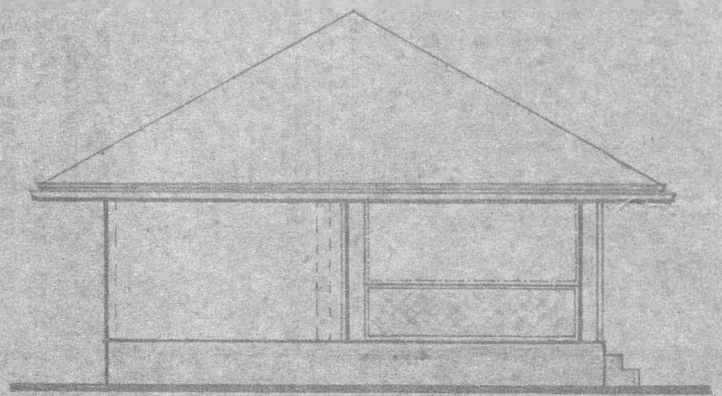
REAR ELEVATION



BEDROOM SIDE



FRONT ELEVATION

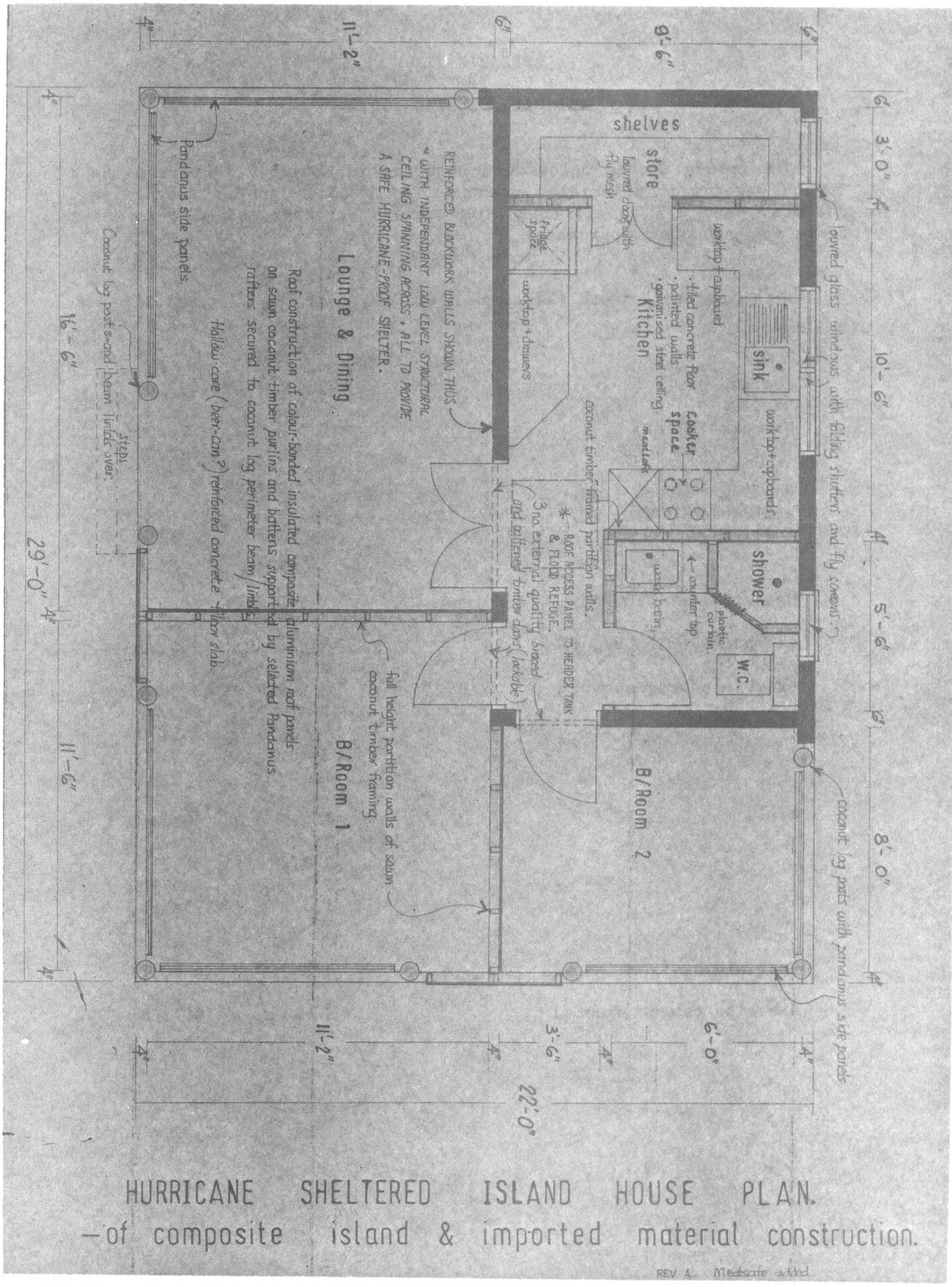


LOUNGE SIDE

44

Rev. A Floor raised to 2'0" high

MINISTRY WORKS & LOCAL GOVERNMENT. FUNAFUTI, TUVALU.	date: 16:9:81	draw: E.M.	scale: 1/8" : 1 FT
Project: OUTER ISLAND HOUSING	Drawing: "E" GRADE ELEVATIONS	File No PW/H 60	02	Rev. A 29-10-91



HURRICANE SHELTERED ISLAND HOUSE PLAN.

— of composite island & imported material construction.

REV A. Meatsafe added.

APPENDIX III:

TYPICAL BUILDING COSTS

The prices quoted below were obtained in November 1981 from the Tuvalu Government materials warehouse. All costs are in Australian dollars. Add 25% to all costs for private purchase; add 15% to all costs for government purchase.

Metal roofing sheets (24-gauge aluminum):	16 ft.	$23.36
	12 ft.	$18.43
	10 ft.	$13.43
Roofing nails (2 1/2 inch):	500	$28.00
Washers (metal)	500	$24.00
(rubber)	500	$20.00
Roofing timbers (imported from Fiji; widths available: 2"x2", 2"x4", 2"x6", 2"x8"; lengths available: 12', 14', 16', 18'):	rough	80¢/bd ft
	dressed	90¢/bd ft
Cement block (18"x6"x6", 2 holes):	1 block	80¢
Cement (40-kilo bag):	1 bag	$10.22
Iron reinforcement:	3/8"x20'	$ 3.09
	1/2"x20'	$ 3.47
	5/8"x20'	$ 5.40
	3/4"x20'	$ 5.00
	1/4"x20'	$ 1.00
Nails:	4"	66¢/lb.
	3"	78¢/lb.
	2 1/2"	66¢/lb.
	2"	72¢/lb.
	1 1/2"	75¢/lb.
	1"	$1.74/lb.
Wood siding (9'x4'x1/4"):	1 sheet	$ 9.11
Asbestos cement sheets:	1 sheet	$17.68