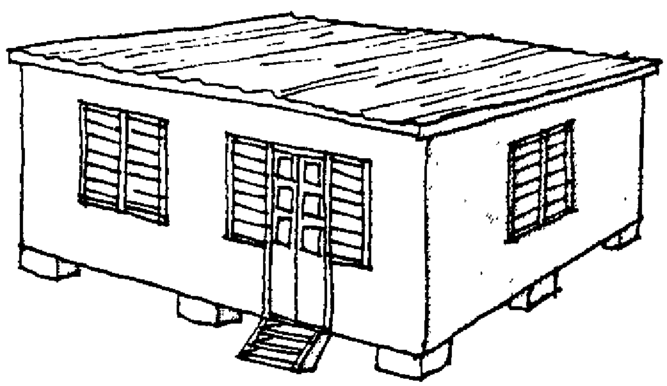
IV. VULNERABILITY ANALYSIS OF VERNACULAR CONSTRUCTION

The purpose of this chapter is to identify the most common types of non-engineered 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.

POPULAR HOUSING DESIGNS

The following drawings illustrate popular designs found in vernacular housing throughout the country. The materials used in the houses vary and are discussed in detail later in the chapter.

A. Basic Rectangular Configuration (Flat Roof)



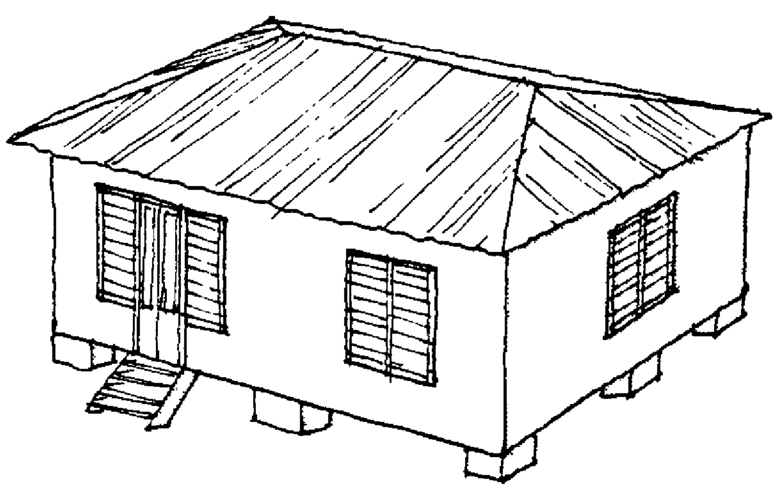
Wall Materials Often Used:

Wood frame
Nog
Spanish wall
Wattle-and-daub

Period: Contemporary

Comments: Likely to roll over in hurricanes unless securely fastened to ground

B. Basic Rectangular Configuration (Hipped Roof)



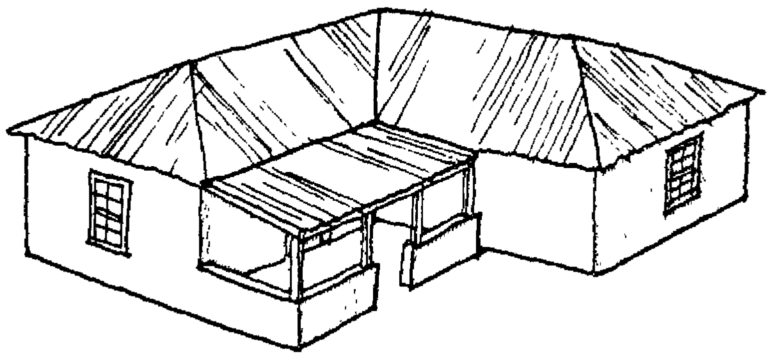
Wall Materials Often Used:

Wood frame
Nog
Spanish wall
Wattle-and-daub

Period: Crown Rule; Contemporary

Comments: Older nog and Spanish wall buildings vulnerable to both hurricanes and earthquakes

C. L-Shaped Configuration (Hipped Roof)



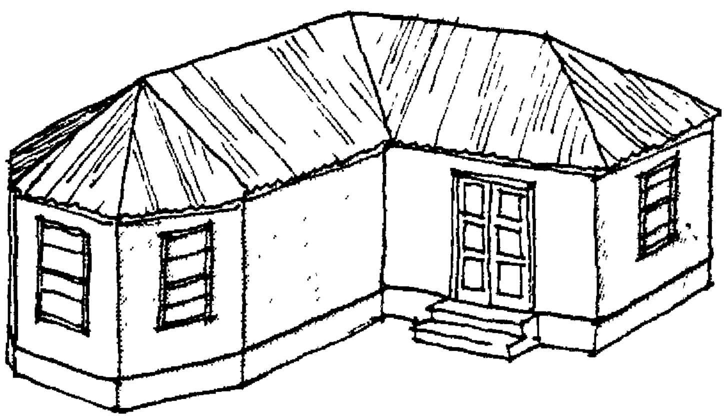
Wall Materials Often Used:

Wood frame
Nog

Period: Crown Rule

Comments: Nog buildings vulnerable to both hurricanes and earthquakes

D. L-Shaped Configuration (Bay Windows)



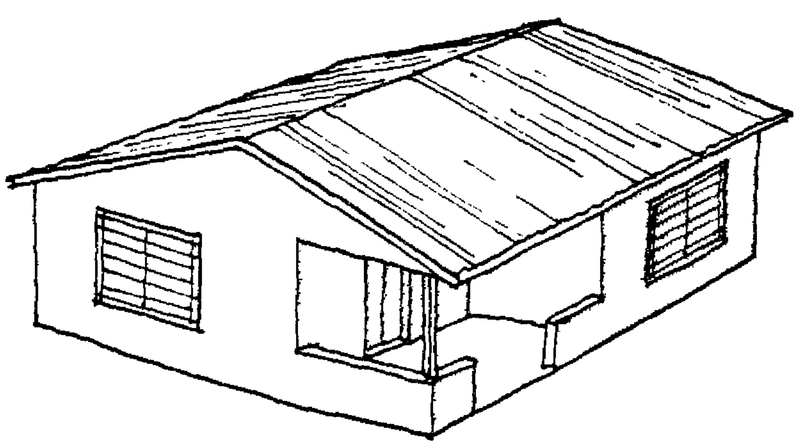
Wall Materials Often Used:

Block
Nog
Wood frame
Wattle-and-daub
Spanish wall

Period: Crown Rule; some in later periods

Comments: Highly vulnerable design

E. L-Shaped Configuration (Overhanging Porch)



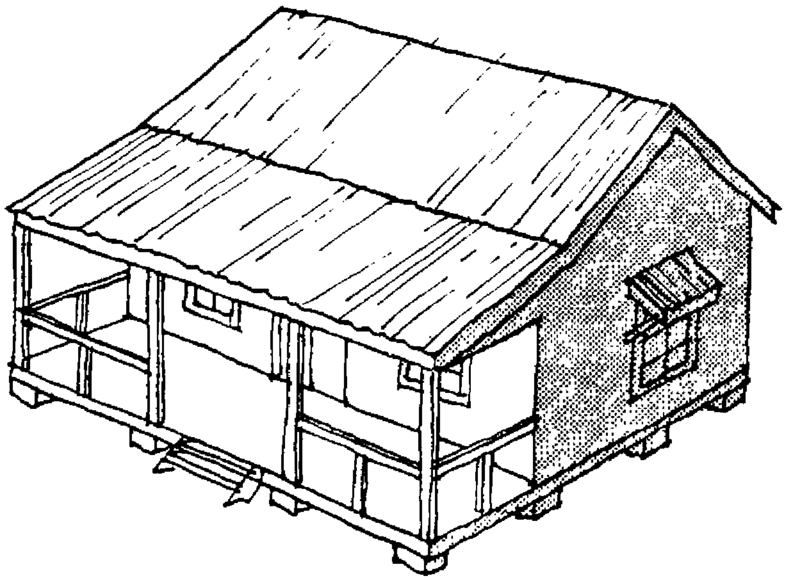
Wall Materials Often Used:

Block
Nog

Period: Contemporary

Comments: Vulnerable to wind damage; very vulnerable to earthquakes

F. Square Configuration (Veranda)



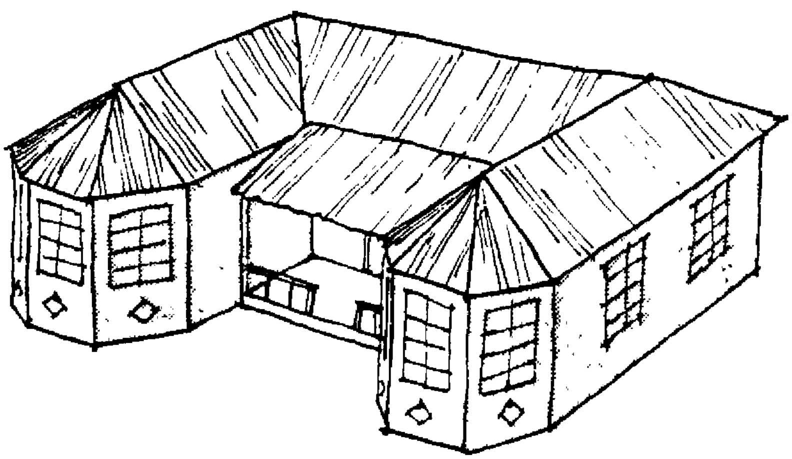
Wall Materials Often Used:

Wood frame

Period: Crown Rule; a few in later periods

Comments: If built with break-away veranda, design is fairly safe

G. U-Shaped Configuration (Bay Windows)



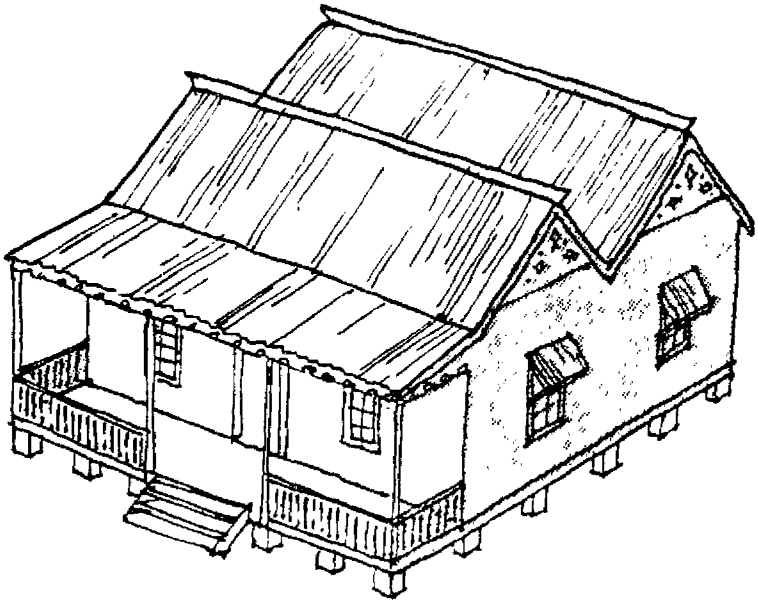
Wall Materials Often Used:

Nog
Block
Spanish wall
Wood frame

Period: Crown Rule; some in later periods

Comments: Highly vulnerable design

H. <u>Rectangular Configuration (Double Roof)</u>



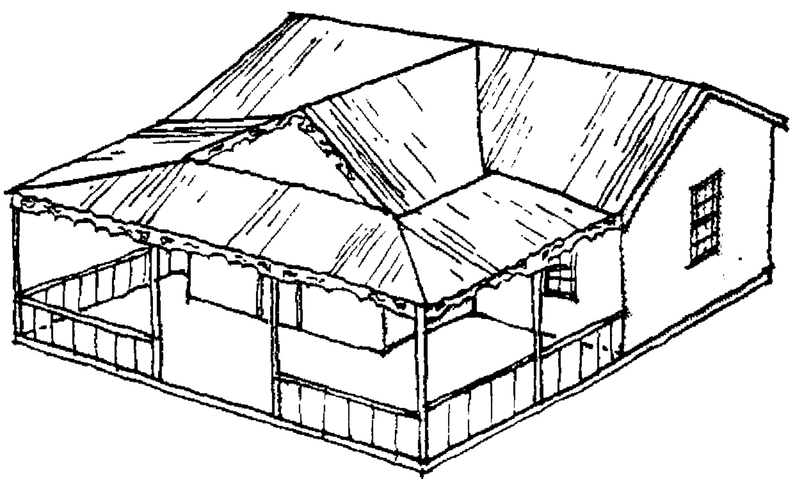
Wall Materials Often Used:

Wood frame
Nog
Mixed

Period: Georgian

Comments: Double (storm) roof excellent for wind resistance

I. <u>T-Shaped Configuration (Break-away Veranda)</u>



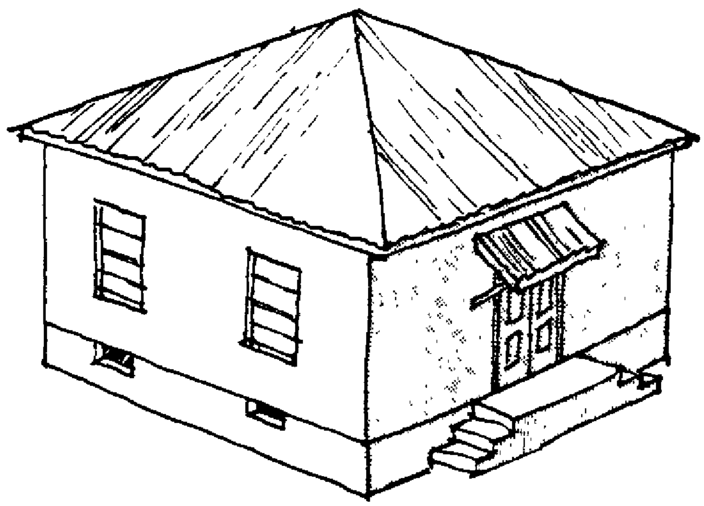
Wall Materials Often Used:

Wood frame
Nog

Period: Kingston

Comments: Verandas usually designed to break away without damage to roof

J. <u>Square Configuration (1 1/2-Story with Rock Foundation)</u>



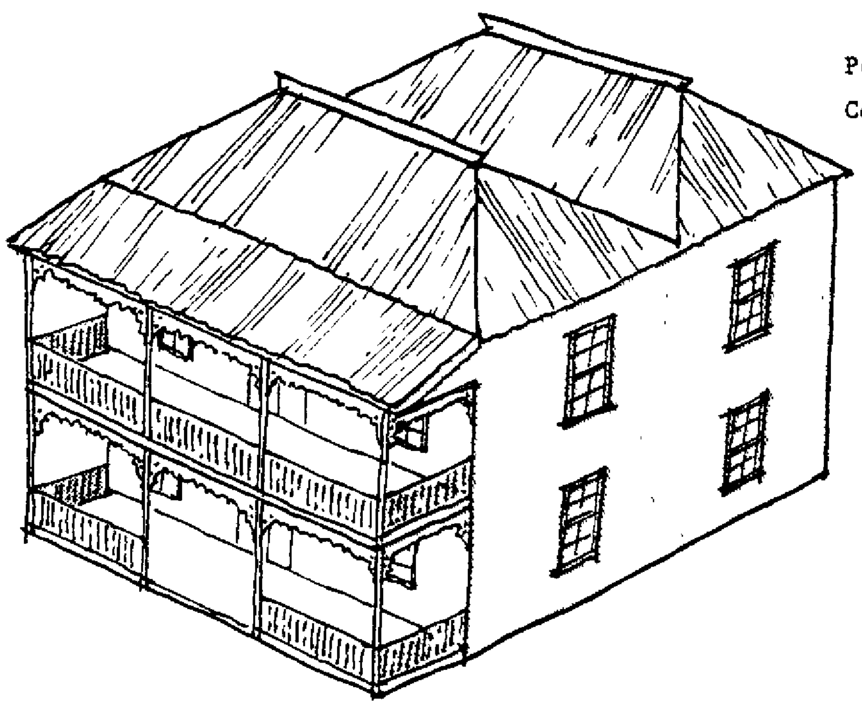
Wall Materials Often Used:

Lower part stone; Upper part wood frame

Period: Georgian

Comments: Fairly resistant to high winds; vulnerability to earthquakes dependent on construction of stone foundation

K. <u>Rectangular Configuration (2-Story, Urban Areas Only)</u>



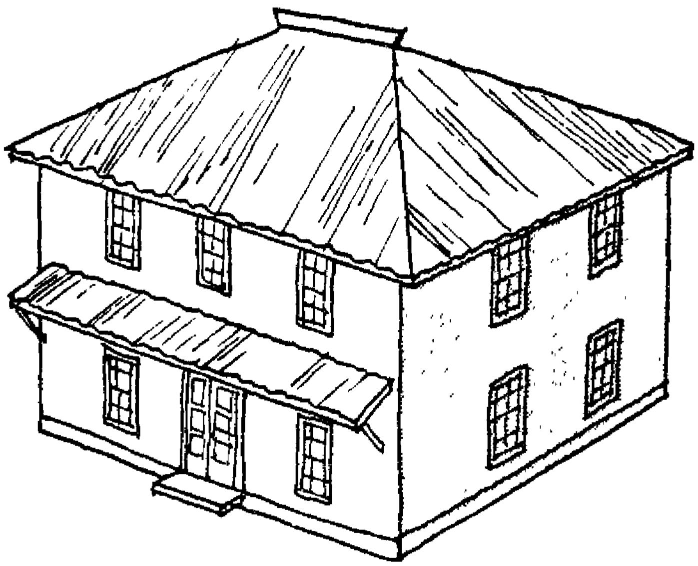
Wall Materials Often Used:

Wood frame

Period: Georgian

Comments: Moderately vulnerable to earthquakes due to age

L. Two-Story Hipped-Roof Townhouse



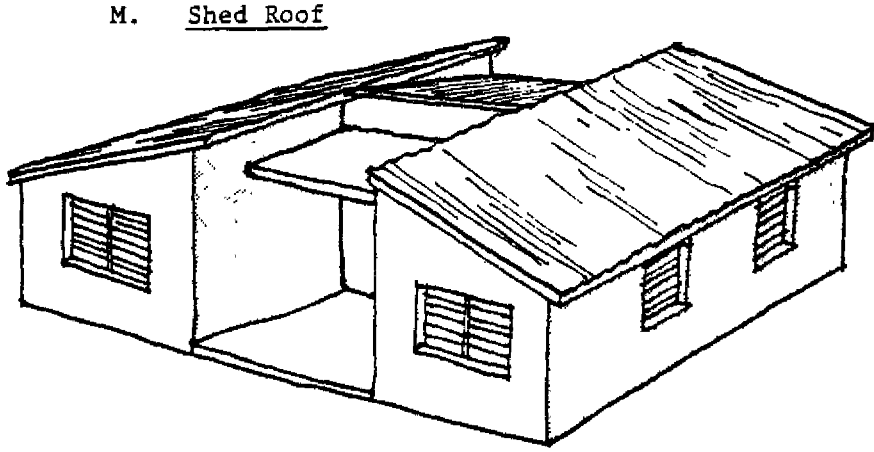
Wall Materials Often Used:

Wood frame

Period: Georgian; some built in later periods

Comments: Moderately vulnerable to high winds due to age

M. Shed Roof



Wall Materials Often Used:

Block and steel

Period: Contemporary

Comments: Highly vulnerable to earthquakes

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 rock, block or concrete panels are more susceptible to damage from earthquakes.

Vulnerability to hurricanes is a function of:

--- Configuration of the building

--- Configuration of the roof

--- 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 wood frame homes and those of older nog, wattle-and-daub, and Spanish wall construction where wood may have 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 configuration and structural integrity (such as continuity of bracing), 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, nog, and concrete panel buildings. Theoretically, these types of housing should be fairly easy to reinforce to a basic standard of earthquake resistance, and most block houses do use adequate iron reinforcement. However, the quality of masonry workmanship and detailing is very poor; thus some buildings may be particularly vulnerable.

Poor siting conditions account for perhaps the greatest number of houses vulnerable to disasters. There are many houses along the country's north and south coasts that are exposed to severe damage from hurricanes due to proximity to the ocean where wave action can damage the buildings. In addition, the widespread practice of using stilts for houses on hillsides exposes the houses to total collapse in both hurricanes and earthquakes.

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.

VULNERABILITY ANALYSIS OF THE BASIC CONSTRUCTION TYPES

The following is an analysis of the principal housing types found in Jamaica. 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.

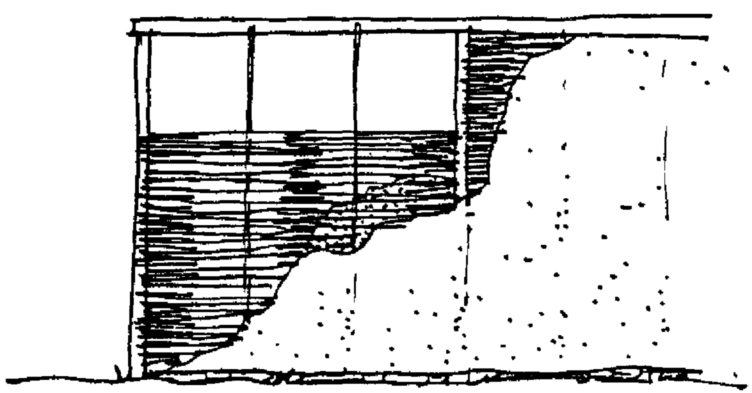
Most recommendations for making the structures more disaster resistant can be incorporated at little or no increase to the total cost of new construction, but some modifications to certain existing building types are both expensive and technically difficult. Thus, recommendations are divided into two 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, the 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. Any type of structure can be made safe if it is designed properly and fastened together securely.

A. Wattle-and-Daub Construction

Wattle-and-daub construction is one of the early forms of building and dates back to the earliest settlements, having been used by the Spanish and English colonists. Some historians believe that the method is reminiscent of African building methods, but the form and features of Jamaican wattle-and-daub clearly follow European lines and methods. Many older wattle-and-daub buildings are found along the North Coast, in the eastern mountains, and in the south between Malvern and Lionel Town. Many people still live in wattle-and-daub structures, but only a few are still being built, mainly in Manchester and Clarendon.

1. Construction: In wattle-and-daub construction, a wooden frame is erected and bamboo, sticks, or cane are woven between the vertical columns, then covered with mud to form the wall. Usually a plaster is applied to both sides of the walls. The plaster is a mixture of mud and lime, usually with an application of a cement-sand mix or lime wash over the outside.



2. Roof: Structures of this type normally have a zinc roof, although in past years a number had wood shingles.

3. Size: Houses built of wattle-and-daub are moderately sized, averaging about 15 x 35 feet.

4. Vulnerability: The older wattle-and-daub houses are very vulnerable to hurricanes because of deterioration of their wood frames. If damaged, the houses will be beyond repair and residents will be forced to rebuild an entirely new structure. The primary causes of structural failure are separation of the roof from the walls (caused by uplift on the roof's surface as well as uplift under the eaves of the roof) and collapse of the walls resulting from lack of reinforcement at the corners and lack of strength in the columns due to deterioration of the wood in the ground. Normally there are few explosions because the houses are not airtight.

5. Other Weak Points: The weak points of the house are the wood columns, the corners (which have inadequate diagonal reinforcement), and the connections between the roof and the walls.

6. Modifications for Wind Resistance: In order to improve the wind resistance of wattle-and-daub houses, the following actions are recommended:

   a. Emergency measures

      --- Increase the number of nails used to fasten the zinc to the roof frame.

      --- Place wood braces in the roof framing.

      --- The roof-wall connection should be strengthened by using metal straps or wire to help bind the roof to the wall, especially at the columns.

      --- Board up the windows in a hurricane.

      --- Place heavy objects such as bricks on the roof to break up suction created by the wind.

   b. Progressive upgrading measures

      --- Use wood treatment for all parts of the house that are placed on the ground. (Use of motor oil with an insecticide would be a low-cost method.)

      --- In existing houses, replace corner posts that are rotten.

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

      --- Cross-braces of galvanized wire should be placed between all the primary columns of the building.

   The hurricane resistance potential of wattle-and-daub, if properly built and reinforced, would be 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 its performance can be attained.

7. Modifications for Earthquake Resistance: In terms of vulnerability to earthquakes, wattle-and-daub structures 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 potential of wattle-and-daub houses can be increased substantially.

It should be pointed out that, even though extensive structural damage may result from either hurricanes or earthquakes, the potential for serious injury resulting from collapse of these buildings is relatively minor. The structures are lightweight and, because they are woven together, big chunks will not come flying off to cause major harm to the occupants.

B. Spanish Wall Construction

Spanish wall construction is one of the oldest types of building methods used in Jamaica. Introduced in the 1700's, the technique was employed for construction of secondary buildings, barns and other non-residential construction prior to its introduction into housing. Because it was cheap and easy to build, it gained popularity, and the majority of small residential rural buildings of the mid-1800's utilized this method. A small number of people still reside in these buildings, but no new construction has been seen in recent years.

1. Construction: Spanish wall houses are constructed by erecting a wooden frame with vertical columns three to four feet apart. Boards are then attached to the inside of the columns and small, flat rocks are cemented vertically to form a section of the wall. When the section is completed, the back boards are moved to another part of the frame and the process is repeated until the entire wall is completed. A diagonal brace is usually placed in each corner, and the upper part of the frame serves as a ring beam for the structure.

2. Roof: Spanish wall houses usually have zinc roofs, although a few still use wood shingles.

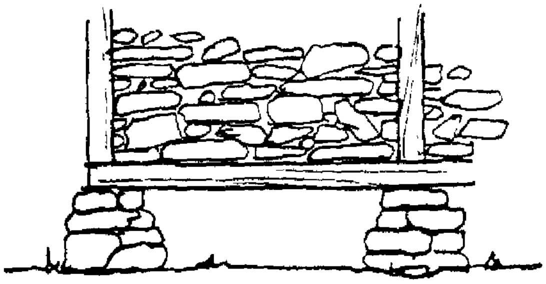
3. Size: Houses built in this manner are usually fairly small, between 10-15 feet wide and 15-20 feet long.

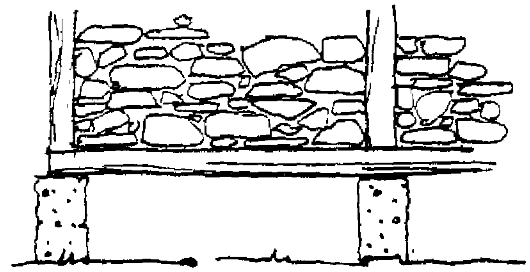
4. Vulnerability: The strength of Spanish wall houses depends on the strength of the frame and the connections between walls. Expected damage includes separation of the roof from the walls, failure of the gables, and separation of the walls. Wall failure is usually a result of deteriorated wooden columns.

5. Other Weak Points: Another weakness of Spanish wall construction is deterioration of the mortar. In high winds, weakened walls may collapse from the pressure of wind gusts.

   Other weak points in high winds include the connections between the roof trusses and the wooden ring beam atop the wall, and the gables at each end of the structure.

   Many Spanish wall buildings are placed on footings or stilts rather than on a solid foundation. These buildings will totally collapse in an earthquake.





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 fasten the zinc sheets to the roof trusses.

--- Tie the roof rafters to the ring beam with metal straps or wire, giving special attention to the corners.

--- Close off the eaves of the structure to reduce uplift under the overhang.

--- Seal the area beneath the walls with rocks and mud.

--- Board up windows in a hurricane.

b. Progressive upgrading measures

--- Add storm shutters to help close off windows during periods of high wind.

--- Treat wood posts before placing them into the wall or the ground.

--- Place all walls on a solid rock or poured concrete foundation.

--- Use diagonal bracing in the roof structure.

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

--- Replace stone gables with wooden gables. In a hurricane, the rock panels would tend to separate from the beams on which they rest and could fall into the house.

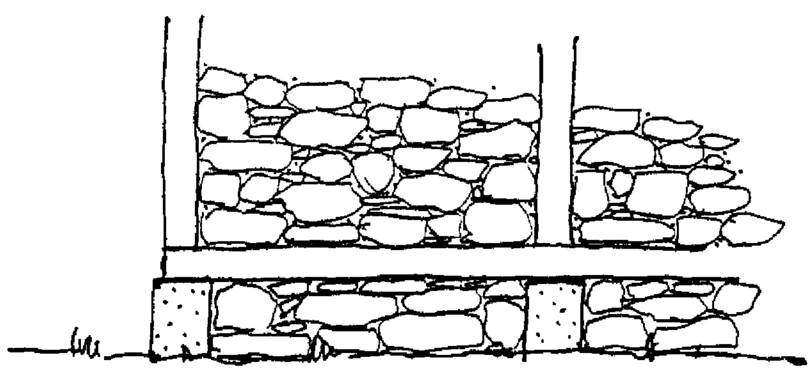
If the above recommendations are carried out, the wind resistance potential of Spanish wall structures will be substantially increased. If properly reinforced, this type of building can be made moderately wind resistant.

7. Modifications for Earthquake Resistance: Structures using Spanish walls can be excellent in terms of resistance to earthquakes because the frames can provide good bracing for the walls. The most important features to consider are the condition of the wood, the connections between the walls, and the strength of the foundation.

C. Stone Nog Construction

Stone nog houses date back to the 18th century and at one time were the most prevalent form of housing. Today many people still live in these buildings, but only a few new ones are built each year. They are found throughout the country in both urban and rural areas, both on the coast and in the western mountains.

1. Construction: Stone nog walls are built with a segmented wooden frame with vertical columns 3-4 feet apart. When the frame has been completed, a rock infill is cemented inside each section of the frame. As soon as one section has set, the process is repeated until the entire wall is completed. Corners are usually reinforced with a wooden diagonal brace. The walls normally rest on blocks or concrete footings, although some do sit on stone or poured concrete foundations.



The mortar of the older stone nog buildings was often made of mud, burnt marl, and fibers such as horse hair. More recently, lime and mud or cement and sand mortars have been used. The sand and cement mortars have weathered well, but the lime and mud show much deterioration.

2. Roof: Stone nog houses usually have zinc roofs, although older buildings may use wood shingles.

3. Size: Houses built in this manner are small to medium in size, between 10-20 feet wide and 30-40 feet long.

4. Vulnerability: Stone nog houses can be extensively damaged in hurricanes. Expected damage includes separation of the roof from the walls, failure of gables, and failure of the walls themselves. Failure of the walls is generally a result of deterioration of the mortar or the wooden frame. Studies of damage to this type of structure show that there is a high percentage of collapse due to buildings being blown off their footings.

5. Other Weak Points: Louvered windows are commonly used in stone nog houses. In high winds, louvers allow excessive amounts of wind through the windows, thereby increasing the pressure which pushes upward on the roof, lifting it off the walls.

   Other weak points of the structure include the connection between the roof trusses and the wooden ring beam atop the wall, gables at each end of the structure, and connections between the walls at the corners.

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 fasten the zinc sheets to the roof trusses.

      --- Fasten the roof rafters to the ring beam with metal straps or hurricane fasteners, giving special attention to the corners.

      --- Close off the eaves of the structure to reduce uplift under the overhang.

      --- Seal open spaces beneath walls with rock and mud.

      --- Board up windows in a hurricane.

   b. Measures for progressive upgrading or new construction

      --- Add storm shutters to help close off louvered windows during periods of high winds.

      --- Treat wood posts before placing them into the wall or the ground.

      --- Place each wall on a solid concrete and stone foundation and tie the wall to it with steel bars buried in the concrete and bent tightly onto the wood frame.

      --- Place diagonal braces in the roof frame of gabled roofs.

      --- Use diagonal bracing to reinforce each vertical column, not just the corners.

      --- Tie corners together by fastening a diagonal brace onto the top of the frame.

      --- Replace nog gables with wooden gables. In a hurricane, nog gables would tend to break away from the beams they rest upon and could fall into the house.

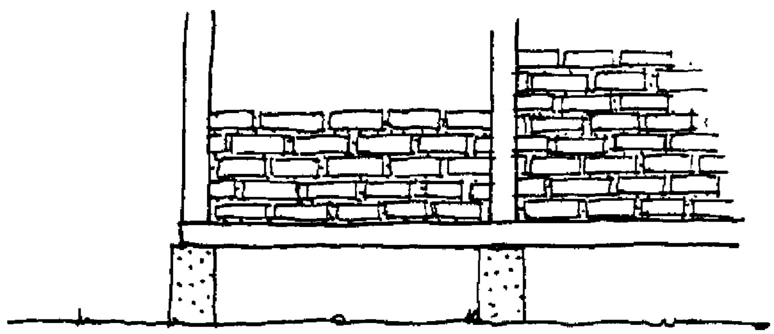
If the above recommendations are carried out, the wind resistance potential of stone nog structures will be substantially increased. If properly reinforced, this type of building can be made moderately wind resistant.

7. Modifications for Earthquake Resistance: Stone nog structures can be excellent structures for resistance to earthquakes if properly built and maintained. The most important features to consider are the connections between the walls, the condition of the wood supports, and the placement of the buildings on a solid concrete and stone foundation.

D. Brick Nog Construction

Brick nog was an outgrowth of stone nog and unreinforced brick construction. The latter had gained popularity, especially in the urban centers, at the turn of the century; but the 1907 Kingston earthquake and the high losses suffered by unreinforced brick buildings led to widespread adoption of nog techniques. As hardwoods became more difficult to obtain and cement blocks became more available, brick nog construction ceased, but large numbers of people in the older sections of Kingston and other cities still live in brick nog buildings. Many tenements are of nog.

1. Construction: Brick nog houses are constructed by building a wooden frame, placing the columns 3-4 feet apart. When the frame has been completed, standard fired bricks are cemented into the frame using a cement and sand mortar. Construction uses standard masonry techniques, the only difference being the wood structure used for reinforcement. Most walls are placed on foundations made of brick, stone or poured cement.



2. Roof: Brick nog houses usually have zinc roofs, although a few use wood shingles.

3. Size: Houses built in this manner vary greatly in size and many are two-story.

4. Vulnerability: Brick nog houses are fairly secure in hurricanes. Expected damage includes separation of the roof from the walls and failure of the walls themselves. The latter damage is usually a result of separation of the bricks from the wooden columns, but this is not too common. In earthquakes, building damage is generally a result of poor foundations and poor connections between walls and between walls and foundation.

5. Other Weak Points: Louvered windows are common features of brick nog houses. In high winds, louvers allow excessive amounts of wind through the windows, thereby increasing the upward pressure on the roof, causing roof loss.

   Another weak point is the connection between the roof and the wooden beams atop the wall.

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 fasten the zinc sheets to the roof trusses.

      --- Tie the roof rafters to the ring beam with metal straps or fasteners.

      --- Close off the eaves of the structure to reduce uplift under the overhang.

      --- Seal open spaces beneath walls with rock and mud.

      --- Board up windows in a hurricane.

   b. Progressive upgrading measures

      --- Add storm shutters to help close off louvered windows during periods of high winds.

      --- Treat wood posts before placing them in the walls or foundation.

      --- Place each wall on a solid concrete and stone foundation and tie the wall to it with steel bars buried in the concrete and bent tightly onto the wood frame.

      --- Use diagonal bracing in the roof structure.

      --- When gables are used, build them with wood. In a hurricane, the bricks can break away from the beam they rest upon and could fall into the house.

      --- Place diagonal braces at each corner to help hold the corners together.

   If the above recommendations are carried out, the wind resistance potential of brick nog structures will be increased. If properly reinforced, this type of building can be made wind resistant.

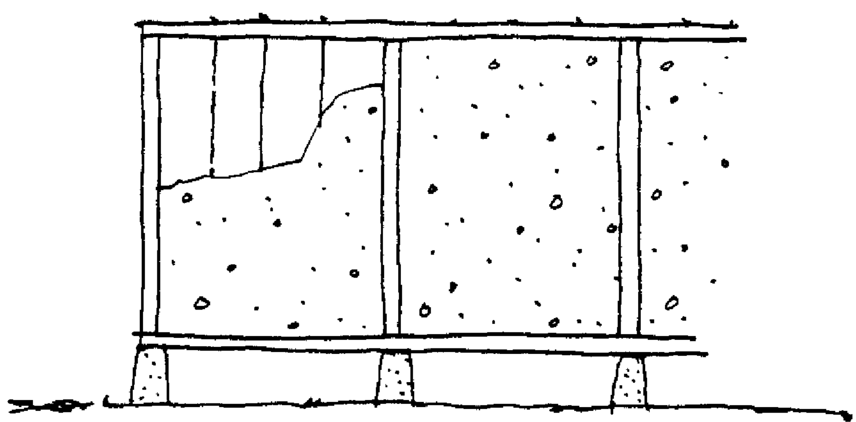
7. Modifications for Earthquake Resistance: Brick nog structures are excellent for resistance to earthquakes. The most important features to consider are the condition of the wood, the connections between the wooden columns, the condition of the brick infill, the placement of the walls on a solid foundation, and adequate strength in the center of the walls.

E. Concrete Nog Construction

1. Construction: Concrete nog walls are built by erecting a wooden frame, placing the columns 3-4 feet apart. When the frame has been completed, wide boards are attached to each side of the columns and concrete is poured between the boards. As soon as the concrete is set, the boards are moved to another part of the frame and the process is repeated until the entire wall is completed.

   The concrete panel is reinforced and held in place either by stapling barbed wire between the columns or by using iron reinforcing rods.

   The foundations for most concrete nog houses are made of concrete which is poured after the frame has been built.



2. Roof: Concrete nog houses usually have zinc roofs.

3. Size: Houses built in this manner are usually fairly small, between 10-15 feet wide and 15-20 feet long.

4. Vulnerability: Concrete nog houses can be extensively damaged in hurricanes. Expected damage includes separation of the roof from the walls, failure of gables, and failure of the walls themselves. Failure of the walls is usually a result of separation of the concrete panels from the wooden columns, due to insufficient strength of the bond between the panel and frame. Even those houses that have iron rebars suffer this type of damage unless there is adequate fastening of the concrete panel to the frame. Studies of damage to this type of structure show that there is a high percentage of explosive damage (caused by differential pressure pulling the house outward).

5. Other Weak Points: Most concrete nog houses have louvered windows. In high winds, louvers allow excessive amounts of wind through the windows, thereby increasing the pressure which creates explosive effect.

Other weak points of the structure include the connection between the roof frame or truss and the wooden ring beam atop the concrete wall, and the gables at each end of the structure.

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

a. Emergency measures

--- Improve the connections between rafters and ridge pole and at top sill plate.

--- Use more nails to secure the metal sheets to the roof trusses.

--- Tie the roof rafters to the ring beam with metal straps or wire, giving special attention to the corners.

--- Close off the eaves of the structure to reduce uplift under the overhang.

--- Place diagonal braces atop the frame at each corner to tie the corners together.

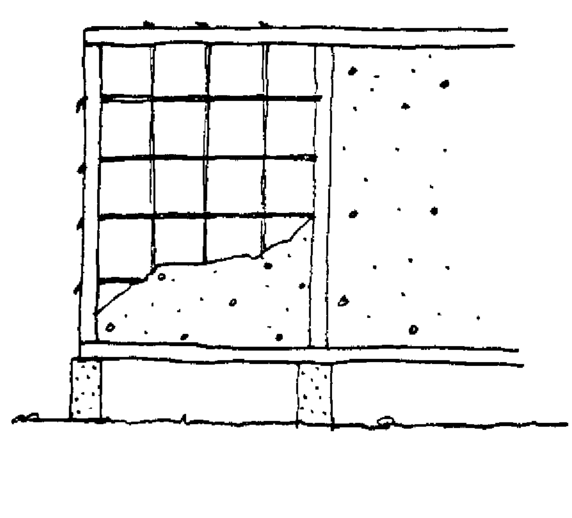
--- Board up windows in a hurricane.

b. Measures for progressive upgrading or new construction

--- Use a hipped roof configuration.

--- Add storm shutters to help close off louvered windows during periods of high winds.

--- Use iron rebars for reinforcing the concrete panels.



--- Treat wood posts before using them in the frame or placing them in/on the ground.

--- Place each wall on a solid concrete and stone foundation and tie the wall to it with steel bars buried in the concrete and bent tightly onto the wood frame.

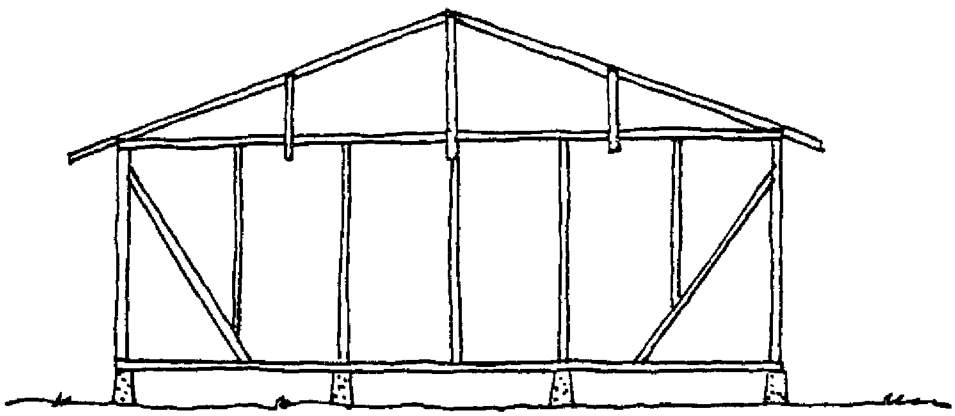
--- Use diagonal bracing in the roof structure of gabled roofs.

--- Replace nog gables with wooden gables. In a hurricane, the concrete would tend to break away from the beams it rests upon and could fall into the house.

If the above recommendations are carried out, the wind resistance potential of concrete nog structures will be substantially increased. If properly reinforced, this type of structure can be made <u>moderately</u> wind resistant.

7. <u>Modifications for Earthquake Resistance</u>: Concrete nog structures can be excellent for resistance to earthquakes. The most important considerations are the condition of the wood, the strength of the foundation, and the connections between the wooden columns and the concrete panels.

F. Wood Frame Construction



1. Construction: The wood frame house is one of the most popular building types in Jamaica and is especially popular with low-income families in rural areas where land tenure cannot be secured. The house offers the advantages of ease in building additions and suitability to the climate. If maintained properly, it will last for many years. Because it is lightweight, it 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 (most of which is now imported from Belize). 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 zinc.

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 those houses which have louvered windows, damage may be caused by differential pressure pushing out on the walls until portions of the walls separate at the corners.

   Many wood frame houses rest on concrete blocks or feet and are anchored to the ground only by the corner posts of the frame, if at all. This is insufficient anchorage