IMPROVEMENT OF LOW-COST HOUSING IN FIJI TO WITHSTAND HURRICANES AND EARTHQUAKES

INTERTECT

P.O. BOX 10502

Dallas, Texas 75207

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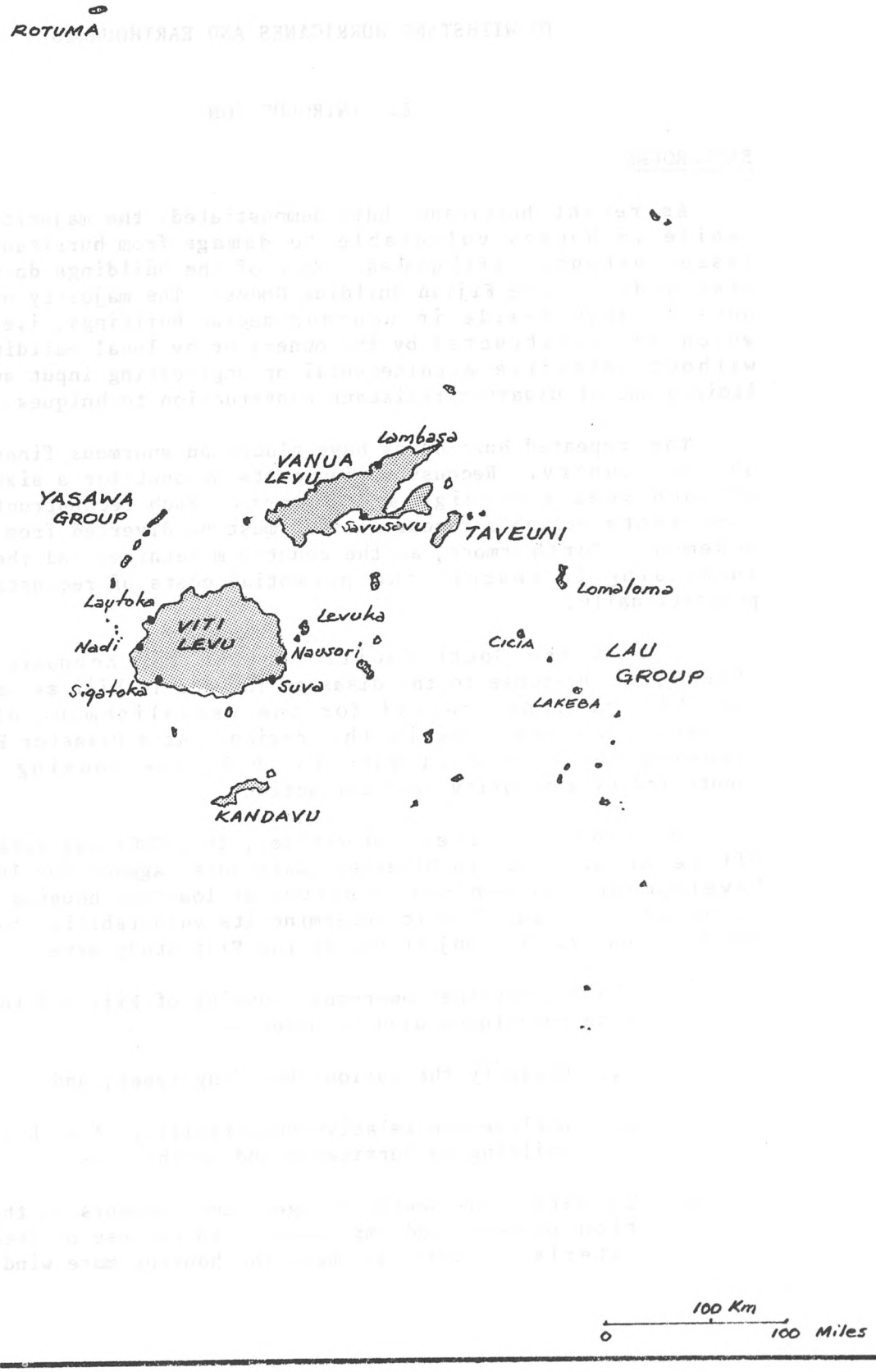


IMPROVEMENT OF LOW-COST HOUSING IN FIJI

TO WITHSTAND HURRICANES AND EARTHQUAKES

I. INTRODUCTION

BACKGROUND

As recent hurricanes have demonstrated, the majority of Fijians reside in houses vulnerable to damage from hurricanes and, to a lesser extent, earthquakes. Most of the buildings do not meet the standards of the Fijian Building Codes. The majority of the people outside Suva reside in non-engineered buildings, i.e., buildings which are constructed by the owners or by local building tradesmen without extensive architectural or engineering input and with only limited use of disaster resistant construction techniques.

The repeated hurricanes have placed an enormous financial burden on the country. Reconstruction costs account for a sizable portion of each year's foreign aid budget. Each reconstruction program represents valuable resources that must be diverted from development schemes. Furthermore, as the country modernizes and the investment in housing increases, the potential costs of reconstruction grow proportionally.

In 1980 the South Pacific Bureau for Economic Cooperation (SPEC), in response to the disaster threats in Fiji as well as other Pacific nations, called for the establishment of disaster preparedness measures in the region. 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 Fiji and three other countries to determine its vulnerability to hurricanes and earthquakes. The objectives of the Fiji study were:

A. To survey the lower-cost housing of Fiji 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 and earthquakes.

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 and earth-

quake 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

1. in short-notice or emergency situations (including instructions that can be disseminated when a hurricane threatens, methods for improving safety, and techniques for reducing damage and strengthening buildings to better withstand hurricane and earthquake forces);

2. through self-help progressive upgrading actions (including suggestions on how existing buildings can be improved and made safer through modification or retrofitting measures as part of normal upgrading and maintenance); and

3. through changes in design and construction of new buildings.

D. To assess the impact of recent reconstruction programs and determine their contribution to vulnerability reduction.

DEFINITION OF TERMS

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

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

B. Non-Engineered Buildings: those structures built either by homeowners or by local building tradesmen such as carpenters and masons without formal architectural or engineering inputs into the design or construction process. For the purposes of this report, the term only includes those structures which could be considered formal houses; it does not include the temporary, makeshift dwellings often used by families in squatter settlements prior to the construction of a more formal house. Buildings erected under housing schemes or those built according to plans or drawings prepared by housing institutions (e.g., the Housing Authority) are not included in this term.

C. Transitional Housing: There are two types of transitional buildings. The first are structures that use a combination of traditional and manufactured materials in a modern house form. The second are structures that are not considered permanent or "formal" houses by their occupants. These are usually wood frame buildings found in peri-urban areas.

D. Vulnerability: a condition wherein human settlements or buildings are exposed to a disaster by virtue of their construction or proximity to hazardous terrain. Buildings are considered vulnerable if they cannot withstand the forces of high winds or earthquakes. Communities in unprotected, lowlying coastal areas exposed to hurricanes, or in seismic areas where a large proportion of the structures cannot withstand the forces of an earthquake, are considered "vulnerable communities".

E. 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.

F. Risk: the relative degree of probability that a hazardous event will occur. An active fault zone, for example, would be an area of high risk.

G. 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.

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

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

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

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

KEY ISSUES

There are a number of housing issues that must be addressed in order to successfully conduct vulnerability reduction efforts. These include:

A. Land Tenure: Land tenure problems in Fiji date back to 1879 when indentured laborers from India were imported to work in agriculture, especially in the sugar cane fields. At that time a policy was established to protect native Fijians' land rights. With the exception of a limited amount of Crown Land and an even smaller amount of freehold land, all real estate is owned and controlled by native Fijians in communal land-owning units called Mataqualis, under the supervision of the Native Land Trust Board. Native Fijians own 82% of the land.

The indentured laborers who came to Fiji could elect to remain in the country at the end of a 10-year period. The majority did so, continuing to farm land leased from the Fijians. In following years, the Indian population increased dramatically, and today approximately half of the total population of Fiji is of Indian origin.

The differing lifestyles and cultural backgrounds of the two groups have created a number of problems which influence housing and vulnerability reduction decisions. The first is that the majority of people have only limited access to land ownership. Even with long-term leases, many Indians feel insecure on the land they occupy and are unwilling to make extensive investments in housing. This means that large numbers of people intentionally live in buildings of a lower quality than they can afford.

The second problem is that, without the possibility of land ownership, the children of some Indian farmers are unwilling to remain on the land, and move to the cities. This increases housing demand in areas where land development and construction costs are much higher.

Finally, the differentiation between the races in housing, as well as in many other fields, has led to the predominance of one ethnic group or the other in various government departments. For example, the Housing Authority is predominantly an Indian-staffed organization, while the Prime Minister's Relief & Rehabilitation Committee (the organization that provides housing in the rural areas and outer islands) is predominantly native Fijian. The by-product of this is competition for resources, some duplication of services, and provision of housing under unequal terms for different groups of people.

B. Rising Expectations: In the last two decades there has been a major change in housing style. Both native Fijian and Indian families have rapidly modernized and developed a much higher standard of living. In housing the demand for buildings reflecting this change is high. The most popular building types are concrete block houses and wood panel houses.

These rising expectations lead to several related problems. First, the building materials required for these housing styles must be imported in significant quantities. Timber board products, asbestos cement panels and sheets, glass, nails, louvered window frames, fixtures and steel products such as corrugated iron roofing sheets and metal reinforcing rods are all imported. This creates a significant balance of payments problem and increases the cost of houses. Thus it is important that the government not only reduce costs in housing but protect the national investment in housing from a disaster which would increase demand and further increase costs and balance of payment problems.

C. Increasing Vulnerability: Another problem is that many of the structures provided under government programs are also vulnerable. Some of the buildings are poorly designed, many use low-quality materials, and the way they are erected in communities may actually increase the speed of winds channeled between structures.

A problem related to rising expectations is that the government cannot currently meet demands for modern buildings through its housing programs. Thus many people build their own structures, often without adequate supervision and using faulty construction techniques.

Many of these buildings are highly vulnerable to hazards and, because they are heavier than traditional buildings, the likelihood of personal injury is increased should a building collapse occur.

D. Low Product-to-Cost Ratio: The final delivered cost of many of the houses provided under government housing and rehousing schemes is far above the real value of the buildings. The housing production methods selected and the strategies for replacing damaged buildings should be reexamined. Methods for incorporating a larger amount of indigenous building materials and methods which rely on self-help should be considered.

OBSTACLES TO VULNERABILITY REDUCTION

A. Level of Building Skills: The level of building skills varies greatly throughout the country. In urban areas the majority of contractors are Indian, and some have attained a very high quality of construction expertise. In rural areas there are fewer Indian contractors and more Fijian carpenters and masons. As distance increases from the major cities, the level of skills decreases dramatically. Coupled with poor quality building materials and the lack of quality control, this contributes to the erection of fairly weak buildings. In all sectors of housing construction there is a general need to upgrade the quality of workmanship and to expand knowledge about disaster resistant techniques.

B. Lack of Technical Assistance in Rural Areas: In Suva and other major cities a number of institutions and organizations can provide guidance, advice or supervision to those building new houses. Outside of these areas, however, technical assistance is difficult to obtain. Theoretically, technical assistance is available from Public Health Inspectors but, in fact, their area of interest is limited to the installation of sanitary facilities, and virtually no effective building inspection is provided off the four main islands. In order to reduce vulnerability, it will be necessary to develop an infrastructure for provision of technical assistance. Organizations from both the government and the private sector should be involved.

C. Transportation: Present housing approaches require that large amounts of building materials be shipped from distribution points on Viti Levu to the other islands. Due to the small size of the transporting vessels, long waiting periods result before a house can be assembled. For normal construction, these delays are tolerable; however, in the aftermath of a disaster the delays increase recovery time far beyond reasonable expectations. Any increased housing cost is an obstacle to vulnerability reduction.

II. RISK IN FIJI

HURRICANE RISK

Fiji is situated in one of the most active hurricane regions in the world. Within the last decade, four hurricanes and numerous tropical storms have struck the islands. The casualties and damage in each hurricane underscore the vulnerability of the population and show that a majority of housing cannot withstand the forces of high winds.

Hurricanes threaten housing in four basic ways:

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

--- Inundation from storm surges (popularly known as tidal waves) affecting lowlying coastal areas;

--- Inundation from flooding caused by the high rainfall accompanying the storm; and

--- Damage resulting from landslides, mudslides or other displacements caused by super-saturation of the soil by heavy rainfall.

All of these exist in Fiji, and many islands are threatened by two or more of these hazards.

Figure 2 depicts the tracks of hurricanes which have struck Fiji in the last 30 years. Figure 3 depicts a cross-section of a typical hurricane, showing the sectors of the storm system which produce 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 country, as well as the number of small islands, no areas are completely safe from high winds.

Figure 4 shows those areas on the largest islands that are susceptible to flooding and landslides. Damage caused by storm surges, flooding or landslides is primarily a siting problem and thus is beyond the scope of this report.

High winds can cause extensive damage in 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 outside the major cities are built with little engineering input and the majority are

FIGURE 2 Hurricane Tracks 1950 - 1980

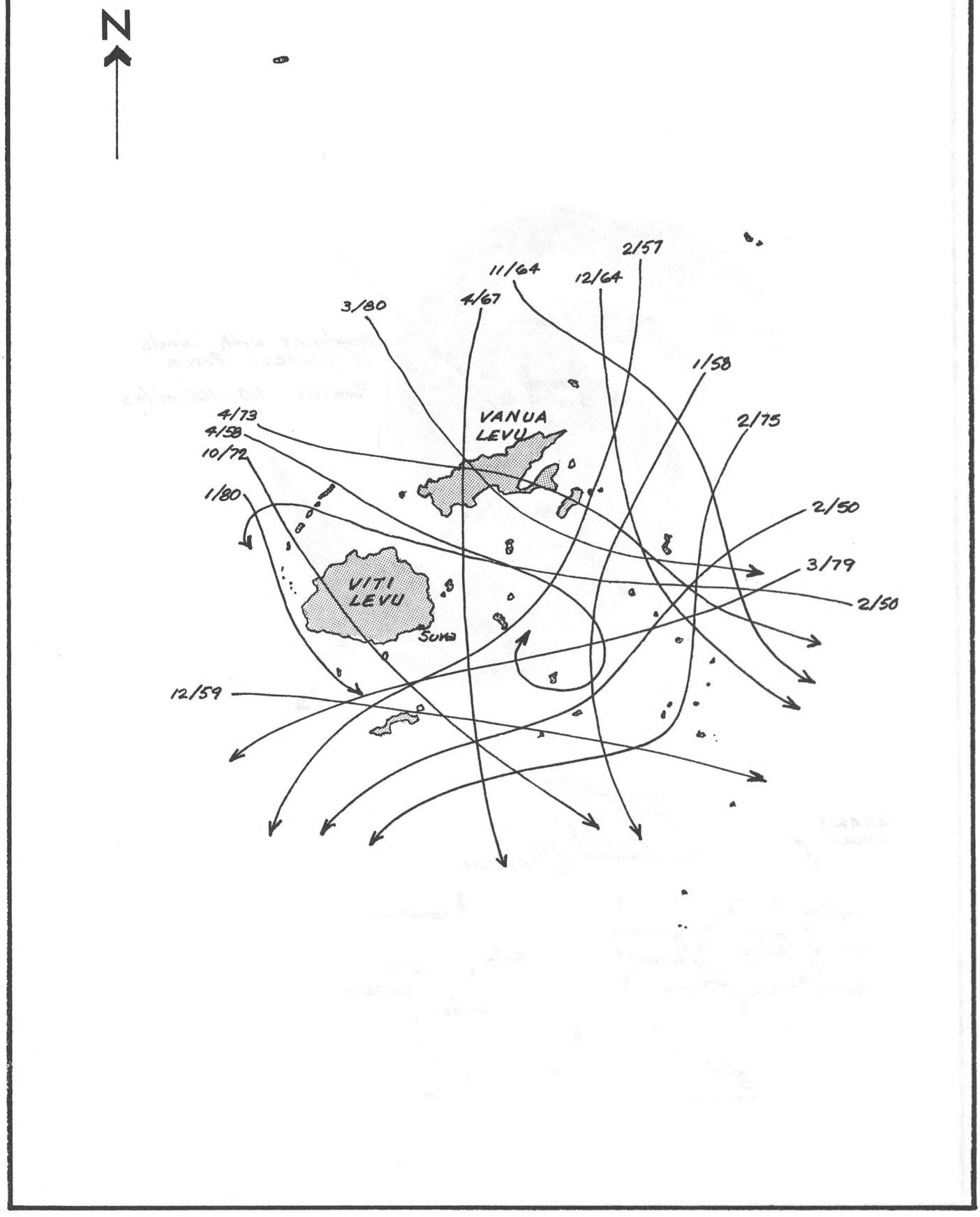


FIGURE 3 Cross Section of a Typical Hurricane

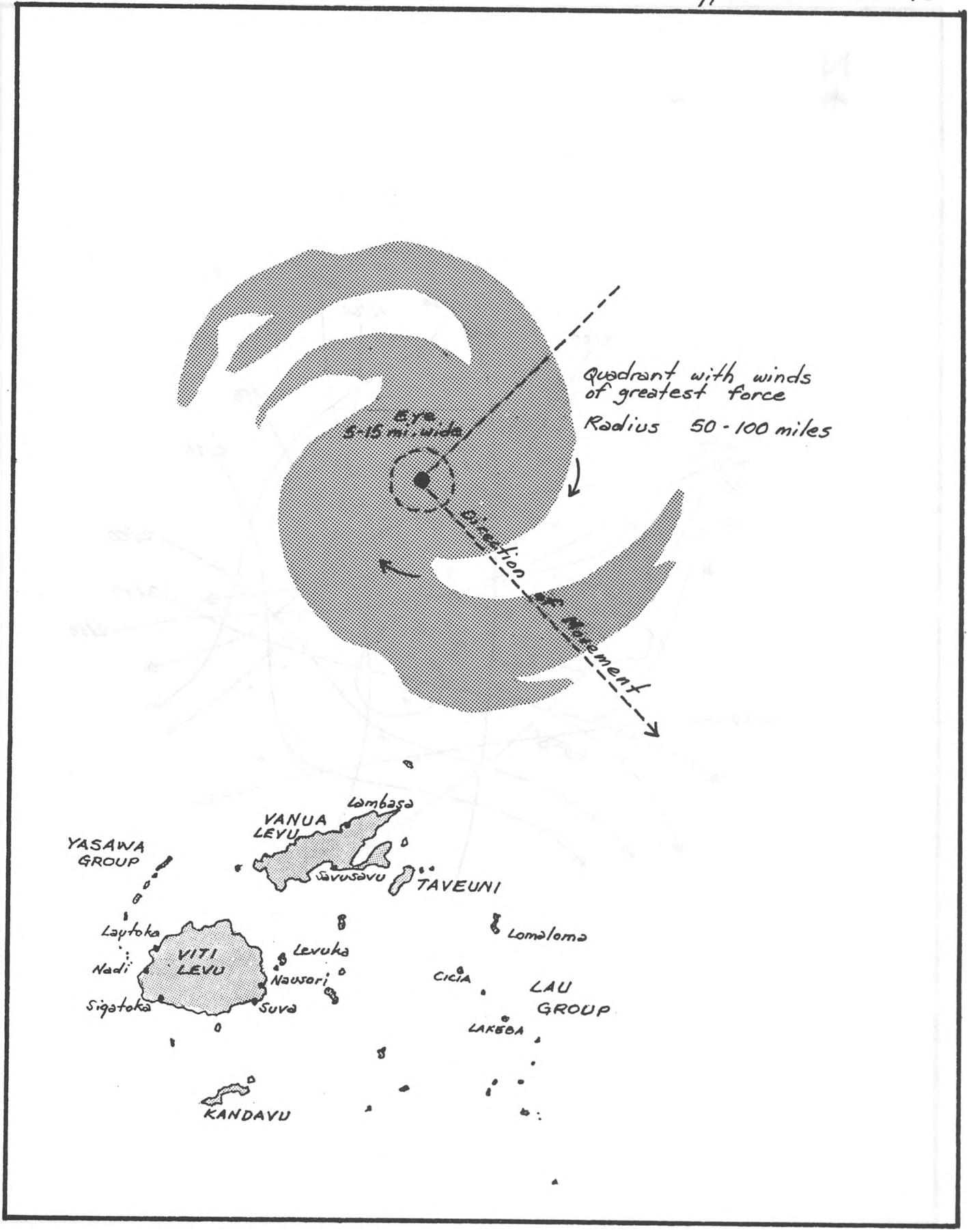
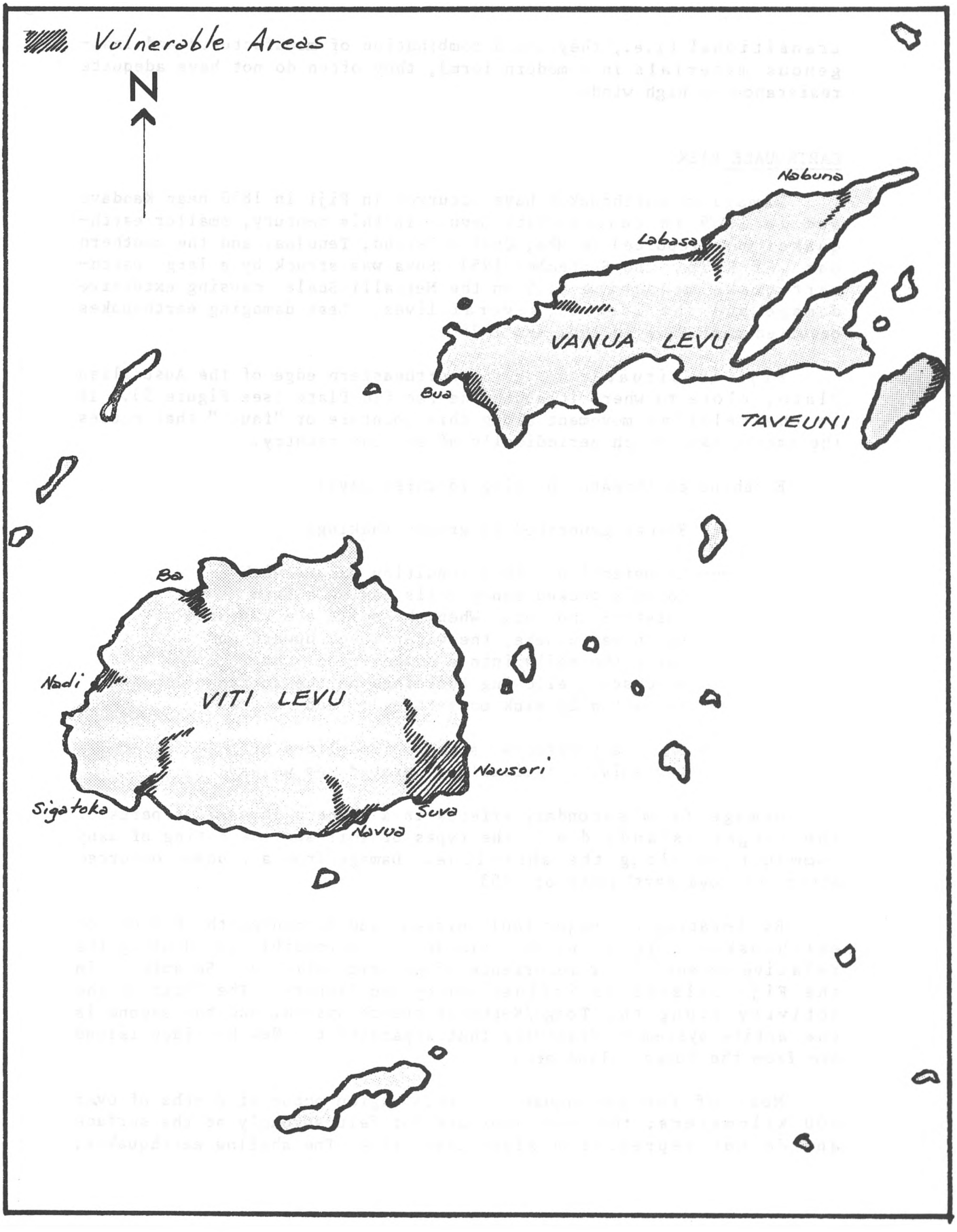


FIGURE 4 Areas Vulnerable to Floods and Landslides



transitional (i.e., they use a combination of manufactured and indigenous materials in a modern form), they often do not have adequate resistance to high winds.

EARTHQUAKE RISK

Damaging earthquakes have occurred in Fiji in 1850 near Kandavu and in 1869 in eastern Viti Levu. In this century, smaller earthquakes were reported in Mba, Ovalau Island, Tenuloa, and the southern part of Koro. In September 1953, Suva was struck by a large earthearthquake measuring 6.75 on the Mercalli Scale, causing extensive damage and the loss of several lives. Less damaging earthquakes occurred near Suva in 1961 and 1975.

Fiji is situated near the northeastern edge of the Australian Plate, close to where it abuts the Pacific Plate (see Figure 5). It is the relative movement along this jointure or "fault" that causes the earthquakes which periodically affect the country.

Earthquakes threaten housing in three ways:

--- Forces generated by ground-shaking;

--- Liquefaction (This condition occurs with loosely-packed sandy soils having a high moisture content. When the soils are vibrated by an earthquake, the water moves upward and turns the soils into a composition like quicksand, allowing buildings on the surface to partially sink or settle.); and

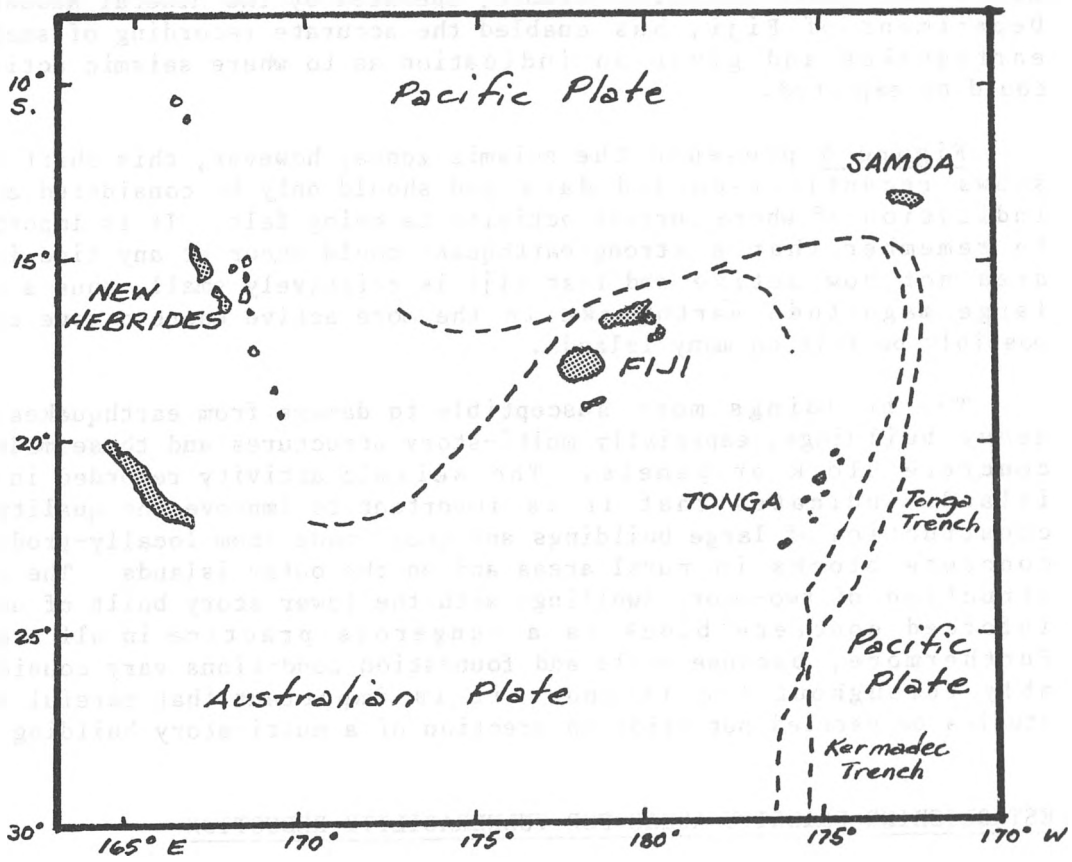
--- Secondary effects, such as landslides or tsunamis (seismically-generated sea waves).

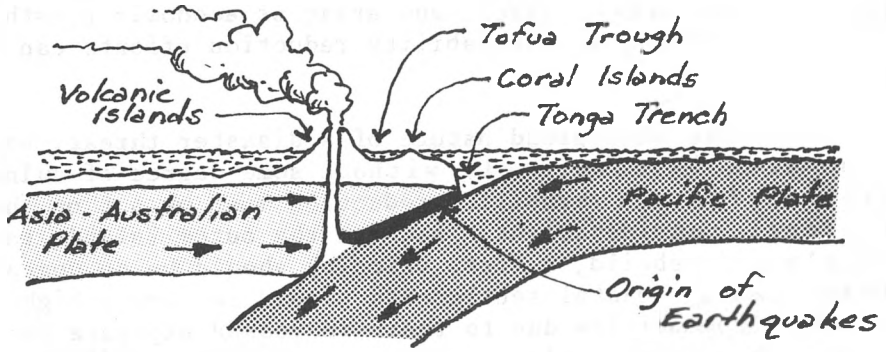
Damage from secondary effects is a concern in various parts of the larger islands due to the types of soil and the siting of many communities along the shoreline. Damage from a tsunami occurred after the Suva earthquake of 1953.

By locating the major fault systems and examining the history of earthquakes throughout the islands, it is possible to identify the relative potential for recurrence of seismic activity. Seismicity in the Fiji islands is influenced by two factors. The first is the activity along the Tonga/Kermadek trench system, and the second is the active system of fractures that separates the New Hebrides island arc from the Tonga island arc.

Most of the earthquakes in this region occur at depths of over 600 kilometers; therefore they are not felt strongly at the surface and do not represent a significant risk. The shallow earthquakes,

FIGURE 5 Tectonics of the S.W. Pacific





however, are of more concern. The recent installation of a local micro-earthquake detection network, operated by the Mineral Resources Department of Fiji, has enabled the accurate recording of smaller earthquakes and gives an indication as to where seismic activity could be expected.

Figure 6 presents the seismic zones; however, this chart only shows recently recorded data and should only be considered as an indication of where current activity is being felt. It is important to remember that a strong earthquake could occur at any time in an area not now active and that Fiji is relatively small, thus a very large magnitude earthquake in the more active eastern zone could possibly be felt on many islands.

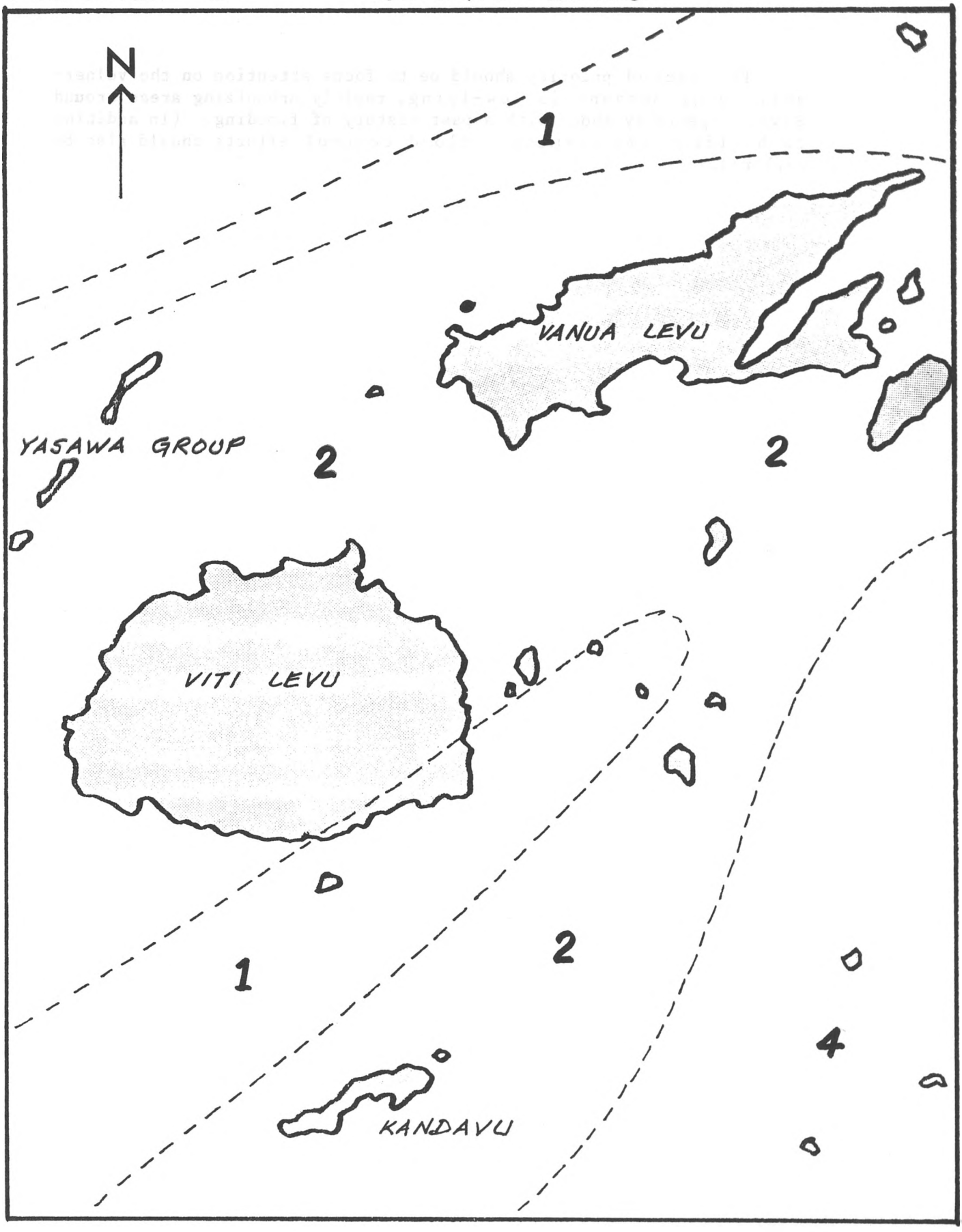
The buildings most susceptible to damage from earthquakes are heavy buildings, especially multi-story structures and those made of concrete block or panels. The seismic activity recorded in the islands indicates that it is important to improve the quality of construction of large buildings and those made from locally-produced concrete blocks in rural areas and on the outer islands. The construction of two-story dwellings with the lower story built of unreinforced concrete block is a dangerous practice in all areas. Furthermore, because soils and foundation conditions vary considerably throughout the islands, it is important that careful soil studies be carried out prior to erection of a multi-story building.

ESTABLISHING PRIORITY AREAS FOR VULNERABILITY REDUCTION

As a general rule, comprehensive vulnerability reduction efforts should be initiated in areas where there are certain indicators that such efforts will succeed. Among the indicators are areas where new construction is occurring (such as the growth areas around cities and towns), areas where agricultural activities are strong and where migration from rural to urban areas is minimal, and areas where a threat from a disaster is perceived as being a major problem to the majority of homeowners within the region. Thus, by examining demographic trends and density, and areas of economic growth, priority areas for establishing vulnerability reduction efforts can be identified.

Due to the widespread nature of a disaster threat, and the fact that no area is completely without some degree of vulnerability, priorities for vulnerability reduction must be set on the basis of operational considerations. Because the outer islands take so long to supply and rebuild, a first priority should be to upgrade housing in these areas. Coastal settlements should receive a higher priority than inland communities due to their increased exposure to hurricanes and to weaker soil conditions that would make buildings situated in these areas more vulnerable to earthquakes.

FIGURE 6 Seismic Zones



The second priority should be to focus attention on the vulnerability of persons in low-lying, rapidly urbanizing areas around Suva, especially those with a past history of flooding. (In addition to building improvements, flood control efforts should also be explored.)

III. CONTEMPORARY HOUSING AND HOUSING TRENDS

CONTEMPORARY LOW-COST HOUSING

Low-cost housing in Fiji can be classified into one of three categories: traditional, transitional or formal housing.

A. Traditional Housing

The traditional house or bure is considered by many to be one of the most beautiful traditional housing forms in the world. Architectural historians have identified over 30 individual types of bures in the islands, many with intricate structural features and ornately appointed interiors. Structurally, most bure designs built with traditional construction methods result in very strong, disaster resistant buildings. Unfortunately, in many of the newer bures that follow traditional designs, several shortcuts have been used to speed the building process and these have increased the bures' vulnerability.

B. Transitional Housing

Transitional houses are buildings that illustrate the architectural transition between traditional buildings and more modern forms, or buildings which are temporary or interim structures erected by families until they can afford more formal houses. The most popular forms in Fijian villages are buildings that have sawn timber frames covered with traditional mats with corrugated iron (C.I.) sheets on the roof. Metal houses made of C.I. sheets attached to wooden posts, and various wood frame houses with palm board siding and metal roofs, are the most popular transitional buildings in Indian communities and urban areas.

C. Formal Low-Cost Housing

Formal housing can be further subdivided into owner-built and government-aided housing. Owner-built housing consists of a variety of concrete block designs and more formal wood frame houses. (The usual means of determining if a house is formal or transitional is by whether or not it has interior running water and sanitary facilities.)

Government-aided housing is primarily provided by two agencies: the Housing Authority, and the Prime Minister's Relief & Rehabilitation Committee.

The Fijian Housing Authority was established in 1957 to provide low-income housing. Its primary area of operation has been the

urban areas due to difficulties encountered with land tenure in rural areas. Housing is provided under four basic schemes: the home purchase scheme; the cash loan scheme; the rental schemes; and the village housing scheme. The Housing Authority also develops housing sites and provides basic services including water, sewer, electricity, roads, and storm sewerage. In 1981, the Housing Authority began a special program for squatters whereby the Authority leases land from Mataqualis (the Fijian communal landowning unit) and then subleases the land on a long-term basis to the squatter.

The Housing Authority both builds houses and provides design assistance to prospective homebuilders. In this way, some degree of quality control is attempted. The building types normally erected in schemes do not fall under the purview of this study. However, any study of vulnerability must address several points regarding these buildings. Problems such as the low roof pitch, excessive overhangs, and open eaves under some of the designs are likely to result in extensive roof damage to these buildings. Furthermore, quality control in many of the buildings appears insufficient and this may further increase vulnerability.

The Prime Minister's Relief & Rehabilitation Committee was established in the aftermath of Hurricane Bebe in 1972. The Committee has continued in operation and provided housing and building materials for housing reconstruction to persons living in rural areas and on the outer islands. Recently, responsibility for providing rural housing in native Fijian villages was also assigned to the Committee.

The housing provided is a variety of prefabricated panel-type buildings that are transported to disaster areas and erected on site. Some of the houses have been provided free of charge, while others have been sold. Many of the houses are poorly designed, poorly built, inadequately braced, and use low-quality materials which are rapidly deteriorating. None of the designs are considered hurricane resistant, and many are more vulnerable than the houses they replace. It is important that the government undertake a thorough review of the vulnerability of these buildings and take steps to remedy the problem before a disaster occurs again.

HOUSING TRENDS

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

A. Decrease in traditional construction

Throughout the country there is a rapid change from traditional buildings to more modern building styles and designs. In the most recent census, the government found that only 12.3% of the total population still lives in traditional bures. As much as half the population lives in transitional buildings, hoping to eventually build a more formal modern-style house.

This changeover in building styles has several implications for vulnerability reduction efforts. Because the changeover is so widespread and because large numbers of people are still waiting to build formal structures, there is an excellent opportunity to have an effect on the design and construction of new buildings to ensure that they are built safely. On the other hand, it means that large numbers of people are living in marginal 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 immediately, not only will people living in transitional buildings be vulnerable, but those building more formal houses are also likely to build vulnerable structures. When a disaster occurs, the cost of reconstruction will be many times higher than reconstruction of the 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.

B. Material preferences

The majority of persons building new homes prefer to use concrete block. At present, block is cheaper than wood. 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 and most believe that concrete block houses better resist hurricanes.

Due to the demand for concrete blocks, a number of small cottage block-making industries have been established in the rural areas of the central islands and on the larger 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 very poor. Thus vulnerability is increasing with a corresponding decrease in safety for the inhabitants of the structures.

C. Development of wood resources

In the mid-1980s, it is anticipated that the Fiji forestry schemes will begin to produce sufficient timber to permit a major reduction in the price of wood. The Ministry of Forests is currently exploring various marketing schemes, and technicians from the Ministry working with the Fiji Institute of Technology and the Architects Section of the Public Works Department are developing a series of recommended building standards and various guidebooks to encourage increased use of Fijian wood in housing. If the costs make wood competitive, a surge in construction might be expected. Planners should anticipate this demand and be prepared to provide technical assistance.

D. Increasing urbanization

The 1976 census showed that 37% of the population (218,495) lived in urban, periurban, or township areas. This percentage is expected to increase to over 50% in the next decade. The new arrivals can be expected to increase the demand for new housing, increase the percentage of people living in transitional buildings and increase the demand for modern building materials. For those unable to obtain houses from the housing authority or have their structures built by reputable skilled contractors, their homes are likely to further increase vulnerability.

E. Squatter settlements

Due to land tenure problems and high costs of government-subsidized housing, many low-income families choose to live in squatter settlements. Squatters are defined as people who have built without the permission of planning authorities and/or the permission of the owner of the land on which the house is built. In recent years, as many as 15% of the urban dwellers were living in squatter settlements, and the rate was increasing at approximately 12% per year.

Squatters normally occupy the land and build an interim house to secure the site. The interim building is usually a one-room, wood-frame shelter with wood or C.I. sheet walls. Additions and improvements to the dwellings are added after tenure becomes more secure.

Squatter settlements are found in all the major cities of Fiji. The people who move to the squatter areas may come from rural areas, but many are city residents who want land and their own single-family home.

The problem with squatter settlements is that they are essentially unplanned communities and are difficult to upgrade until tenure becomes secure. The buildings are usually highly vulnerable to both hurricanes and earthquakes. The quality of construction of the interim and transitional buildings is fairly poor, and even the few concrete block buildings are susceptible to damage. Because few families have secure tenure, there is little interest in borrowing or expending resources to upgrade homes; thus in these areas planners must concentrate on very low-cost improvement measures rather than actions which could be taken to significantly reduce vulnerability.

In 1981, the Housing Authority initiated a series of innovative programs to help persons in the squatter settlements. The programs concentrate on improving the sites and services to the areas, but assistance for housing construction may also soon be offered.

F. Decline in building skills

In recent years there has been a general decline in the level and quality of building skills. This decline is evident in the damage levels observed after recent hurricanes. For example, the timber posts which form the main structural components of traditional bures are insufficiently imbedded in the ground. Roofs that were traditionally bound together and to the main frame of the building are now nailed, with a dramatic loss in strength. In more modern types of construction, building skills are not considered to be of a high standard. Poor building practices in masonry construction often result in extremely weak buildings. Carpentry skills, especially the making of joints, leave much to be desired. Furthermore, several observers have noted a decline in worker productivity in the building trades.

Vulnerability reduction efforts depend on good workmanship. Thus, it is extremely important that planners support institutions and activities which will improve building skills.

G. Increased use of contractors

In recent years, there has been a trend towards increased use of contractors to build or supervise construction. This is due in part to the demand for more modern building materials and the growing sophistication of housing designs. The majority of

housing in both rural and urban communities is built with at least some input from a tradesman. Contractors with a carpentry background are generally more plentiful than masons in the rural areas, although most contractors are familiar with both types of construction. A contractor may play many different roles. Sometimes he may be asked to furnish the construction materials as well as the labor. In other cases, the contractor 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. Efforts should focus on upgrading contractors' skills and capabilities. Without full participation by contractors, vulnerability reduction will be difficult to achieve.

HOUSING DEMAND

Demands for new housing are a result of several factors: increased urbanization; increased desire on the part of Fijian villagers for more modern housing; a need to replace substandard, deteriorating buildings; and a desire for more formal buildings on the part of families living in interim buildings in squatter settlements. The demand for new housing in urban areas alone has been estimated by Cook to be approximately 1,356 new units per year. The principal approaches used by the government (housing schemes, loans, sites & services programs, etc.) together meet only one-quarter to one-third of the demand. Furthermore, a recent survey by the Housing Authority (in 1979) found that many persons were no longer interested in Housing Authority schemes because of the long waiting period, questions of loan eligibility, and the high costs of meeting standards of construction set by the Housing Authority.

Further increases in housing demand occur in the aftermath of disasters. In some cases, the sudden need for replacement housing has increased the total housing deficit by as much as 25%. According to the Prime Minister's Relief & Rehabilitation Committee, Hurricane Meli destroyed 1,328 houses, which was equivalent to 75% of the total new housing demand for that year. Thus it can be seen that the improvement of low-cost housing to better withstand natural hazards should be viewed as part of the total response to the overall housing problem. A house that withstands a disaster not only provides a safe refuge for its occupants; it also eliminates an economic burden on both the family and the government, and represents savings in building materials and financial resources.

IMPACT OF RECONSTRUCTION PROGRAMS

Hurricane reconstruction programs conducted in the last 10 years have had a profound effect on the overall housing picture both at the national and village level. Some of the most important aspects are:

A. Impact on development plans and budgets:

Various disasters have substantially increased the annual and total demand for new housing. Because the government has chosen to replace damaged buildings with prefabricated structures, reconstruction costs have risen appreciably. This requires funds and resources which might otherwise have been devoted to social and economic development programs. By 1981 the PMRRC reported that overhead alone for reconstruction efforts amounted to $7,000,000, representing 20% of the total development funds received from abroad in 1980. Because many of these buildings are not disaster resistant, should another hurricane strike in the same area, the government could be faced with having to rebuild houses built under previous reconstruction programs not already paid for. Thus it is extremely important that existing relief housing be upgraded and that, if the same approach is continued, new housing be redesigned and strengthened.

B. Rising expectations caused by relief programs:

Relief and reconstruction programs have been cited as one of the major contributors to rising expectations on the outer islands. Many houses have been provided free or at very low cost. Several observers report that many people on the outer islands now expect a free building in the aftermath of any disaster. Self-help reconstruction is now rare. Many have been without replacement housing for as long as two years after a disaster. Thus, the relief programs have served as a disincentive to self-help and have actually delayed recovery.

C. Increased vulnerability:

As pointed out in other sections of this report, the hurricane relief houses are extremely vulnerable to high winds and moderately vulnerable to earthquakes. In many cases, hurricane houses have replaced buildings that might have been repaired at a much lower cost and that might provide more safety to the occupant if properly rebuilt. **Thus the hurricane housing programs are contributing to increased vulnerability rather than reducing it.**

D. Impact on village lifestyles:

The drawings on the next page illustrate the layout of a Fijian village before and after a hurricane. The first drawing shows houses arranged in the traditional manner around a large open common ground. Historically this space has served as an area for social gatherings and sports events, and has provided a sense of identity among villagers.

The second drawing shows houses in a grid pattern without the common open space. This layout has been lamented by planners in other parts of the world. Sociologists have noted that people living in this arrangement feel crowded, yet isolated from their neighbors. It is probably too early to tell what effect this will have on village lifestyles, but it is hoped that the more traditional arrangement could be maintained.

IV. VULNERABILITY ANALYSIS OF LOW-COST CONSTRUCTION

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 both high winds and earthquakes. 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 the 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 more susceptible to damage from high winds, while buildings made of heavier materials (such as block or concrete panels) are more susceptible to damage from earthquakes.

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.

Thus the buildings most vulnerable to hurricanes are lightweight structures with wood frames, especially older buildings where wood has deteriorated and weakened the walls. Houses made of unreinforced or poorly constructed concrete block are also vulnerable.

Roof configuration and construction are very important considerations for all types of housing. If the roof is not adequately attached and braced, and has a large overhanging eave, it is potentially the weakest part of the house.

Vulnerability of housing to earthquakes is determined by many of these same factors, plus several others. In addition to configura-

tion and structural integrity, other determinants are:

--- Site (should be flat with stable soils)

--- Foundation (should be strong and level)

--- Balance (parallel walls should be of equal size and weight)

--- Center of Gravity (walls should be low; roof should be lightweight)

--- Reinforcement in the Walls (adequate vertical, horizontal and diagonal reinforcing should be placed in each wall).

In areas of seismic activity, the most vulnerable houses are the unreinforced or poorly constructed concrete block and concrete panel buildings. Theoretically, these types of housing should be fairly easy to reinforce to basic standards of earthquake resistance, and some block houses do use adequate iron reinforcement. However, the quality of the blocks in many areas and the workmanship and detailing are very poor; thus some buildings may be particularly vulnerable.

Again, it is important to remember that "risk" means the chance that some type of event like a hurricane might strike an area; "vulnerability" refers to the possibility of a building or settlement being damaged by that event. Thus, if a strong building is sited in a high risk area, it may not be vulnerable.

POPULAR BUILDING FEATURES

A. Features and Practices Which Reduce Vulnerability

1. Hipped Roofs: Many buildings, especially traditional bures and older wood frame houses, use "hipped" or 4-sided roofs which offer excellent protection in high winds. Continued use of hipped roof configurations should be encouraged.

2. Hurricane Straps: In many buildings, the practice of using metal straps and other devices to fasten the roof trusses to the building is fairly common. In recent years this practice seems to have gained more acceptance, and planners should encourage increased use of these measures.

3. Small Eaves: The roofs of many bures project only a few inches over the sides of the walls. This reduces uplift under the eaves and damage to the roof. Where shading is required for windows, breakaway awnings can be used, as is the practice in many of the older wooden homes.

4. Stone Foundations: Many older buildings, especially those constructed during the Victorian period, used stone foundations. When heavier wall construction is used, this not only helps to prevent cracking and settling in earthquakes, but also helps strengthen the walls by distributing the weight. In hurricanes, the foundation prevents wind from getting under the house to lift upwards on the building.

5. Low Center of Gravity: Many early buildings were built so that the weight of the structure was distributed with heavier construction materials at the base and progressively lighter materials as the height increased. In part this was due to architectural and engineering techniques of that period. The practice offers excellent protection against earthquakes and hurricanes, and should be encouraged, particularly for two-story buildings.

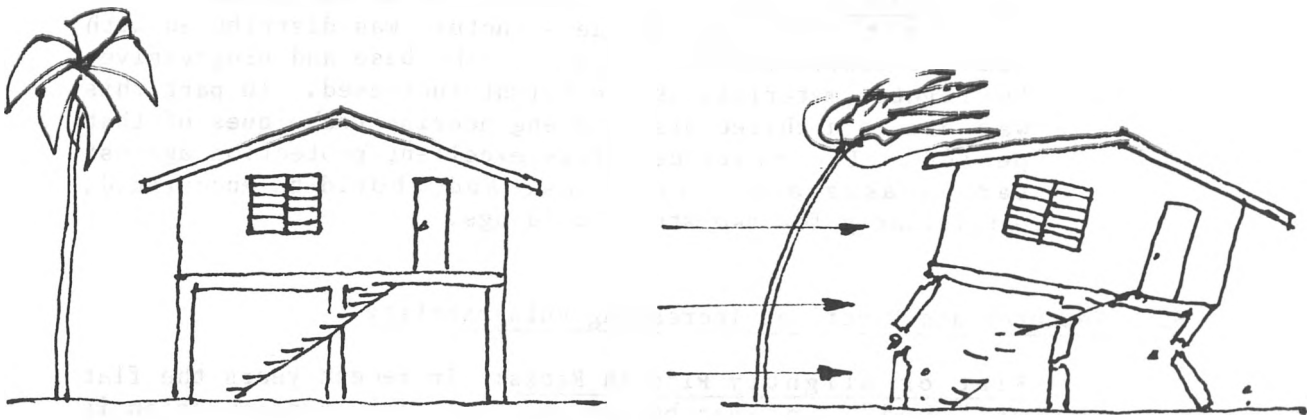
B. Features and Practices Increasing Vulnerability

1. Flat or Slightly Pitched Roofs: In recent years the flat or "shed" roof has become popular. This configuration is especially vulnerable to damage in hurricanes. The low pitch increases suction and uplifting forces, and the normally large overhang associated with this type of roof lends itself to uplifting at the edges.

2. Louvered Windows: Louvered windows, particularly those made of glass or flimsy metal, can be dangerous in hurricanes. Vibrations caused by high winds can 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.

3. Verandas: Verandas or open porches are a popular feature on many houses. Many of the designs used for verandas 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. Stilts: A common practice when building two-story houses is to build the upper story on "stilts" formed by the vertical columns, until such time that the owner can afford to enclose the lower part of the building. Until the lower floor is built, the structure is very unstable due to the great mass balanced above the ground. In hurricanes, strong winds can push the building off the columns. In earthquakes, the upper story cannot be supported by the few columns and the buildings are likely to topple with even moderate ground-shaking. Furthermore, when the lower floor is enclosed, it is difficult to reinforce or attach the walls safely, and the concrete blocks as infill between the columns become extremely dangerous. In some cases, vulnerability may even be increased.



This type of building should be officially discouraged. If a homeowner wants a two-story home, a one-story structure can be built with a flat concrete roof which will permit a second story to be added later. Provisions can be made so that vertical columns can be extended into the second story, thereby providing the necessary structural strength.

For existing buildings, some degree of strength can be obtained by adding cable cross-braces in the corners of the building. When owners prepare to build the second floor, shear walls made of concrete panels should be installed rather than concrete blocks, in order to provide the necessary rigidity for structural support. In some cases, the walls can be poured in place.

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 hurri-

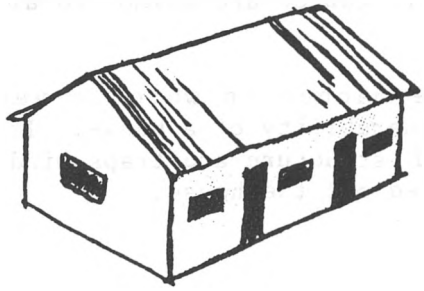
canes, fast-moving turbulent air can pass under the structure, lifting it off the footings and contributing to its collapse.

In earthquakes, the ground motion is likely to shake the footings underneath the building, thereby collapsing the walls. Wood frame buildings need strong wall-to-ground connections; a complete and solid rock and/or poured concrete foundation is required.

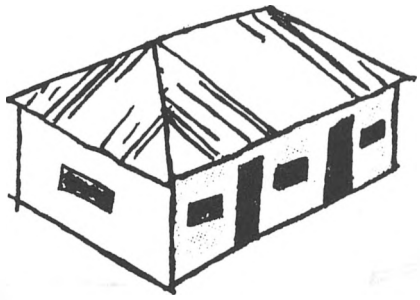
PROBLEMS COMMON TO ALL BUILDING TYPES

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

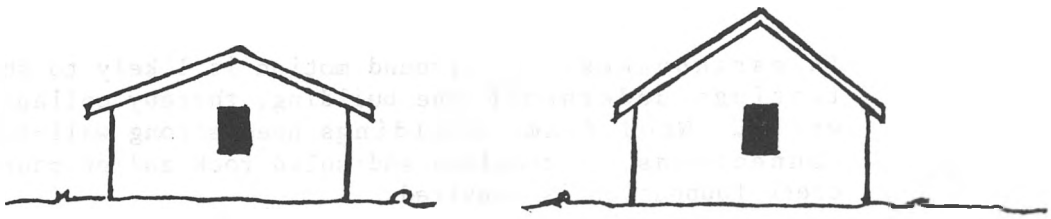
A. Roof Configuration: Many buildings in Fiji utilize a gable roof such as the one illlustrated in the figure below.



For both hurricane and earthquake resistance, a hipped roof such as that illustrated below is preferred.



A gable roof may be used, however, if the angle of inclination of the roof is approximately 30-40°, and if the roof trusses are adequately braced so that they do not collapse when forces are applied along the longitudinal axis of the house,



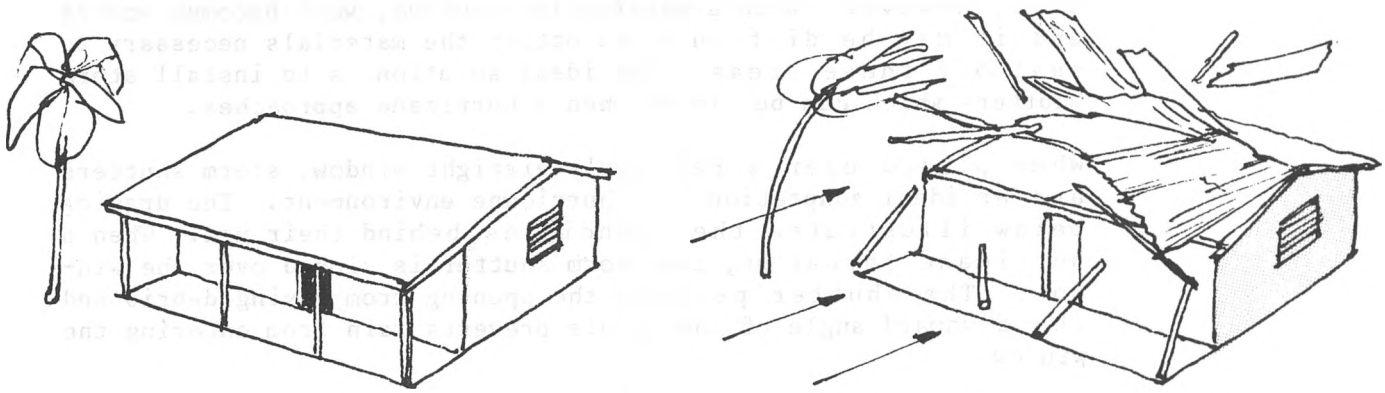
NO YES

and provided that the gable is sufficiently reinforced so that it does not fail and collapse when pressures are exerted from either an earthquake or a hurricane.

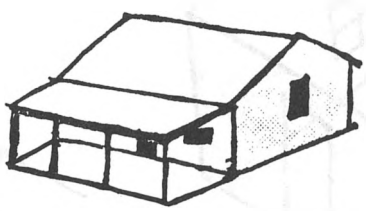
The roofs of bures are well configured and meet the requirements for wind resistance. However, in the other types of houses the roofs are often too flat. The lack of roof truss reinforcing and poorly-built gables are common to all types of transitional buildings.

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.

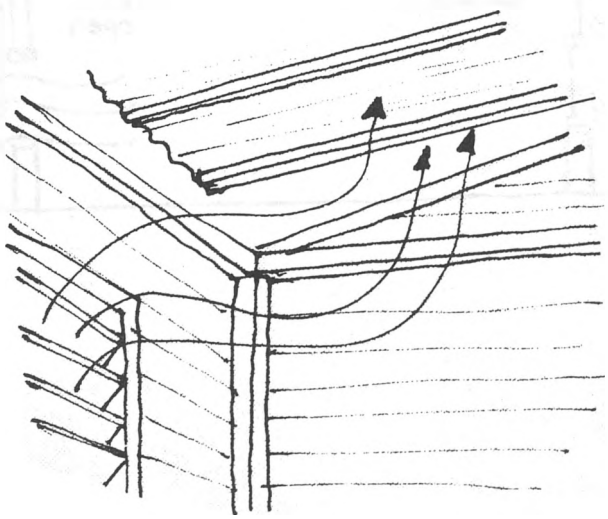
A popular veranda and its pattern of failure is illustrated below.



If this configuration is to be used, the connections between the veranda and walls and roof structure 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.

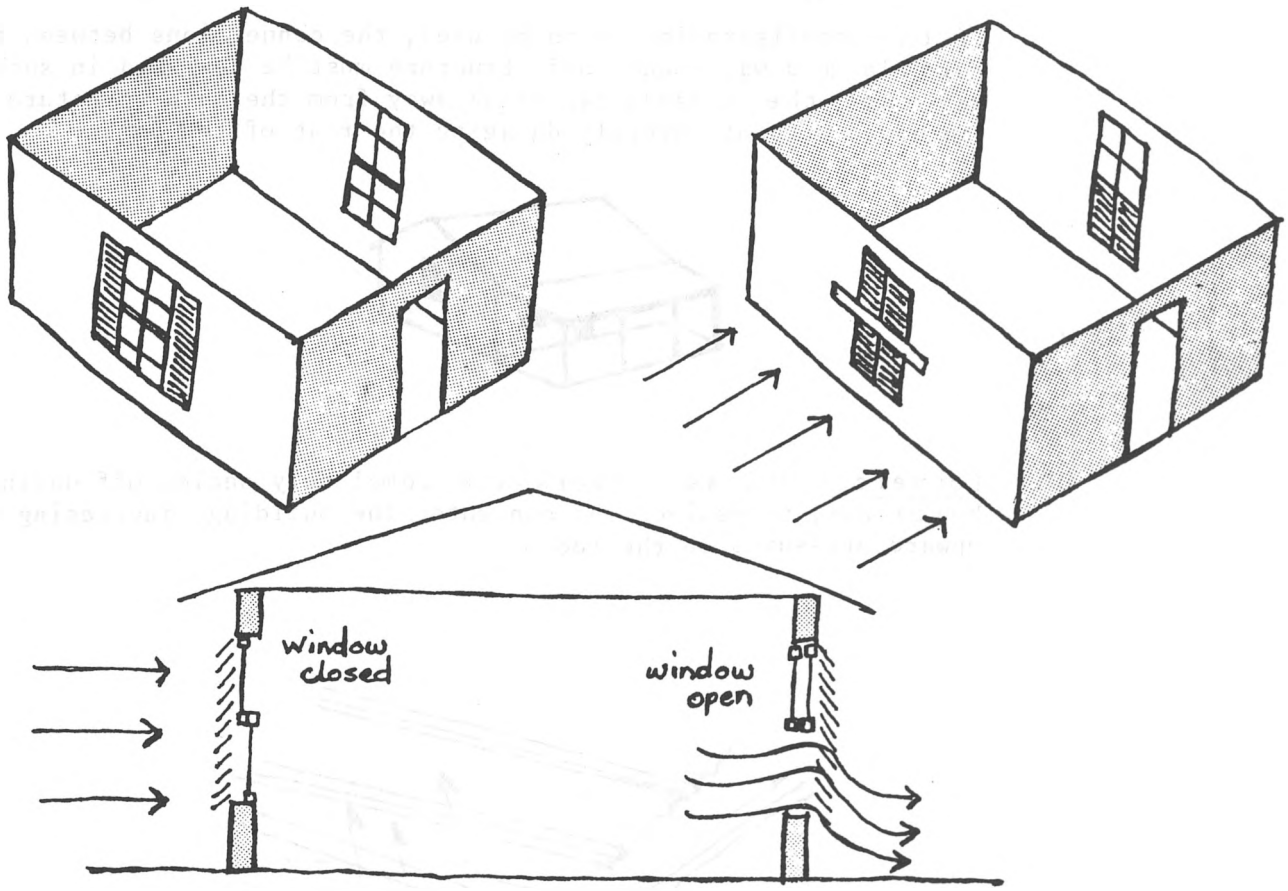


C. Louvers: Unless louvers are completely sealed off during a hurricane, excessive wind can enter the building, increasing the upward pressures on the roof.

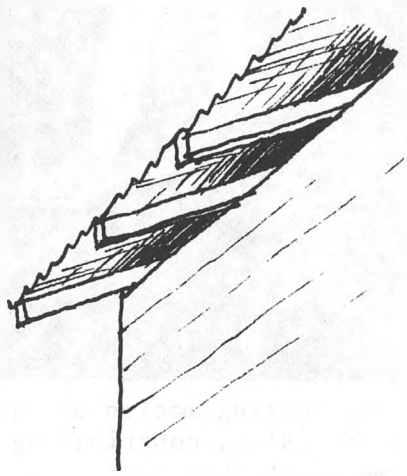


In theory, it should be possible to board up these areas before a hurricane, especially if adequate warning is given. In practice, however, when a warning is received, wood becomes scarce and it may be difficult to obtain the materials necessary to seal off these areas. The ideal solution is to install storm shutters which can be closed when a hurricane approaches.

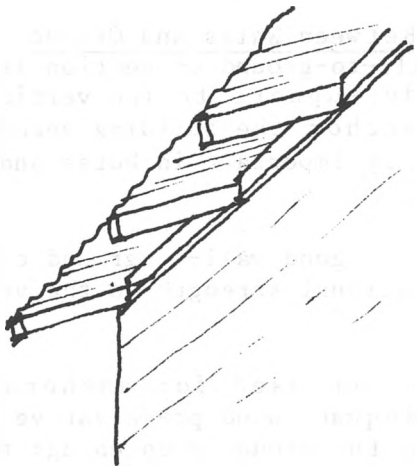
When placed over a relatively airtight window, storm shutters are an ideal adaptation to a hurricane environment. The drawing below illustrates the principles behind their use. When a hurricane threatens, the storm shutter is closed over the window. The shutter protects the opening from flying debris and the downward angle of the panels prevents rain from entering the window.



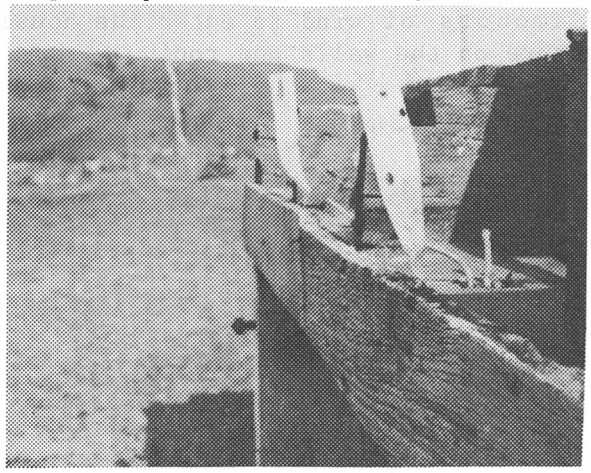
D. Open Spaces: Many houses in the rural areas leave open space between the roof and walls. This allows air to enter the house for cooling purposes. But during high winds this space permits excessive amounts of wind to enter the house and increase the outward pressure on the walls and roof.



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.



E. Poor Fastenings of the Roof to the Walls: Many roofs are inadequately fastened to the walls. In hurricanes, the roof can be lifted completely off the building.



In earthquakes, the rocking motion of the roof can create additional loads on the walls, contributing to their collapse. It is especially important that roof trusses be securely fastened to the frame of the house. Wire, hurricane straps made from strips of C.I. sheets, or commercial hurricane fasteners may be used.

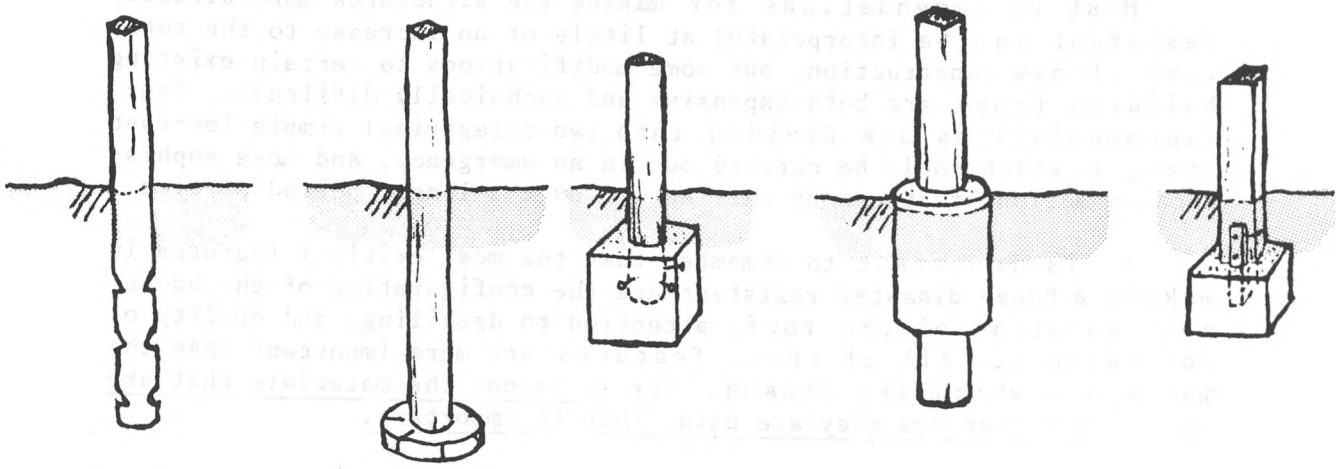
The importance of these fastenings should not be underestimated. Recent studies have shown that adding one fastener at every point where the roof joins the wall can substantially improve the survivability of even marginally-built structures.

F. Poor Connections Between Walls and Ground: For hurricane resistance, a good wall-to-ground connection is important for two reasons: to provide support to the vertical elements of the building, and to anchor the building securely to the ground. This is particularly important in bures and wood frame buildings.

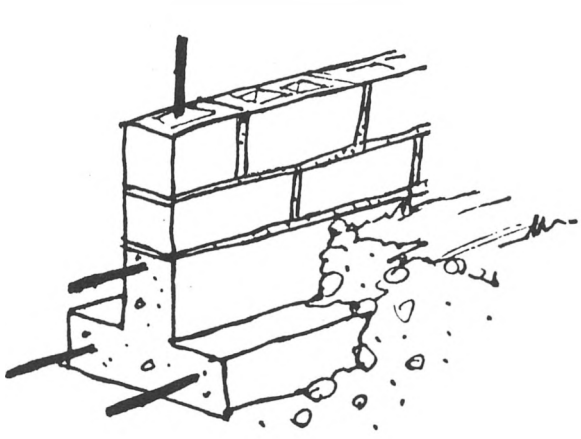
In earthquake areas, a good wall-to-ground connection is important to provide additional strength to the vertical elements of a building.

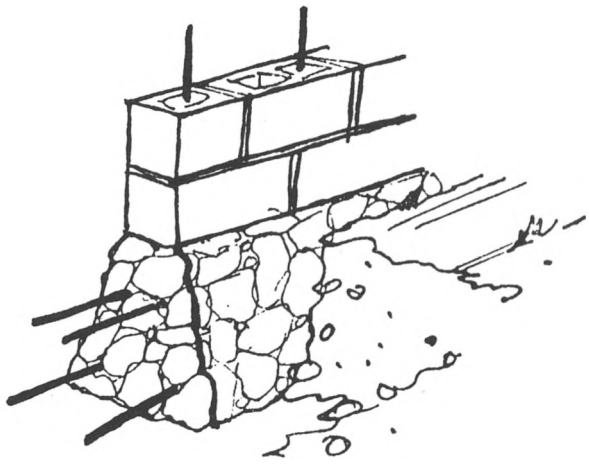
Where wood columns are used for anchorage, they should be treated with an adequate wood preservative (such as crankcase oil) and placed in the ground deep enough to provide friction and resistance against uplift. A number of anchors can also be incorporated in the design of the posts to help reduce uplift.

Several of these are shown in the drawings below.



For buildings made of concrete block, a strong foundation is required in order to help stabilize and support the building. The designs shown below could be used.





VULNERABILITY ANALYSIS OF THE BASIC CONSTRUCTION TYPES

The following is an analysis of the principal housing types found in Fiji. Primary emphasis is on the wind resistance potential of each structure, as hurricanes and wind storms are the greater hazard due to their frequency. However, the earthquake resistance potential is also discussed.

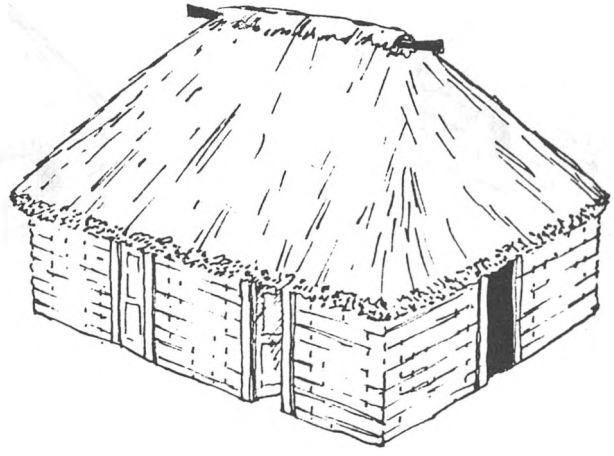
Most recommendations for making the structures more disaster resistant can be incorporated at little or no increase to the total cost of new construction, but some modifications to certain existing building types are both expensive and technically difficult. Thus, recommendations are divided into two categories: simple low-cost changes which could be carried out in an emergency, and more sophisticated actions that can be carried out over a longer period of time.

It is important to remember that the most critical features in making a house disaster resistant are the configuration of the house, configuration of the roof, attention to detailing, and quality of workmanship. All of these features are more important than the materials which are chosen. For it is not the materials that are used, but rather how they are used, that is important.

A. Traditional Construction

The traditional Fijian house, or bure, is still found in large numbers throughout the country. Architectural historians have observed over 30 different types of bures of varying shapes and architectural styles. Bures are particularly well adapted to the Fijian climate and environment. They are comfortable, inexpensive to build and maintain, and often display great craftsmanship and woodworking skills in their construction.

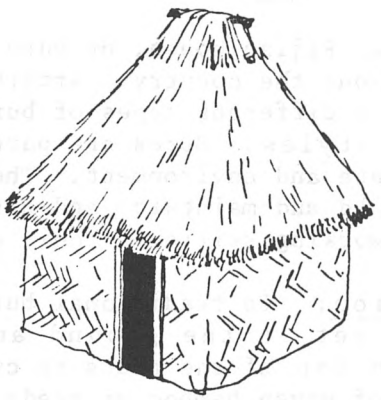
1. Construction: In traditional bures, strong wooden corner posts are set in the ground and a wooden roof frame is erected on top of the posts to create the building frame. Mats made of woven bamboo or reeds are attached between the corner posts to make the walls. These are often supported by small vertical 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 construction wire has been used. In many of the newer bures, nails have replaced the binding.

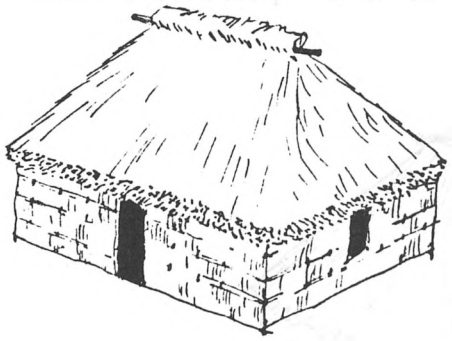


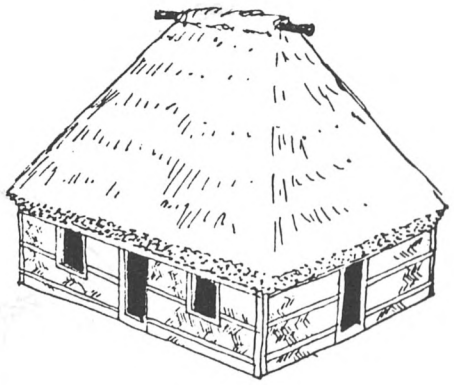
2. Roof: Bures normally have a thatched roof made from pandanus (or in a few cases palm leaves). Almost all roofs are high and use a hipped (4-sided) configuration. In recent years, many thatched roofs have been replaced by corrugated iron (C.I.) sheets.

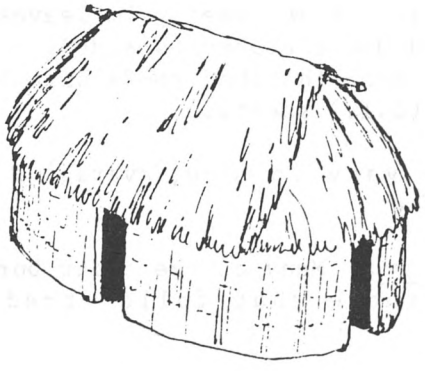
3. Size: Bures vary in size, averaging between 15 x 35 feet and 25 x 60 feet.

4. Vulnerability: Many of the older bures are quite strong, especially those that follow traditional construction









methods and bind the buildings together with rope or wire. The configuration of bures is considered strong, and the configuration and pitch of the roof is excellent. The corner posts are normally fairly strong and buried sufficiently to resist uplift.

The newer bures which use nails are very vulnerable to hurricanes because nails have insufficient friction and strength to resist the pressures on the joints caused by hurricanes.

When damaged, bures are difficult to repair and most residents usually rebuild a new structure. However, even total collapse of a bure is rarely life-threatening. The roof usually blows off the structure intact, and it is common practice that the occupants then rush outside and crawl under the roof for the remainder of the hurricane.

The primary causes of structural failure are separation of the roof from the walls (caused by uplift on the roof's surface and failure of the connections between the roof and walls), collapse of the walls resulting from lack of rigidity in the center portion of the wall, and failure of the corner posts due to deterioration of the wood in the ground.

5. Weak Points: The weak points of the house are the connections between the roof and corner posts, the central portions of the walls due to lack of rigidity in the center, and the corner posts if they have deteriorated. Other weak points which allow excessive amounts of air to enter a building during a storm are the doors and windows.

6. Modifications for Wind Resistance: In order to improve the wind resistance of bures, the following actions are recommended:

   a. Emergency measures

      --- The roof-to-wall connections should be strengthened by using metal straps or wire to help bind the roof to the walls, especially at the corner posts.

      --- Check all connections in the roof structure to ensure that they are properly bound. Next, place additional heavy vertical posts in the central portion of the walls and bind them to the roof frame.

      --- Board up the windows.

--- Throw ropes or nets over the roof and anchor securely to the ground.

--- Install cross-braces of wire between the columns of the building and the corner posts.

b. Progressive upgrading measures

--- Replace corner posts that are rotten.

--- Install cross-braces of galvanized wire or wood between all the primary columns and corner posts of the building.

--- Use wood treatment for all parts of the house that are placed on or in the ground.

--- The primary columns (corner posts and columns in the middle of each wall) should be buried a minimum of 24 inches and should use some form of anchoring device.

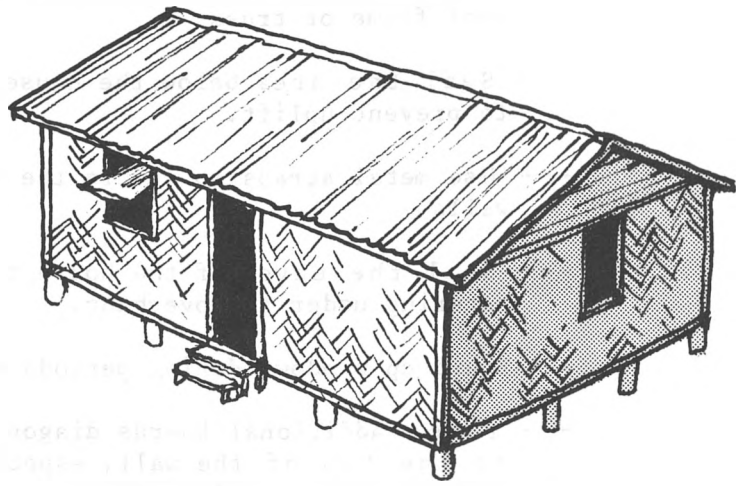
The hurricane resistance of bures, if properly built and reinforced, is moderate. Structural performance can be improved although, due to the type of construction, the building cannot be made airtight or sufficiently strong to withstand extremely high winds (over 100 mph) and structural damage can still be expected. If all the basic rules are followed, however, a substantial improvement in performance can be attained.

7. Modifications for Earthquake Resistance: In terms of vulnerability to earthquakes, bures are relatively safe. The principal weakness is still the columns in the ground. In a strong-motion earthquake, the columns may break and displacement or collapse of the walls will result. By following the recommendations outlined above, the earthquake resistance of bures can be substantially increased.

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 the occupants.

B. Wood Frame with Pandanus Mat Wall

1. Construction: Wood frame houses with walls made of traditional mats are one of the most popular building types found in rural Fijian villages. The house offers the advantages of ease in construction and suitability to the climate. If properly maintained, it will last for many years and can be upgraded by replacing the mats with boards.



2. Roof: Corrugated iron sheets are used most often, but some roofs are made of pandanus thatch. The most popular configuration is a two-sided (gable) roof.

3. Size: Sizes vary from 12 x 15 feet to 15 x 30 feet.

4. Vulnerability: The most common damages caused by high winds are roof separation and destruction of the walls. In houses with louvered windows, damage may be caused by differential pressure pushing out on the walls until portions of the walls rip away.

   Many wood frame houses rest on short concrete piers or are anchored to the ground only by the corner posts of the frame, if at all. This is insufficient anchorage for hurricanes, and the houses will be lifted off the ground and toppled over.

5. Other Weak Points: Typical weak points of wood frame and mat houses are the connections between the roof sheeting and roof trusses, connections between the roof trusses and walls, and 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 nails to secure the roofing sheets to the roof frame or truss.

      --- Seal the area below the house with rocks and mud to prevent uplift.

      --- Use metal straps to secure the roof trusses to the walls.

      --- Seal the eaves of the house to prevent wind from entering under the overhang.

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

      --- Place additional boards diagonally from the floor to the top of the wall, especially in the center of the wall, to add rigidity.

   b. Progressive upgrading measures

      --- Use a hipped roof configuration.

      --- Increase the pitch of the roof.

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

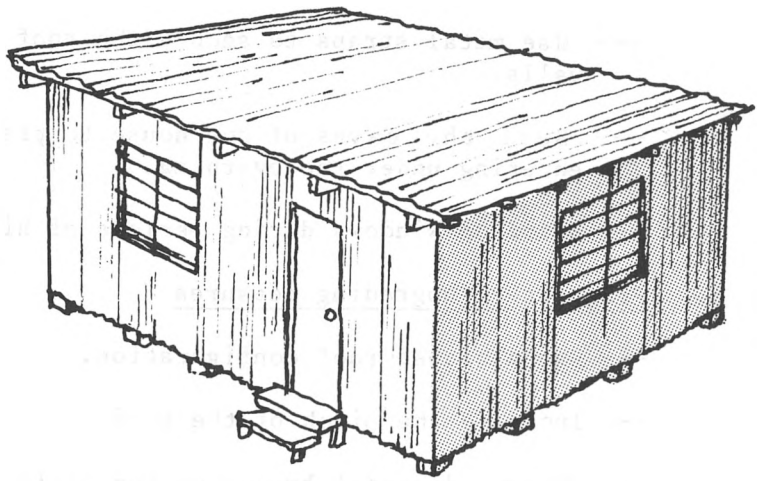
      --- Anchor the structure securely by replacing the short piers with longer piers that have built-in anchors and stronger beam-to-pier connections.

   If these recommendations are carried out, the potential for this type of structure to resist high winds will be substantially increased. If properly built, this type of structure will provide moderate safety in hurricanes.

7. Modifications for Earthquake Resistance: The earthquake resistance of wood frame housing is very good, and by following the recommendations above, the margin of safety will be increased. The only major type of damage that should occur in an earthquake would be collapse of the structure at the base due to insufficient vertical resistance of the piers.

C. Wood Frame Construction with Corrugated Iron Walls

1. Construction: A wood frame house with C.I. sheet walls is one of the most popular transitional building types in Fiji, and is especially popular with low-income families in rural areas where land tenure cannot be secured. The metal house offers the advantages of ease in building additions and suitability to the climate. If properly maintained, it will last for many years. Because it is lightweight, it can be moved if necessary.



2. Roof: The roof covering for these houses is C.I. sheets. The most popular configuration is a one-sided sloping or "shed" roof.

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

4. Vulnerability: The most common damage caused by high winds is roof separation. In houses with louvered windows, damage may be caused by differential pressure pushing out on the walls until the C.I. sheets separate from the posts.

   Most metal houses are anchored to the ground by large corner posts attached to the frame which provide enough strength to hold the buildings down in high winds. Others, however, rest on short concrete piers. The piers offer insufficient anchorage for hurricanes, and the houses will be lifted off the ground and toppled over.

5. Other Weak Points: Typical weak points of metal houses are the connections between the roof sheeting and roof trusses, connections between the roof trusses and the walls, and connections between the building and the ground.

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

a. Emergency measures

--- Use more nails to secure the roofing sheets to the roof frame or truss.

--- Seal the area below the house with rocks and mud to prevent uplift.

--- Use metal straps to secure the roof trusses to the walls.

--- Seal 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

--- Use a hipped roof configuration.

--- Increase the pitch of the roof.

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

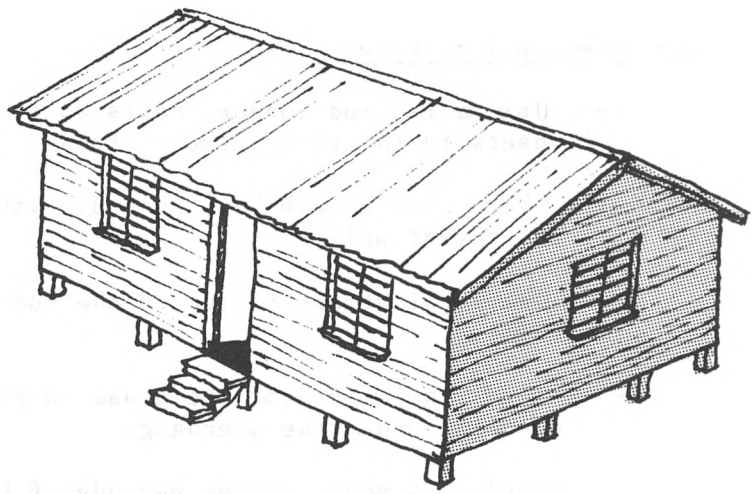
--- Anchor the structure securely by placing anchoring devices on all columns.

If these recommendations are carried out, the potential for this type of structure to resist high winds will be substantially increased. If properly built, this type of structure will provide moderate safety in hurricanes.

7. Modifications for Earthquake Resistance: The earthquake resistance of metal housing is very good; by following the recommendations above, the margin of safety will be increased. The only major type of damage that should occur in an earthquake is collapse of the structure at the base due to deterioration of wood columns. Diagonal bracing and treatment of all wood in or on the ground would make earthquake damage almost negligible..

D. Wood Frame Construction

1. Construction: Wood frame houses are increasingly popular in Fiji. Popularity is expected to increase when Fijian timber becomes more available and less expensive. The houses offer the advantages of ease in building additions and suitability to the climate. If properly maintained, they will last for many years. Because they are lightweight, they can be moved if necessary.



Wood frame houses at one time were very reasonably priced and affordable to almost all income groups. In the last decade, however, this type of house has become more expensive because of the cost of lumber. In some areas, it is almost as expensive to build a house of wood as it is to build one of block and steel.

2. Roof: The preferred roof covering for wooden houses is C.I. sheets. Most roofs are gabled, although many use a hipped configuration.

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

4. Vulnerability: The most common damage caused by high winds is roof separation. In houses with louvered windows, damage may be caused by differential pressure pushing out on the walls until boards separate from the columns.

Many wood frame houses rest on short concrete posts or piers or are anchored to the ground only by the corner posts of the frame. This is insufficient anchorage for hurricanes, and the houses will be lifted off the ground and toppled over.

5. Other Weak Points: Typical weak points of wood frame houses are the connections between the roof sheeting and roof trusses (most nails are too short), connections between the roof trusses and the walls, and 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 or truss.

      --- Seal the area below the house with rocks and mud to prevent uplift.

      --- Use metal straps to secure the roof trusses to the walls.

      --- Seal 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

      --- Use a hipped roof configuration.

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

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

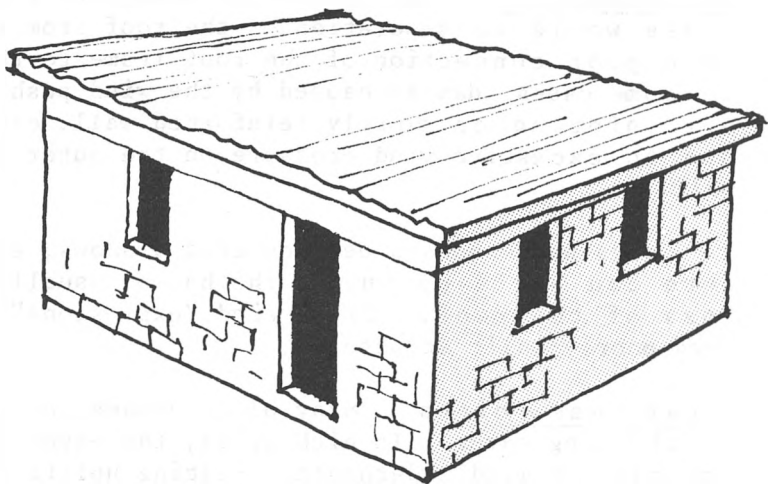
      --- Anchor the structure securely by placing anchoring devices on all columns.

   If these recommendations are carried out, the potential for this type of structure to resist high winds will be substantially increased. If properly built, this type of structure will provide moderate safety in hurricanes.

7. Modifications for Earthquake Resistance: The earthquake resistance of wood frame housing is very good, and by following the recommendations above, the margin of safety will be increased. The only major type of damage that should occur in an earthquake would be collapse of the structure at the base due to slippage from the piers.

E. Concrete Block Construction

If properly built, a concrete block house can withstand the forces of both earthquakes and windstorms and is a safe form of construction. If improperly built and reinforced, this type of construction is the most dangerous.



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. Ideally, reinforcing rods are placed vertically in the corners and 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 cementing a course of blocks slightly below ground on which the walls rest.

2. Roof: The roofs of concrete block houses in Fiji are of 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 nut on the bolt.

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

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

4. Vulnerability: The principal damage to a concrete block house would be separation of the roof from the walls (due to a poor connection of the roof frame to the walls) and, in some cases, damage caused by the wind pushing against an unreinforced or poorly reinforced wall, causing collapse due to excessive wind pressure on the outer surface of the wall.

   In cases where houses use louvered windows, excessive pressure can build up inside the house, usually resulting in loss of the roof. High wind "explosions" occur only to very poorly-built structures.

5. Other Weak Points: Many block houses in Fiji have large overhanging eaves. In high winds, the eaves trap excessive amounts of wind underneath, creating uplift under the edge of the roof and thereby 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 special fasteners on each connection.

   b. Progressive upgrading measures

      --- Use a hipped roof configuration.

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

      --- Reduce roof overhangs.

      --- Replace flat roofs with hipped roofs.

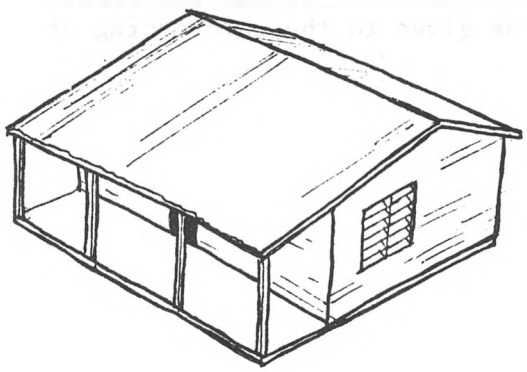
If the recommendations outlined above are incorporated into the design of concrete block houses, the wind resistance of the structures will be excellent and only minor damage should occur in windstorms.

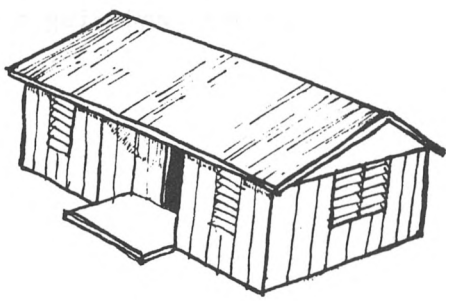
7. Modifications for Earthquake Resistance: The recommendations above also apply to construction of earthquake resistant housing. In order to be earthquake resistant, special attention needs to be given to the reinforcing of columns and ring beams.

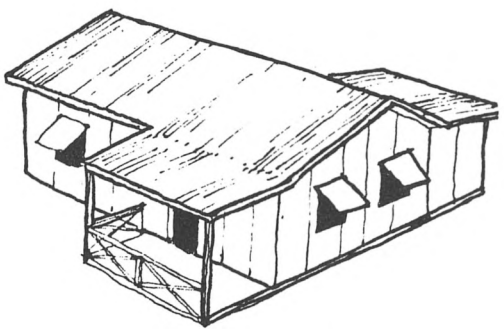
VULNERABILITY ANALYSIS OF GOVERNMENT-AIDED LOW-COST HOUSING

A. Housing Authority Buildings

The most popular buildings provided under the various Housing Authority schemes are illustrated below.







Even buildings of the same design vary greatly in quality of construction, sometimes even within the same community. If built properly, most would be moderately safe in hurricanes and very safe in earthquakes. However, due to the varying quality of construction, many are susceptible to damage. The following is a summary of deficiencies which could affect performance.

1. Most buildings use a gable roof.

2. The angle of pitch on many roofs is too flat.

3. Roofing nails are too short and would not prevent the C.I. sheets from blowing off.

4. Porches and verandas are attached in such a way that they would damage the roof if they blew off.

5. There is insufficient use of hurricane straps. Many of the straps that are used would provide little or no resistance to uplift.

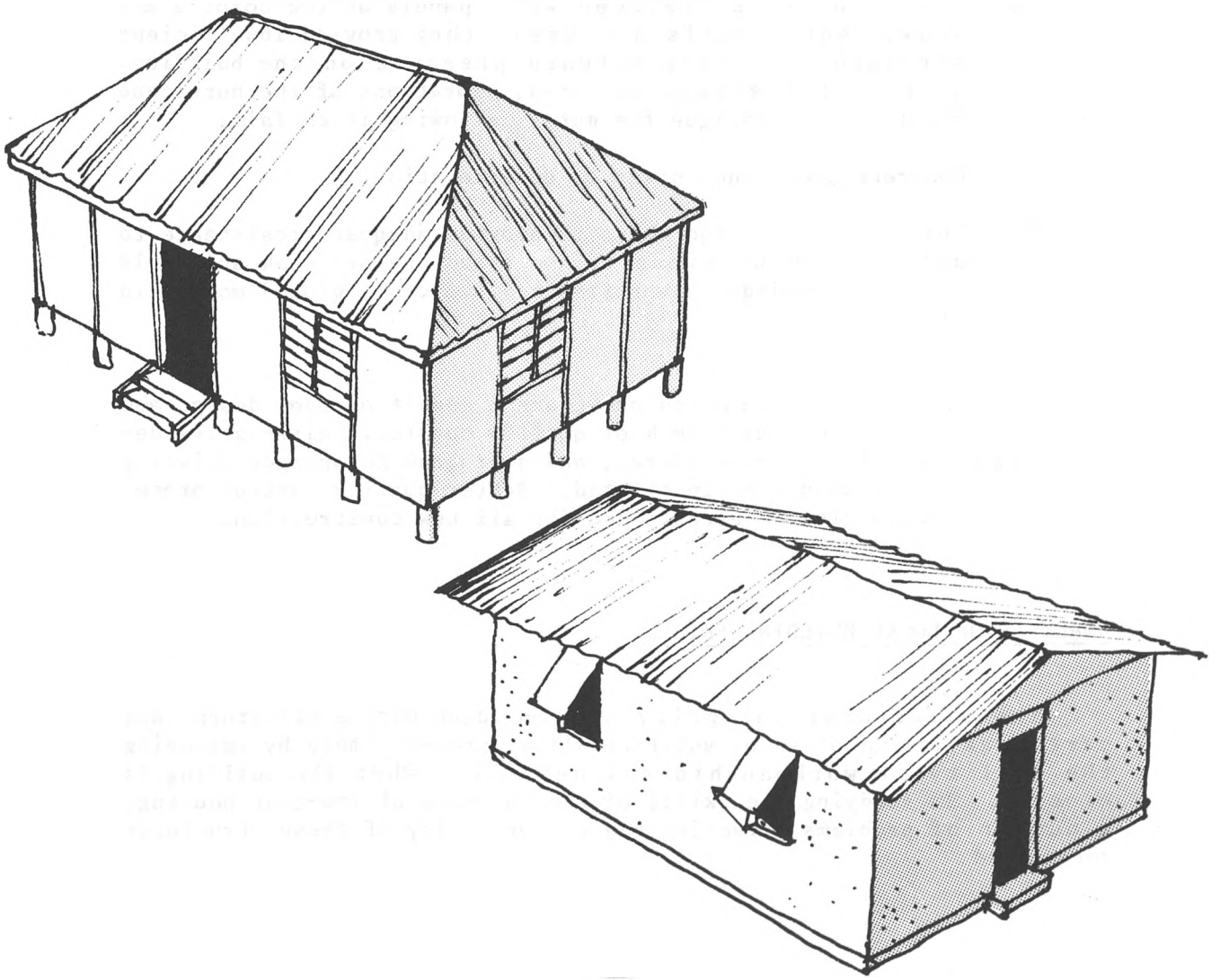
6. Some of the materials used are below the quality specified by the Housing Authority. They appear to be deteriorating rapidly and will soon have no structural strength.

7. There is excessive open space between the top of the wall and the roof. This will permit excessive wind to enter the house and push upward on the roof.

Most of the problems mentioned above can be resolved through better quality control during the construction process.

B. Relief Housing of the Prime Minister's Relief & Rehabilitation Committee (PMRRC)

Several types of housing have been provided to disaster victims by the PMRRC. The drawings below illustrate two types of units erected.



Many of these structures are inadequately designed and poorly built and are vulnerable to hurricanes. The following deficiencies have been identified:

1. The roof sheets are too thin. A much heavier gauge is required.

2. The roofing nails are too short to hold the C.I. sheets to the purlins.

3. There are insufficient numbers of hurricane straps to hold the roof frame to the building. Many of the straps that are used are improperly attached and have no strength.

4. There are large open spaces beneath the roof eaves.

5. The wall materials are often of poor quality and begin to show signs of deterioration after relatively short periods of time.

6. The connections between wall panels at the corners are weak. Where nails are used, they provide insufficient strength to resist outward pressure on the building. Where metal straps are used, vibrations of the hurricane are likely to fatigue the metal, allowing it to fail.

7. Concrete piers show signs of deterioration.

8. The piers are too short to provide adequate resistance to uplift. Connections to the structure are weak and would provide inadequate vertical resistance to ground motion in an earthquake.

The problems identified above are a result of poor design and specifications, and lack of quality control. Alternative designs should be considered, and a program to upgrade existing structures should be instituted. Better quality control procedures should also be established for all new construction.

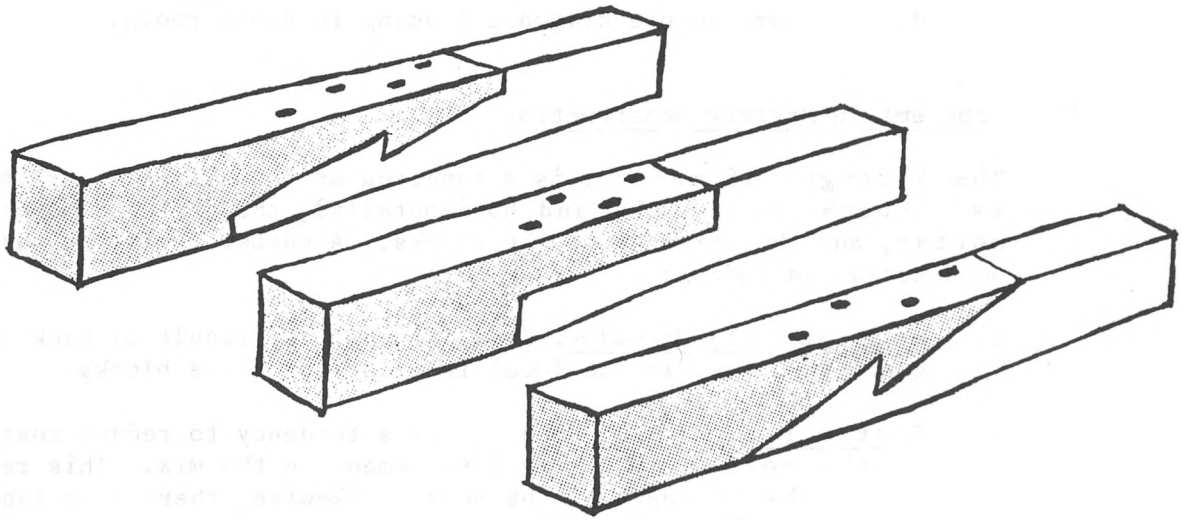
ANALYSIS OF LOCAL BUILDING SKILLS

The structural integrity of a building during windstorms and earthquakes can often be substantially improved simply by improving the quality of workmanship and detailing when the building is erected. In studying the skills of the builders of low-cost housing, a number of problems affecting the vulnerability of these structures were noted.

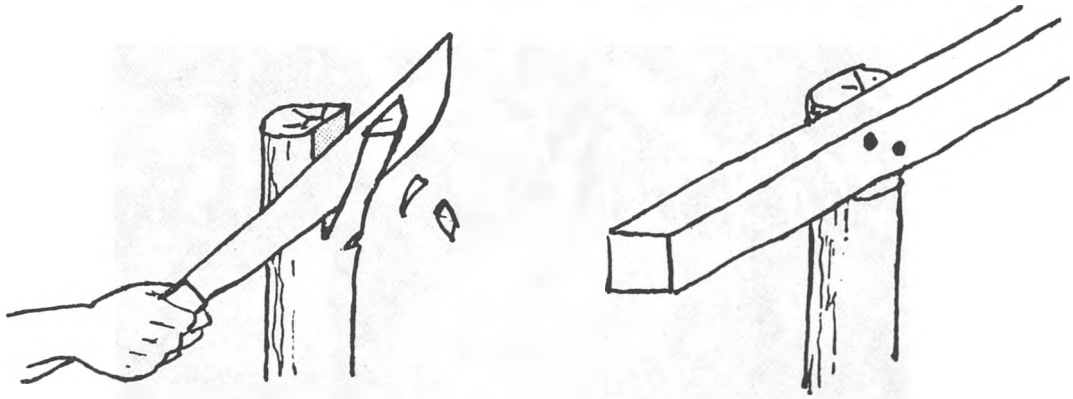
A. Carpentry Skills

1. Joints: The key problem in wood frame structures is that many of the joints are weak in terms of both design and fastening. Structurally important joints are often nailed in tension rather than in shear. When forces are applied, the nail will slip out and the joint will separate.

2. Splicing: The splicing of wood in wood frame construction is a major problem. Many splices are held together with only a nail. Few carpenters use joints that would add strength to the detail. The following splices should be used.



In pole construction, many joints have insufficient friction to strengthen the connection. The place where a joint will be made should be carved flat as illustrated below.



3. Improper Use of Bracing: Structural reinforcements in the building frame do not provide adequate strength. Common problems include:

   a. Placement of braces in tension where they can easily separate.

   b. Placement of braces at angles which are insufficient to provide adequate rigidity or resistance, and placement of supports in such a manner that they do not adequately distribute loads.

   c. Failure to use braces in critical parts of a building.

   d. Failure to use diagonal bracing in gable roofs.

B. Problems in Masonry Construction

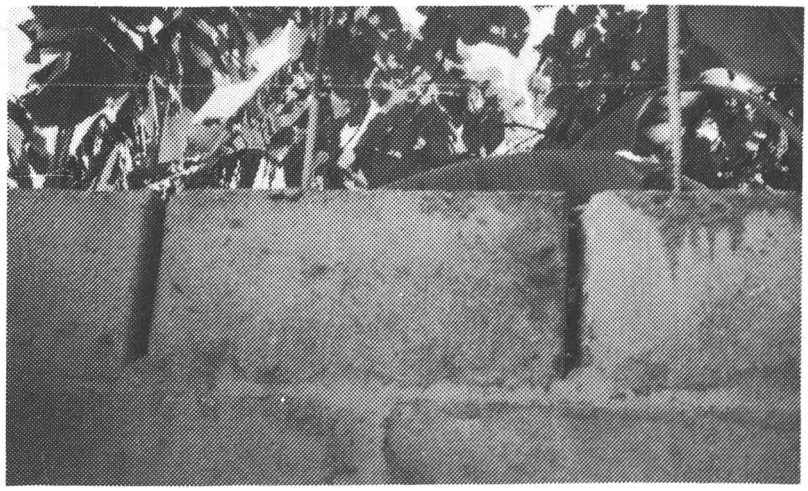
The strength of masonry is a function of the alignment of the wall (both vertically and horizontally), the strength of the mortar, and the strength of the blocks. A number of faults have been noted, including:

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

2. 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.

3. Poor concrete mix in the structural columns and building piers.

4. Insufficient mortar between blocks.



5. Poor connections between interior and exterior walls.

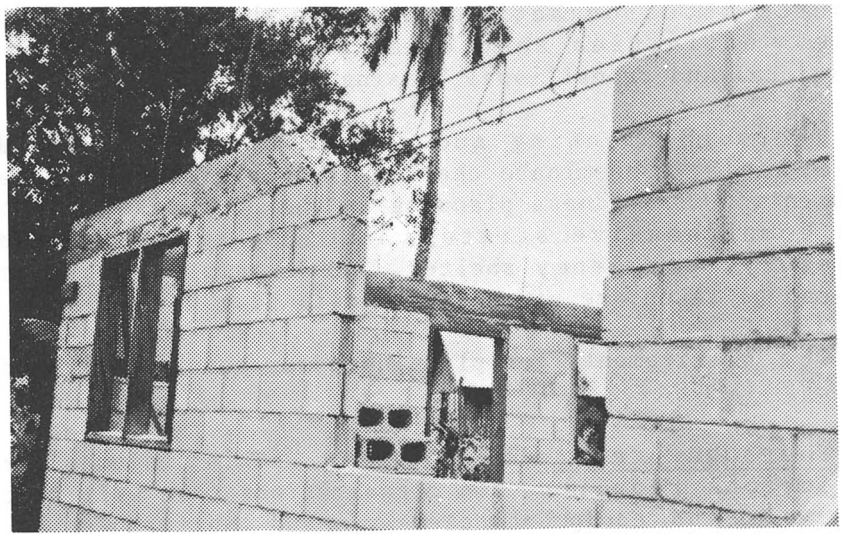
6. Unlevel masonry on each course.

7. Insufficient reinforcement in poured columns, and insufficient use of rebars placed inside block walls.

8. Poor detailing around doors and windows.

9. Improper or insufficient foundations.

10. Excessive spans and questionable detailing of lintels above windows.



NOTE: The problems of poor detailing are common to both owner-built and contractor-built houses, but problems of insufficient or poor-quality reinforcement reportedly appear more in contractor-built housing and represent attempts to cut costs. This is a problem that can only be addressed through expanded and stricter code enforcement activities.

V. VULNERABILITY REDUCTION STRATEGIES

Vulnerability reduction measures include three types of activities: 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 to ensure the safety of persons within a house. Activities should emphasize protection of those living in traditional and transitional housing.

Thorough planning and preparation are required in order to effectively disseminate the required information when a disaster is imminent. Preparedness planning in the housing sector should be part of a comprehensive strategy including housing, evacuation and, if necessary, emergency shelter. Some examples of emergency measures that can be taken are given in Appendix II.

The requirements for planning comprehensive emergency activities are:

A. Thorough preparedness planning. This includes a review of the actions required, the organizations that will participate, the tools and equipment necessary, and the formulation of a comprehensive plan to guide the response.

B. Identification of public information requirements. A variety of media is required in order to disseminate the information thoroughly including leaflets, posters, pre-recorded radio announcements, newspaper inserts and supplements. These must be designed to show how to protect a house, reduce damage from blowing debris, and reduce injury in case a building fails. Information should also be available to enable homeowners to determine flood or storm surge threat, and whether they should evacuate. For those who will evacuate, an evacuation plan is required, and maps showing evacuation routes must be prepared and disseminated to appropriate organizations and news media. In addition, route markings and equipment for personnel must be prepared and pre-positioned. In some cases, hurricane shelters may be required, and they must be designated and strengthened in advance.

C. Training and technical assistance for local emergency relief officials and organizations. Not only must information on how

to protect houses be distributed in advance, but also a sufficient number of people acquainted with how to use the techniques should be trained and available to help the public on each island.

D. Information dissemination mechanisms. The most effective means of communicating information on protection of buildings is through visual media. To a limited extent, newspapers can be helpful in disseminating this information. More comprehensive information, however, will require highly illustrated booklets and leaflets. A system for distributing this information must be established in advance, and the materials for distribution must be pre-positioned for rapid distribution to these outlets prior to the occurrence of a disaster.

Overall responsibility for implementation of short-term activities is now assigned to the Emergency Services Committee (EMSEC). The other agencies that should be involved are the Prime Minister's Relief & Rehabilitation Committee (PMRRC), the Housing Authority, the Royal Fiji Police, and the Public Works Department.

PROGRESSIVE UPGRADING

The overall objective of progressive upgrading is to strengthen existing housing to withstand a hurricane or earthquake. Actions focus on activities that can be carried out by the homeowner with minimal financial and technical assistance, and that do not require extensive reconstruction or modification of the existing building. Because some measures represent a cost to homeowners, activities normally concentrate on formal rather than transitional houses.

Examples of progressive upgrading measures are:

--- Changing the configuration of a roof.

--- Reducing roof overhangs.

--- Sealing the eaves.

--- Adding storm shutters.

--- Installing or increasing hurricane straps in the roof.

--- Installing breakaway verandas.

--- Installing braces in walls and corners.

--- Improving foundations.

--- Replacing deteriorated wood.

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

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

The objective of upgrading is to reduce the need for replacement housing after a disaster. To be successful, activities should also improve livability and reduce costs of maintenance and operation.

Progressive upgrading requires a comprehensive approach and a commitment from many agencies. The government should first develop a policy to guide the activities and an appropriate framework for implementation. In addition, the government should designate one agency to serve as coordinator.

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

1. Building Performance Standards. To provide a framework for determining which actions are appropriate for the upgrading of different types of structures, minimum building standards based on building performance and emphasizing the safety of occupants should be developed by the government for all types of low-cost housing. These will provide criteria that financial institutions can use to determine which improvements can be funded by loans, and the standards will help to identify the critical components and features of a disaster resistant building for each housing type.

   Current building codes can be used for certain types of formal construction. However, transitional and traditional buildings are not covered, and enforcement of the existing code on these types of buildings is not practical.

2. Financial Assistance or Other Incentives. Some families will require financial assistance for upgrading their houses. The government may want to consider expanding existing loan programs to accomodate the demand. Special plans will be required to handle requests from families without clear title to their lands.

3. Information. In order to both encourage and guide progressive upgrading, a variety of information is needed including:

   a. Information about how to decide what modifications are required and practical.

   b. Information on where to obtain assistance.

c. A variety of media, especially films and heavily illustrated booklets, to provide detailed "how to do it" information.

To help homeowners determine whether they need to upgrade their homes and what techniques would be practical, a simple "home test" should be devised and disseminated. This test would use a numerical grading system to help determine how safe the building is and would show the homeowner how vulnerability could be reduced through the addition of certain components or features.

4. 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.

5. Development of Local Skills. Some housing improvements will require the services of contractors. It is important that the government provide training to existing building contractors to enable them to participate in housing improvement activities. A certification program for local contractors would be a means of improving the skill level, as well as ensuring that an adequate reservoir of talent is developed.

B. Coordination and Implementation: Overall responsibility for implementation of the upgrading of existing buildings would best be assigned to a single agency. Possibilities include the Directorate of Town & Country Planning, the Ministry of Urban Development, Housing & Social Welfare, or the Ministry of Works & Communications. Other ministries and organizations that should participate include the Housing Authority, the PMRRC, the Ministry of Health, the Ministry of Forests, and the Ministry of Fijian Affairs & Rural Development. The Fiji National Training Council and the Fiji Institute of Technology should provide training in support of the program in the implementation phase.

C. Financial Assistance: New approaches should be examined for the provision of financial assistance to homeowners for upgrading of their homes. Primary emphasis should remain with existing financing programs and institutions. To enable a greater number of people to be served, the eligibility criteria for small loans would need to be expanded. This may require loan guarantees from the government or other institutions. Loans would be provided only for those improvements specified in the building standards. For persons unable to obtain loans,

alternative programs where they can obtain easy access to materials or cash should be considered. An example would be a community service work program wherein people could obtain credits toward purchase of materials at discount or subsidized prices. As a general principle, the provision of direct cash grants should be avoided.

D. Technical Assistance: Some provisions for making technical assistance available on a permanent basis should be established. One method that could be tried is to form a corps of building inspector/instructors to work with people building new housing. The inspector/instructors would not only provide advice to those building or upgrading their homes, but would also work with local contractors to train and encourage them to participate. The inspector/instructors would maintain a list of certified contractors and help homeowners determine what improvements are necessary or practical, as well as helping them to obtain the appropriate financial and technical assistance required.

The inspector/instructors could either replace or complement the inspectors from the Ministry of Health. Their function would be "active" enforcement of building standards. In the more remote areas or outer islands, private contractors could be licensed to serve as inspector/instructors if no government representative is on the island full-time.

E. Technical Information Resources: At the present time, there is no single repository for information regarding low-cost housing or the techniques and skills required to maintain and upgrade these buildings. There are several organizations currently involved in building research using indigenous building materials and skills. Several proposals have been forwarded regarding a building institute, but no such organization has yet been established. The government should consider establishing a "national center for building & construction" which would include:

1. A housing information center with library and public information materials on all types of construction in Fiji, including both engineered and non-engineered structures and building techniques;

2. A national housing reference library that would be useful to architects, engineers, planners, builders, public officials, material suppliers, or anyone interested in any aspect of building construction and human settlements in Fiji. It is especially important that data be developed concerning historic and vernacular construction.

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 the development of a reservoir of talent and public information on how to build safely.

The methods used to improve new buildings are often simple and uncomplicated, and usually add little, if any, extra cost when they are routinely installed 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 building design specifications 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.

--- Improved quality control.

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. Specific programs may have to be modified as appropriate.

B. Coordination: Responsibility for effecting improvements in new construction should be assigned to the same Ministry that coordinates progressive upgrading.

C. Incentives: The most effective way to encourage improvement of new building construction is by offering increased financial assistance to homeowners on the condition that disaster resistant construction techniques be used. To affect all types of housing, the need to provide financial assistance to those building outside the formal construction process should be recognized and appropriate means of providing limited funds in this sector should be developed.

D. Technical Assistance: A more comprehensive range of technical assistance and information would be required to effect improvement in new construction. The focus is on formal houses, so the number of building types involved is much smaller. Initial emphasis should be placed on concrete block buildings. Provision of technical assistance at the local level should be carried out in the same manner as for progressive upgrading, but increased emphasis should be placed on training contractors. Simplified plans and drawings should be developed for families to enable them to build safe concrete block and wood frame buildings.

VI. COMPREHENSIVE VULNERABILITY REDUCTION ACTIVITIES

The following are suggestions for comprehensive activities designed to reduce vulnerability of low-cost housing in Fiji. These activities will encourage safer construction and establish better building methods as part of the normal building processes.

The vulnerability of low-cost housing can be reduced. Interest is high throughout the country, and recent hurricanes have demonstrated the need. Thus, activities to reduce vulnerability and improve housing can have substantial impact.

ACTIVITIES

The following activities are recommended for reducing vulnerability:

A. Designate a coordinating agency.

B. Establish an intergovernmental coordinating committee to coordinate technical assistance and other inputs from the different government agencies. Members should include the Ministry of Urban Development, Housing & Social Welfare, the Public Works Department, the Prime Minister's Relief & Rehabilitation Committee (PMRRC), the Ministry of Health, the Fiji Institute of Technology, Town & Country Planning, and the Ministry of Fijian Affairs & Rural Development.

C. Prepare minimum performance standards for all types of non-engineered and low-cost housing.

D. Convene a series of workshops for assisting institutions, especially financial institutions, to encourage their participation in the activities and to develop approaches for increasing their services.

E. Prepare a comprehensive set of instructional materials including materials necessary to train the staff, materials for training contractors and homebuilders, and general public information materials to promote vulnerability reduction. (A list of these materials is attached as Appendix I.)

F. Conduct periodic workshops for housebuilders in all parts of the country. Training should stress use of the modification techniques and how to promote adoption of the methods by the general public.

TARGET GROUPS

Public information activities should focus on those groups within the general population that are most likely to be receptive. In general these groups are:

A. Young people between the ages of 18 and 30. This is the primary group involved in construction of new housing. Promotional activities should stress the long-term advantages of investing in housing improvements, and promotional media should depict people in this age group.

B. Building tradesmen. Emphasis should be placed on improving the skills of the contractors. Without their participation in the program, it is unlikely that the ideas will be perpetuated.

C. Persons living in squatter settlements. The majority of new construction occurs in settlements in the urban areas. Efforts to affect these houses should be carried out in cooperation with other programs to assist squatter settlements and the newly developing areas.

D. Persons living in transitional housing. Many families currently reside in temporary buildings until land tenure is secure or until they obtain the resources for construction of a more formal structure. Educational materials on how to upgrade these buildings and/or how to build small core structures that can be gradually enlarged in a safe manner should be provided to these families.

E. Homeowners living in deteriorated older-period buildings. There are many older buildings that could be brought up to standard. It is important to focus on homeowners rather than renters as they are most likely to make investments in their buildings.

COST REDUCTION STRATEGIES

In order to make housing improvements affordable, a number of cost reduction strategies and incentives can be explored, including:

A. Cost Reductions: To enable some families to participate, the cost of materials may have to be reduced. Program implementers should identify those materials that are critical and require a decrease in cost, then identify methods to reduce the costs. Methods may include:

   1. Payment of transportation costs;

   2. Local production of components;

3. Subsidies.

B. Multiple Financial Approaches: Financial assistance will be required to ensure that every group of people can participate. A balanced program with several different approaches is necessary. Possible programs include loan guarantees, subsidized loans, soft loans, and revolving loans.

C. Cooperative Activities: One of the best means of lowering the cost of housing is for families to work cooperatively. One method is the formation of a group of four or five families to help each other build or repair. The families collectively pay for the services of a certified contractor to supervise their work. Construction occurs simultaneously, thereby lessening the possibility that one family would fail to assist the others once their house has been finished. Other forms of cooperative action should also be explored.

APPENDIX I:

RECOMMENDED TRAINING AIDS AND PROMOTIONAL MATERIALS

The following sets of materials are recommended. Many of these materials are already available or can be quickly adapted from existing resources. Also, many of the materials can be used interchangably between sets. An asterisk denotes materials that should be prepared specifically for Fiji.

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 used for both public information activities and portions of the instructional program. 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 distribution to radio stations, describing methods for protecting buildings in an emergency as well as where and how to obtain technical information, should be prepared.

3. *"How Safe is Your House?": Pamphlet to help families determine whether their houses need improvement or modification. The pamphlet should use a checklist and numerical grading system to help homeowners determine the relative safety of a building, and it should help them determine the relative value of various options they may choose. (A simplified version of the checklist may be produced and printed in newspapers to help encourage people to determine safety at the beginning of each hurricane season.)

MATERIALS FOR TRAINING CONTRACTORS AND HOMEBUILDERS

A. Training Aids for Design and Construction of New Buildings

4. *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.

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

6. *"How to Build a Safe Wood Frame House": Pamphlet to serve as a guide for those building new wood frame houses.

7. *"How to Build a Safe Bure": Pamphlet to serve as a guide for those building bures.

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

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).

10. *Flipcharts: Training aids to amplify points made in the various booklets, for use by instructors in the classes. These charts should be prepared on cloth or plastic to make them more durable.

B. Training Aids for Upgrading Existing Buildings

11. *"How to Strengthen Transitional Housing": Pamphlet to guide owners of the different types of transitional houses in how to correctly strengthen their buildings. The pamphlet should discuss the relative value of the different types of modifications and retrofitting measures possible, and provide guidance in how to determine the structural integrity of wooden components.

12. *"How to Strengthen a Bure": Pamphlet to illustrate simple techniques for improving hurricane and earthquake resistance, to be developed for owners of traditional bures.

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

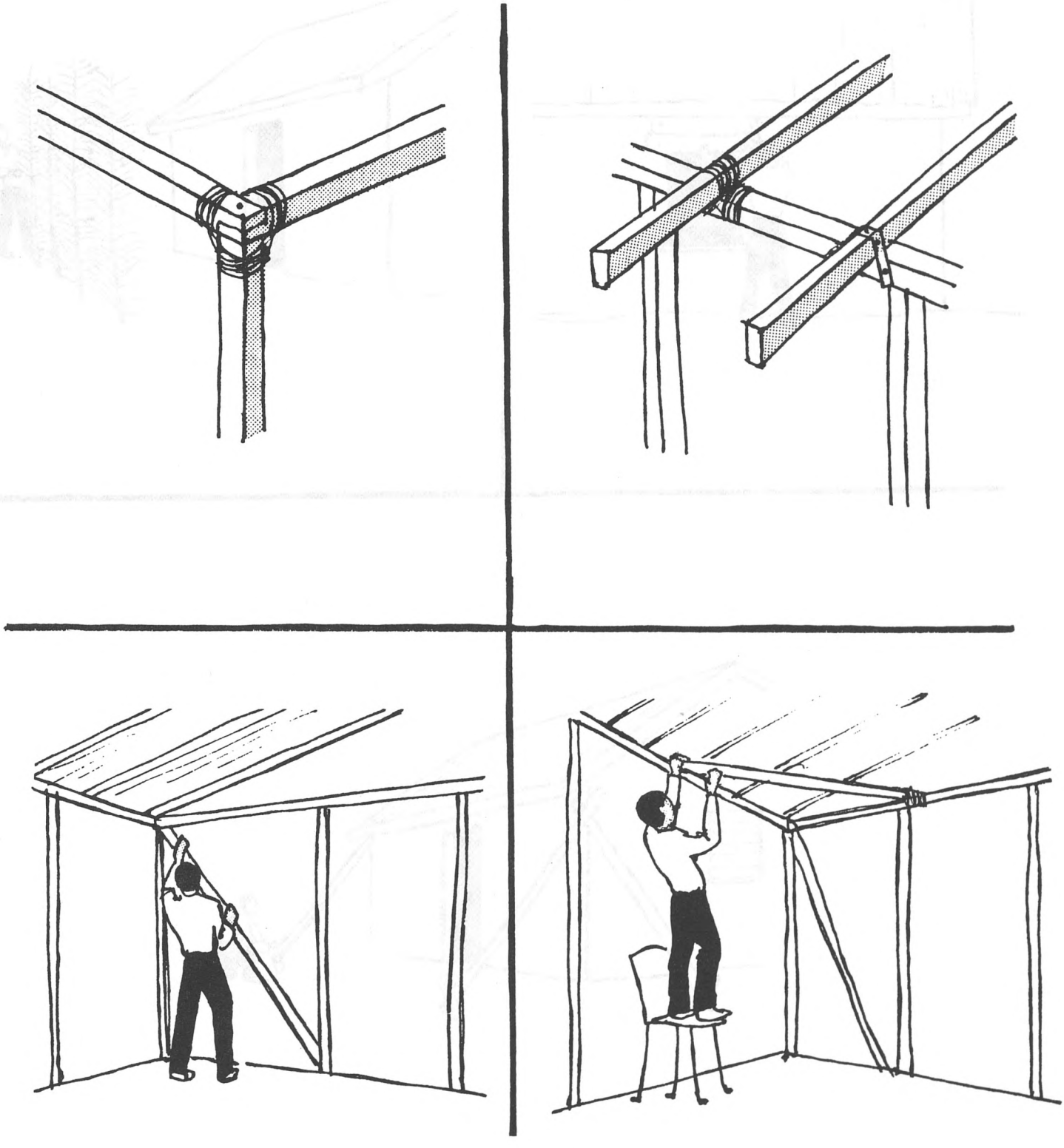
14. "How to Strengthen Houses Made of Concrete Block": Pamphlet to guide homeowners in how to reduce vulnerability, placing special emphasis on reinforcing the connections between the roof and walls.

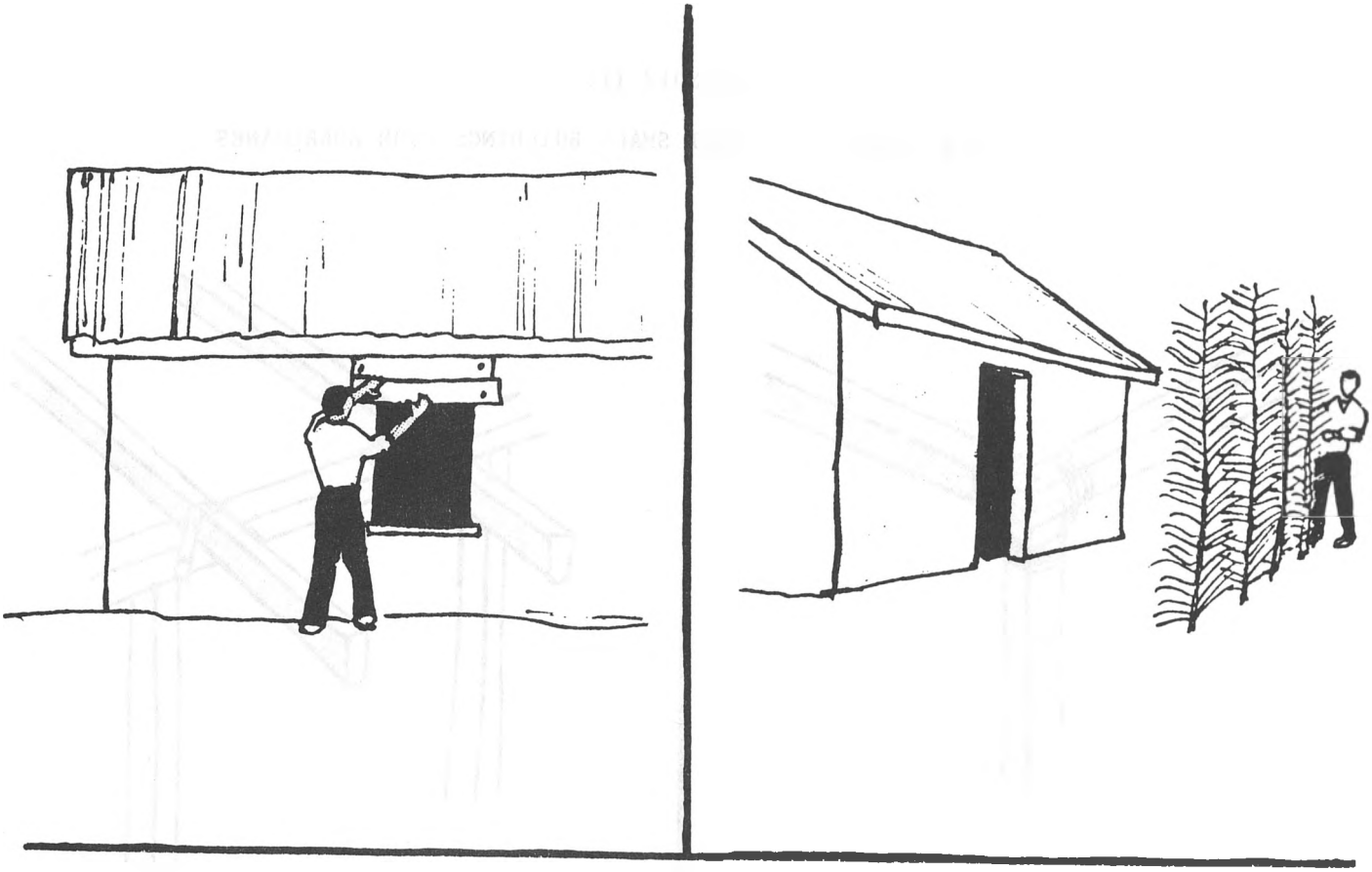
C. Instructional Materials for Emergency Protection of Existing Buildings

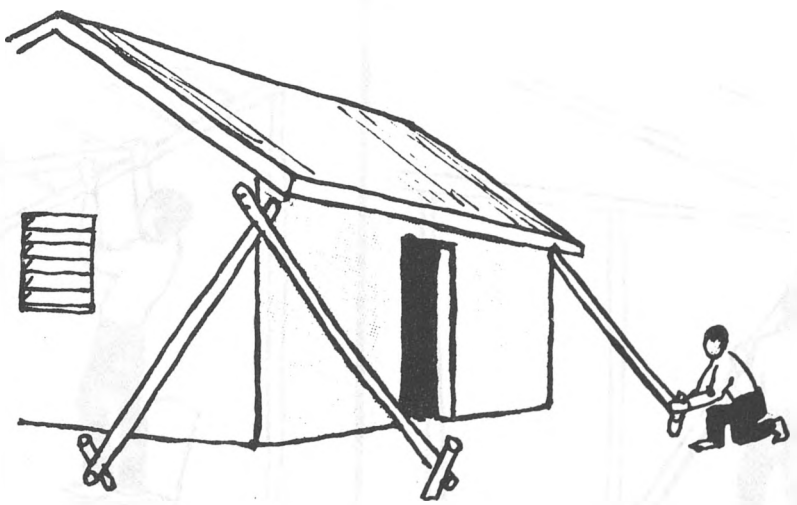
Many of the materials identified above can be used to provide homeowners with information on repairs, modifications or retrofits that can be carried out when a hurricane threatens. In addition, a special pamphlet entitled "How to Protect Your House in Hurricanes" should be developed. This would be a guide to simple improvements for all types of housing, and would provide information on how to protect the building and the site, and how to determine whether or not a family should evacuate to a safer area.

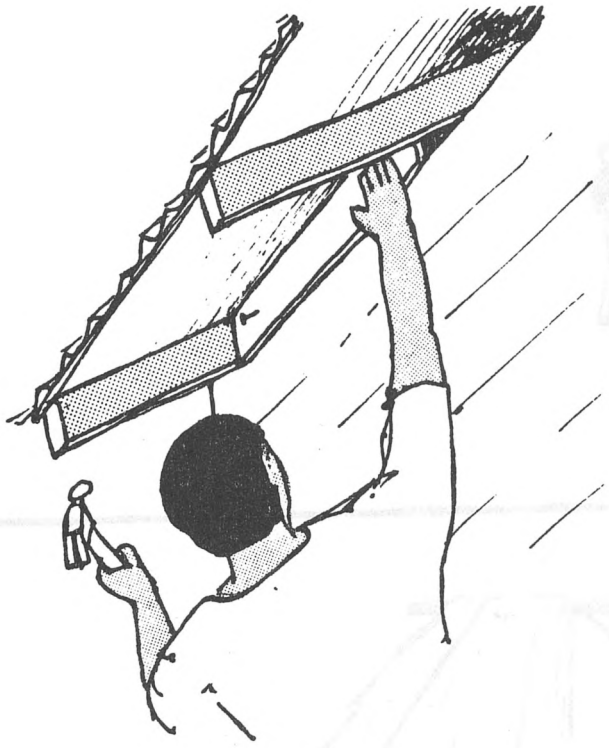
APPENDIX II:

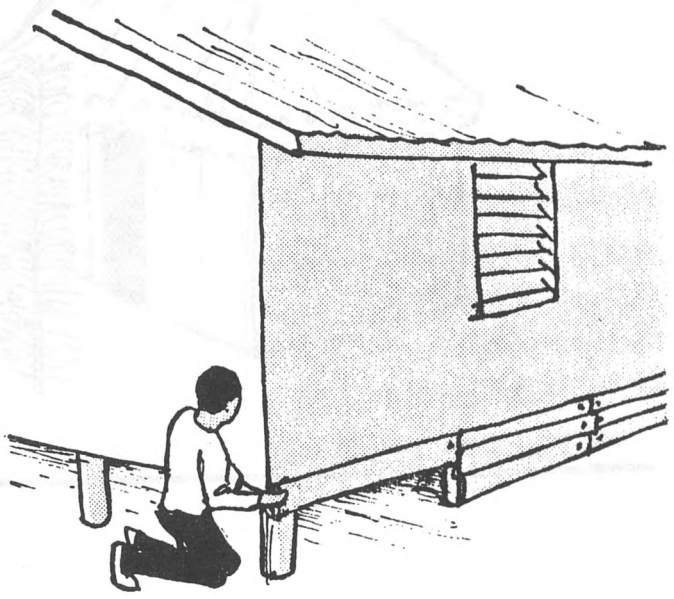
EMERGENCY MEASURES TO PROTECT SMALL BUILDINGS FROM HURRICANES

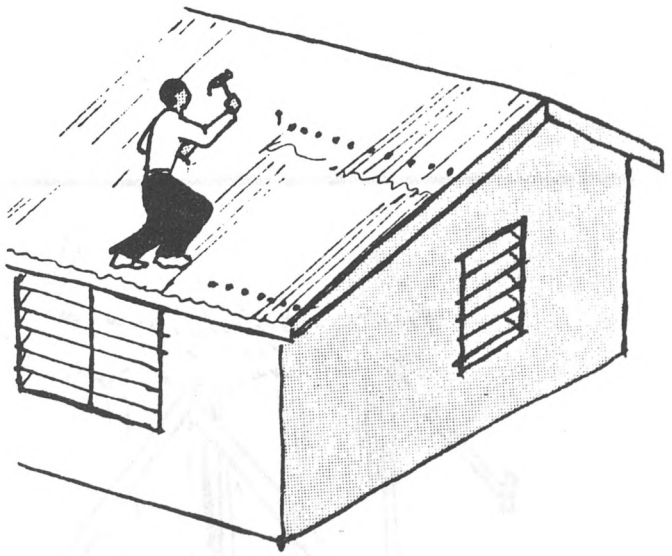


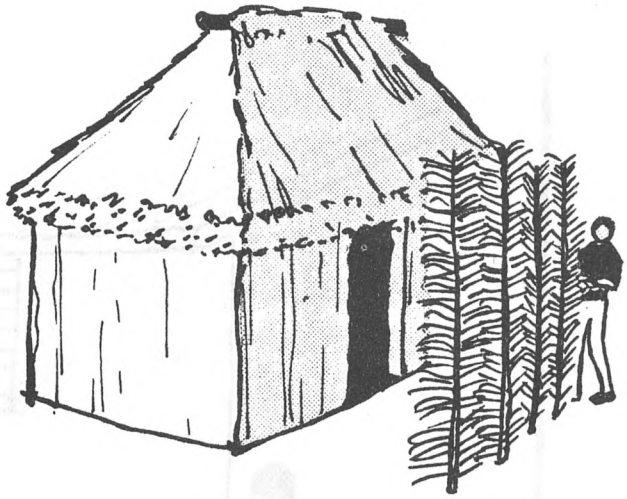


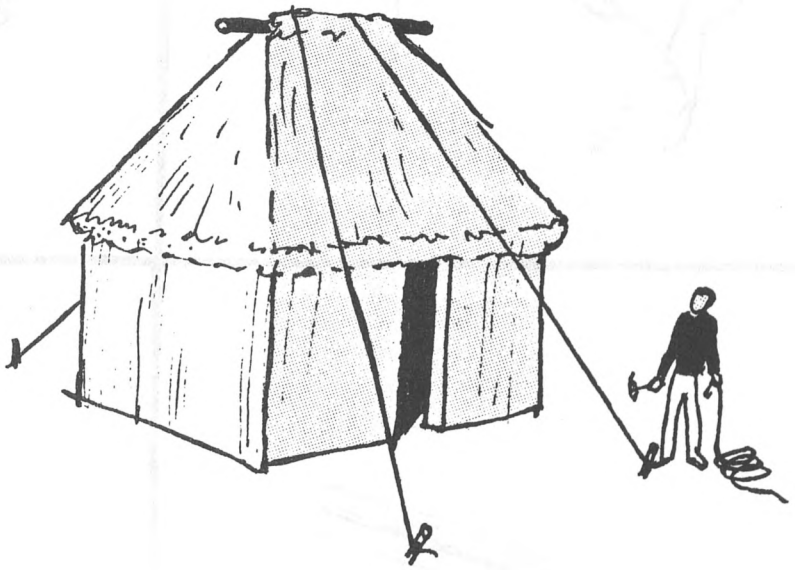


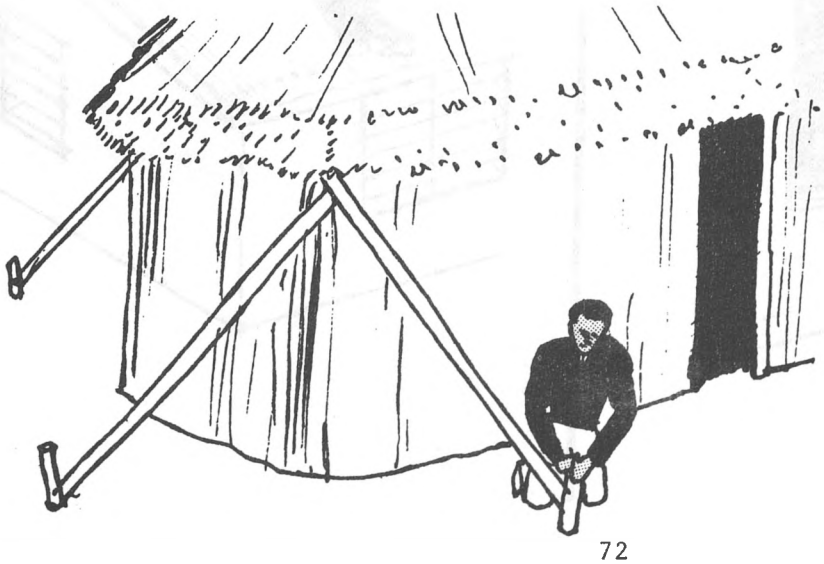










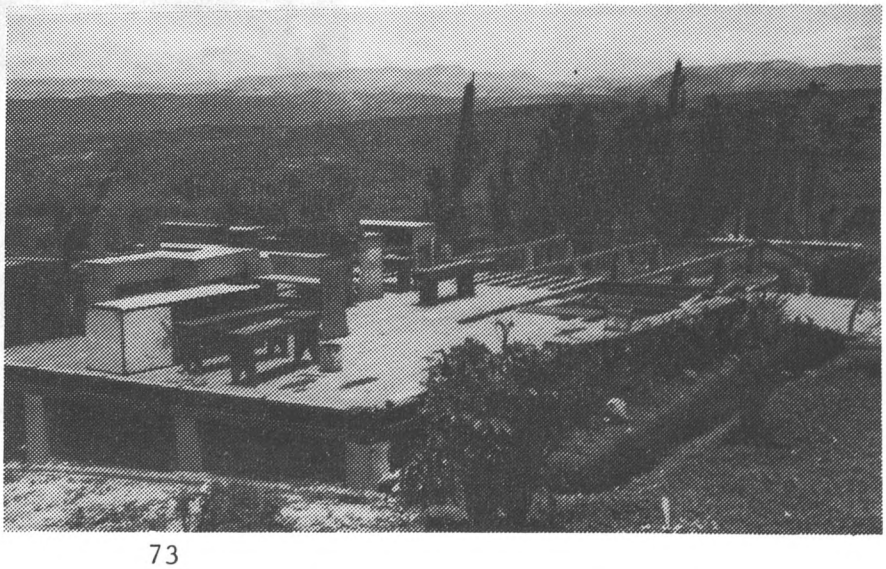


APPENDIX III:

COMMON PROBLEMS EXPERIENCED BY FIJIAN HOUSES

IN PAST HURRICANES

Poor Connections Between Walls and Floor



Inadequate Nailing of
Corrugated Iron to Purlins

Corrugated Iron
Too Thin

Inadequate Fastenings of
Roof to Walls

Inadequate Bracing in Walls

Inadequate Tying of Reinforcement Bars