Minimum Building Standards and Environmental Guidelines for Housing

Safer Housing and Retrofit Program

St. Lucia National Research and Development Foundation

This document was originally prepared in May 1997
and substantially updated in May 2003

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Minimum Building Standards

Introduction

Providing comfortable and safe shelter for the family is perhaps the single most important aspiration of heads of household anywhere in the world. In St. Lucia, a safe home must be able to stand up to tropical storm winds, rains and hurricanes, which all too often visit the region. When a house suffers damage, family members' lives are disrupted, belongings are lost, and sacrifices need to be made to reconstruct and replace what was lost.

Low and modest income families are particularly vulnerable to the effects of natural hazards. The bulk of these families' financial worth is tied up in their house belongings. Their houses are likely to be constructed without due regard to building standards and quality of materials; they may be located in hazardous areas and are unlikely to be insured.

Each year tens of thousands of people die and billions of dollars of property damages result from disasters related to natural hazards. The risks from natural hazards change and increase as the Caribbean region grows and develops. Economic losses from these disasters will continue to increase and economic development will be retarded, unless serious attention is paid to mitigating the effects of these hazards.

Preface

This document has been compiled to provide guidelines to local builders and agencies in St. Lucia involved in safer housing/retrofitting work, so as to ensure that such work is carried out in the most effective manner. This document highlights the basic minimum standards for retrofitting and quality control tips for both new and existing wooden houses. Its purpose is to inform homeowners of the proper design and construction of safe housing and to serve as a reference for builders, artisans and inspectors. Inspectors play an important role, as frequent and informed inspections are necessary to ensure that structures are being built correctly and safely.

This document is not intended to be a detailed construction manual, but presents a summary of the recommendations of the writers' experience, observations and research over the years. It is intended to be used as a reference/guide for artisans, builders and homeowners in St. Lucia. Specific solutions are not offered, but the document details a number of options that the homeowner can use in building a home.

St. Lucia has developed a national Building Code and the accompanying Building Guidelines for Small Structures. The guidelines in this document are not intended to replace any National Code or Housing Manual in existence, but recommends, in some cases, techniques that may be stronger than the ones required in the code.

Acknowledgements

Under the USAID-sponsored Caribbean Disaster Mitigation Project (CDMP, 1993-99), the Organization of American States helped the St. Lucia national Research and Development Foundation (NRDF) with the establishment of a Hurricane Resistant Home Improvement Program. After seven years of operation, a thorough review was called for to update the procedures and revitalize the program. Principal funding for this review project was provided by the World Bank and the Government of the Netherlands, through the Bank-Netherlands Partnership Program. The World Bank established a cooperation agreement with the Organization of American States (OAS) for the implementation of this project. The Government of Brazil provided the OAS with seed funding as counterpart to the Word Bank funds.

Arnaud Guinard of the Latin America and the Caribbean Regional Group of the World Bank served as project manager for this activity and provided significant guidance throughout its implementation.

Assistance was also provided by Alcira Kreimer and Margaret Arnold of the World Bank's Disaster Management Facility. The support of Orsalia Kalantzopolous, Caroline Anstey and Tova Solo is also appreciated.

Jan Vermeiren of the Unit for Sustainable Development and the Environment of the OAS provided oversight through field visits to St. Lucia and review of the documentation. Steven Stichter served as the project manager for this activity and was responsible for the review and editing of the final documents.

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The *Environmental Siting* section of this document was prepared by Peter Norville. Peter Norville is a Registered Professional Engineer based in St. Lucia. He has over twenty years of experience in the areas of soil and water engineering, environmental engineering, agricultural engineering, environmental planning and management, rural development and project management. He has held several professional and managerial positions within the St. Lucia Public Service. He has also worked with the Organisation of Eastern Caribbean States. Mr. Norville currently operates as a Consultant Engineer, practicing in St. Lucia and in several other Eastern Caribbean States. Mr. Norville wishes to express his thanks to the following persons who provided assistance during the writing of this document: Mr. Bryan Walcott (NRDF), Ms. Joan Cools (NRDF), Mr. Roland Charles (NRDF), Mr. George Dujon (Sir Arthur Lewis Community College), Mr. Wenn Gabriel (Ministry of Health) and Mr. Joseph Medard (Ministry of Health).

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Hurricanes

Before one can seriously appreciate and be committed to the importance of safer housing construction or retrofitting, one needs first to understand hurricanes and how their destructive wind forces affect or destroy buildings and homes, especially those built of timber.

How are they formed?

The word Hurricane comes from the Spanish word 'hucan', which originates from the arrival of the Spaniards to the Caribbean. It comes from the Taino word 'Juracan' that means 'Evil Spirit', according to the Indians who lived in the Antilles at the time.

A hurricane can be described as a low-pressure area into which the hot and humid tropical air enters and tends to rise. This process acts as the motive force of the storm. The rotation of the earth causes the wind to turn in a counter clockwise, spiral path. A hurricane has several distinctive structural features, shown in Figure 1.

Eye: In the Northern Hemisphere, hurricane winds spiral counter clockwise around an eye, which is a low pressure area in which wind speeds are only 10 to 20 m.p.h. The area in the eye is characterized by a marked reduction in wind speed, a ceasing of heavy rain, and a partial clearing of the sky. In the most spectacular cases, the wind speed drops to nearly calm over an appreciable area, and all clouds disappear. The eye is usually circular in shape, the size of which can vary 10 – 100 miles in diameter.

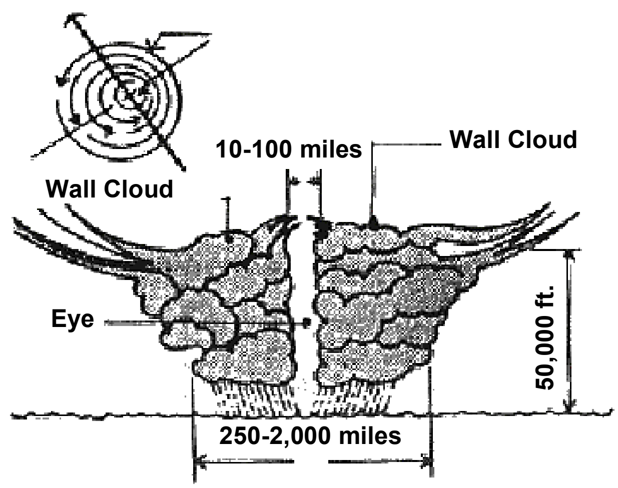


Figure 1 Structure of a Hurricane

Wall Cloud: Surrounding the eye of the hurricane is the so-called wall cloud. In the best-developed cases, this cloud structure completely encircles the eye and extends from the earth's surface to above 50,000 feet. The strongest wind speeds are usually found in the wall cloud, normally in the upper right quadrant, because the forward movement of the storm is added to the wind speeds in the storm. It is in this area that the pressure gradient is strongest and the rainfall is heaviest.

Storms are classified by the U.S. National Hurricane Centre using the Saffir/Simpson Scale, which is based on wind velocity and barometric pressure. The scale establishes five categories, of which Category 1 is a minimal hurricane and Category 5 the worst case. See the table below.

Category	Wind speed (m.p.h.)	Storm surge height	Barometric pressure (in.)
1	74 - 95	4 - 5 ft. above normal	greater than 28.94"
2	96 - 110	6 - 8 ft above normal	28.50 - 28.91"
3	111 - 130	9 - 12 ft above normal	27.91 - 28.47"
4	131 - 155	13 - 18 ft above normal	27.17 - 27.88"
5	Greater than 155	greater than 18ft	less than 27.17"

How do they affect/destroy buildings?

As the eye of a hurricane approaches a site, the winds increase gradually to a peak before the eye passes over the site. On the backside of the eye, winds increase again to another, lower peak. The winds on the backside blow in an opposite direction to those on the forward side as a result of the circular wind pattern in the hurricane. Since buildings may be subject to winds from several different directions as the storm approaches and passes, buildings must be designed to resist wind from all directions.

Wind damage is caused by the wrenching and bending forces imposed by gusting winds and the rapid increase in wind force as the wind speed increases. Wind force increases with the square of the wind speed, which means that when the wind speed doubles, the force of the wind on the structure increases four times.

Wind striking a building produces pressure, which pushes against the building on the windward side, and suction, which pulls the leeward side of the building and the roof (Figure 2). If no air leaves the building, then the pressure inside pushes against the walls and the roof.

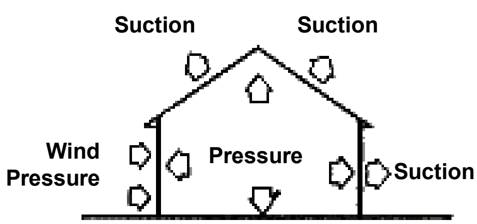


Figure 2

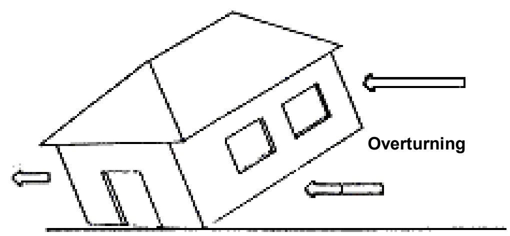


Figure 3

Failure may occur when the external pressure and suction on the wall combine to push and pull the building off its foundation. Overturning can occur particularly if the structure is lightweight and its weight is insufficient to resist the tendency of the building to be blown over (Figure 3).

Wind penetrating an opening on the windward side of a building during a hurricane will increase the pressure on the internal surfaces. This pressure, in combination with the external suction, may be sufficient to cause the roof to be blown off and the walls to explode (Figure 4).

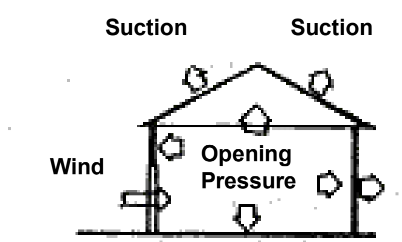


Figure 4

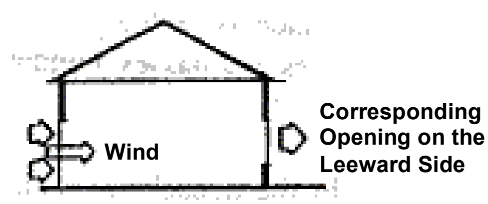


Figure 5

During a hurricane an opening may suddenly occur on the windward side of the building. The internal pressure that builds up as a result may be relieved by providing a corresponding opening on the leeward side (Figure 5).

Another mode of failure occurs when then windward side of the house collapses under the pressure of the wind (Figure 6).

If the building is not securely tied to its foundation and the walls cannot resist the push/pull forces they are subjected to, the structure tends to collapse, starting at the roof, with the building leaning in the direction of the wind (Figure 7).

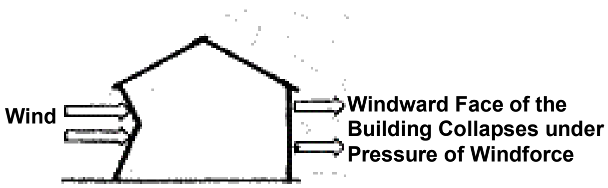


Figure 6

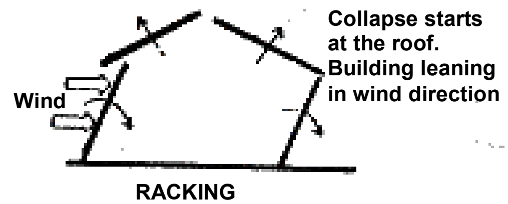


Figure 7

All modes of failure can be avoided or mitigated by providing adequate bracing, clamping and anchoring of framing components in timber construction, and by the use of good quality concrete and concrete elements with adequate steel reinforcement, particularly in foundations.

Basic Minimum Standards and Quality Control Tips for Builders, Artisans and Homeowners

The following areas will be given attention in this document since they are the areas that cause the most concern during a storm or hurricane. They are:

- Building Shape
- Foundations
- Framing (external walls and cladding)
- Roofs
- Floors
- Porches
- Shutters, Doors and Windows
- Connections between all components
- Location

Building Shape

It is reasonable to say that low-income house owners typically pay much more attention to size than design when building their homes. The shape of the house, however, is an important factor to be considered when thinking of resistance to high winds. The shape should be as simple as possible, preferably rectangular or square. Avoid 'T' or 'L' shaped houses; because they channel the wind into the junction between the two wings, they are especially vulnerable to high winds. The increase in wind pressure in the junction may lead to failure of the structure. When building rectangular houses, the length to width ratio should be 3:1 or less.

Figure 8 shows four building configurations, in order of increasing vulnerability to wind forces. The L-shaped houses are particularly vulnerable to hurricane-force winds at the interior corner where the winds develop higher forces.

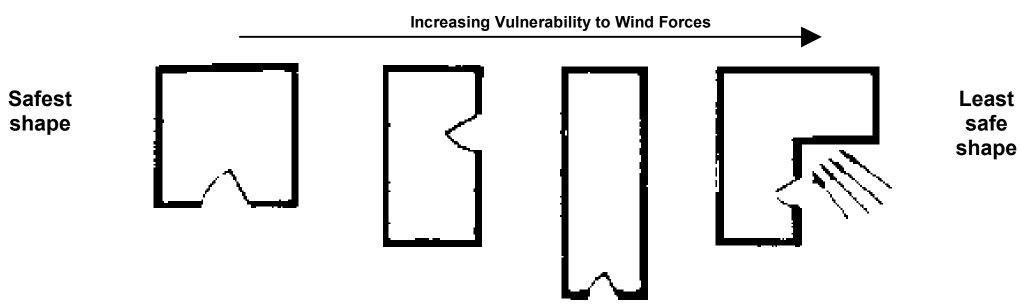


Figure 8

Recommendations—Building Shape

- Ensure that the house is rectangular or square in shape. Avoid irregular shaped houses (i.e. L- or T-shaped). If the need for extensions or additions to an existing house requires such shapes, it is safer to separate the two units by a corridor or walkway, which is itself a separate, self-supporting structure.

Foundations

The foundation anchors the house and transfers the weight of the structure to the ground. The practice of simply laying a structure on large stones, loose concrete blocks or wooden pillars is not recommended.

A safer practice is the use of concrete columns or concrete block walls, reinforced with ½" mild steel bars. The use of mild steel is encouraged since it is easier to bend than is high tensile steel. These bars must be continuous and project beyond the foundation by at least 12" to 14" (300mm to 350mm) to facilitate the securing of the structure to the foundation (Figure 9).

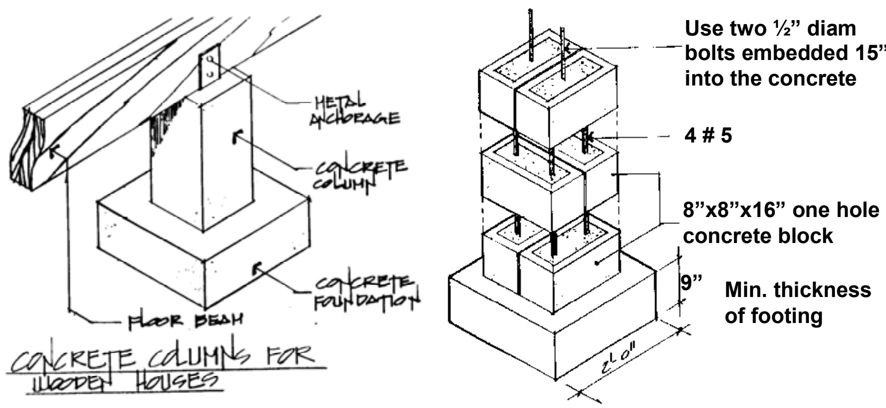


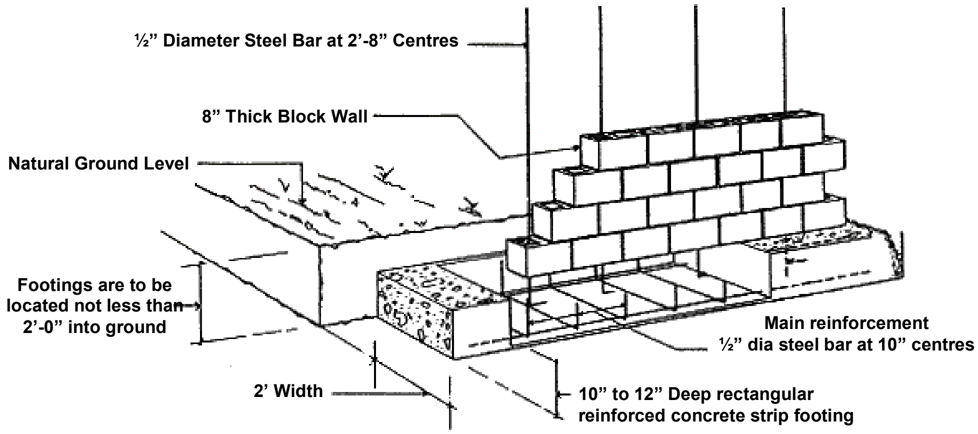
Figure 9 Concrete Columns for Wooden Houses

The footing of the foundation should be on firm soil, 2'-0" (600mm) wide by 10"-12" deep (200mm – 300mm) with 6" or 8" concrete blocks (Figure 10). When concrete columns are used, column that are up to 3 ft above ground should be a minimum of 9"x9". The length of column below ground should be roughly equivalent to the length of column above ground. With every increase of 1 ft in the height of the columns, the width should be increased by 1 inch in each dimension.

Height (up to)	Minimum Column Width
3 ft	9" x 9"
4 ft	10" x 10"
5 ft	11" x 11" (etc)

When wood posts are used instead of a concrete block or column foundation, the posts should be treated with preservative and then buried in concrete four to eight feet (4'-0" to 8'-0") into the ground. The posts should have a minimum dimension of six by six inches (6" x 6") (Figure 11). The minimum diameter for round posts should be eight inches (8"). The hole in which the post is placed should be larger than the post itself to accommodate the backfill. Existing houses that do not meet the above recommendation should be improved by building proper pillars and securing the structure to them.

Existing houses with wooden pillars can be strengthened by excavating around the pillar, casting them in the ground with quality strength concrete (Figure 12) and bracing the pillars to provide lateral support to resist wind action (Figure 13). It is important that very strong pillars be used. Green heart, Capeche, Glory Cedar, Coconut trunks or Balata are a few examples of appropriate choices for pillars. For all types of pillars, the depth of pillar below ground should be similar to its height above ground to the underside of the floor.



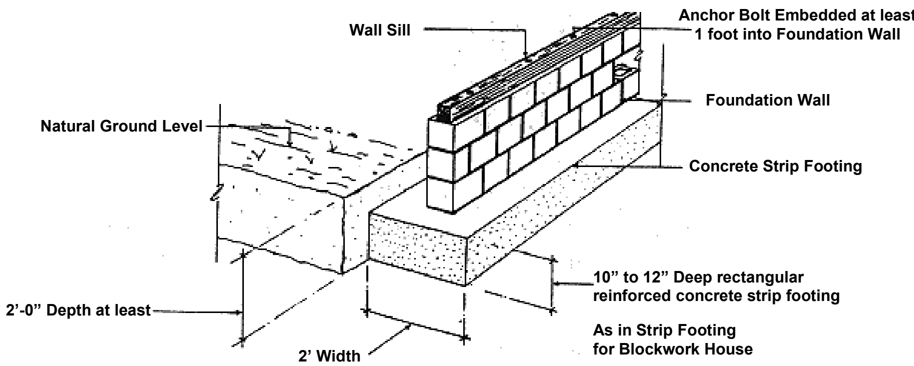
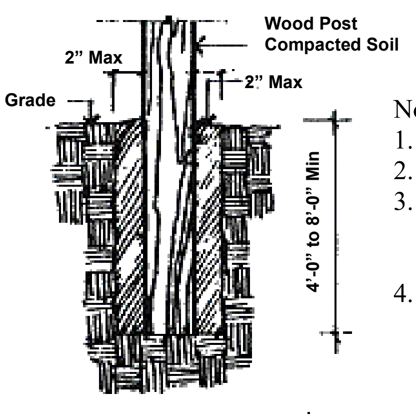


Figure 10 Strip Footing for Wooden Houses



Notes:

1. Minimum size of posts: 6"x6" or 8" diameter when round.
2. Backfill: well-compacted materials that will provide drainage.
3. Soil cement is made by mixing 5 parts each of crushed rock and sand and 1 part of cement plus water. All particles larger than one inch and all organic matter should be removed from the earth.
4. Steel bars in the concrete pier should be covered with at least 3" of concrete.

Figure 11

Many existing houses on reinforced concrete block pillars do not have any projecting steel bars left to secure the structure to the foundation. To correct this serious problem, a metal strap can be fastened to the pillars, which is then nailed to the bottom plate of the structure, to offer some resistance (Figure 14).

Foundations of buildings located in areas potentially subjected to erosion, including flood plains and along coastal areas, must be designed to withstand dynamic water force and battering action from floating debris, and the effects of erosion due to scouring.

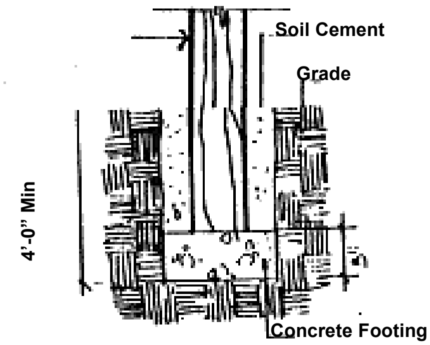
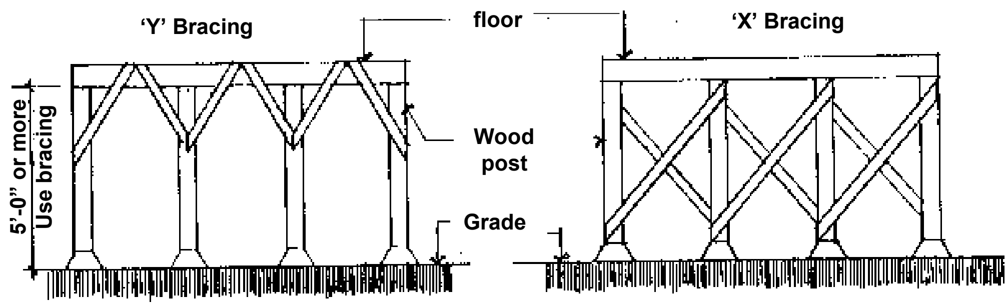
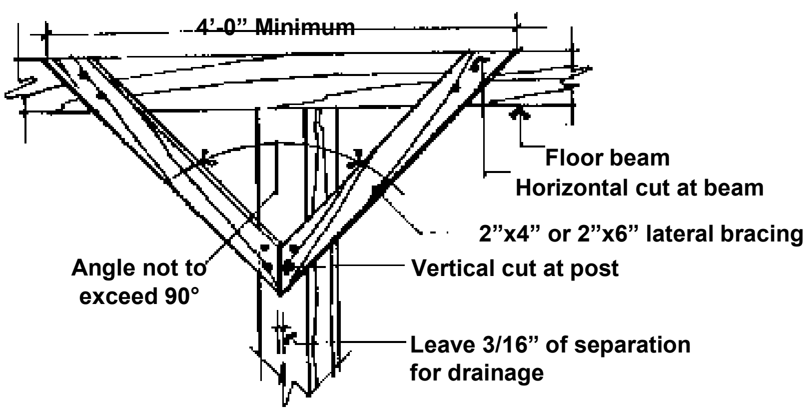


Figure 12





Notes:

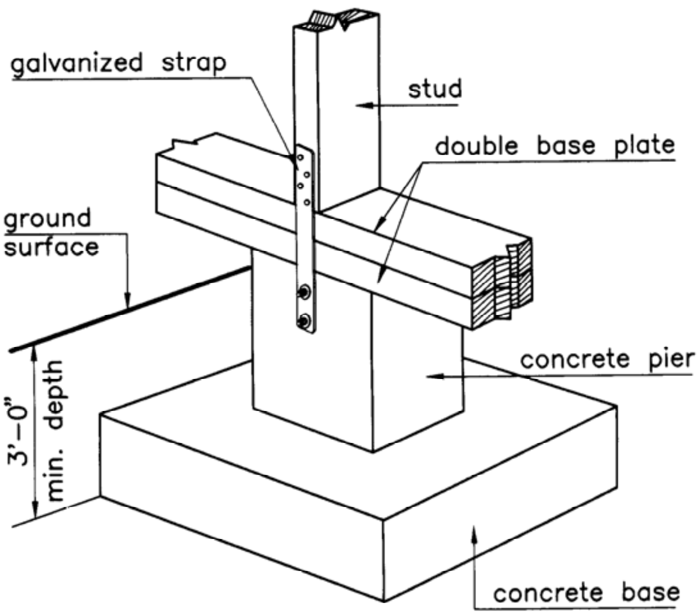
Use bolts or lag screws. Do not use nails.

During design, multi-hazards should be considered. Buildings on stilts, necessary construction in some flood-prone areas, are unstable during earthquakes and large open spaces under buildings encourage hurricane uplift. Consequently, height above ground should be limited.

Figure 13 Lateral Bracing for Wood Posts

Recommendations—Foundations

- Design and construct foundations using quality materials.
- Ensure that steel bars extend beyond the foundation walls to aid proper securing of the wooden structure to the foundation.
- If timber posts are used to support the building, make certain that they are adequately secured into the ground using concrete. To aid stability and to avoid isolated movement of the posts, diagonal braces can be used for reinforcement.
- Foundations of buildings located in flood plains must be designed to withstand dynamic water force, battering action from floating debris, and effects of erosion due to scouring.



Note:

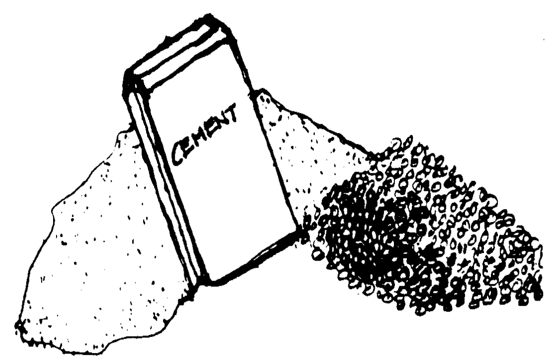
3"–4" nails should be put into double base plates at 12–18" centres to resist horizontal shear (stress along and between the plates). This nail lamination (whether with or without glue) will help resist possible separation of the plates.

In nail laminating, the nails must go completely through the thickness of the timbers and be staggered along the length of the plate.

Figure 14 Stud to foundation connection: Foundation anchorage

Concrete

Concrete is a mixture of cement, sand, gravel and water in correct proportions. A 1:2:4 mix, for example, consists of 1 part cement, 2 parts sand or fine aggregates and 4 parts crushed stones or course aggregates. Special attention must be given to the water/cement ratio, because if too much water is used when mixing, the potential strength will be reduced.



Concrete is inherently strong in compression but weak in tension. To handle tensile forces, it can encase and bond with steel reinforcement. It has different compressive strengths based on mix designs. Typical mixes range in strength between 2000 and 3500 pounds per square inch.

For thorough curing of the concrete, forms should be kept damp and left on for at least one week. The curing process is important as it prevents rapid drying of the concrete, which results in shrinkage. Shrinkage appears as cracks on the surface of the cured concrete. The curing process also keeps the hydration process (the chemical reaction between cement and water) going, which enables the concrete to develop its full strength more quickly. It must be noted that full compressive strength will develop within 28 days after placement; as a result, suspended floor slabs should remain supported for the full 28-day period

Floors

Wooden floors consist of joists laid on beams supported by wooden or concrete pillars and covered with plywood or tongue and groove boards (Figure 17). Another approach is to place the beams on top of a low wall of hollow concrete blocks along the perimeter of the house; the joists are placed on these beams and the floor covering is laid on the joists. Beams are the members supported directly by the pillars and make up the bottom plate. Joists are the members that are spaced on top of (and at right angles to) the beams; the floor covering is secured to the joists. Ground floor slabs made of concrete are typically laid directly on top of the hardcore and foundation walls.

Wooden floors should be a minimum of 18" above the ground level. There should be ventilation under the house and enough space for maintenance work to be carried out.

Materials used as floor joists should be two by six inches (2" x 6") or greater while members used as beams should be four by ten inches (4" x 10") to six by twelve inches (6" x 12"), depending upon the distance to be spanned (see table below). Seasoning of larger timber such as these, is more difficult than seasoning of smaller pieces. This can be addressed by combining members to achieve desired sizes measuring two by ten inches (2" x 10") or two by twelve inches (2" x 12").

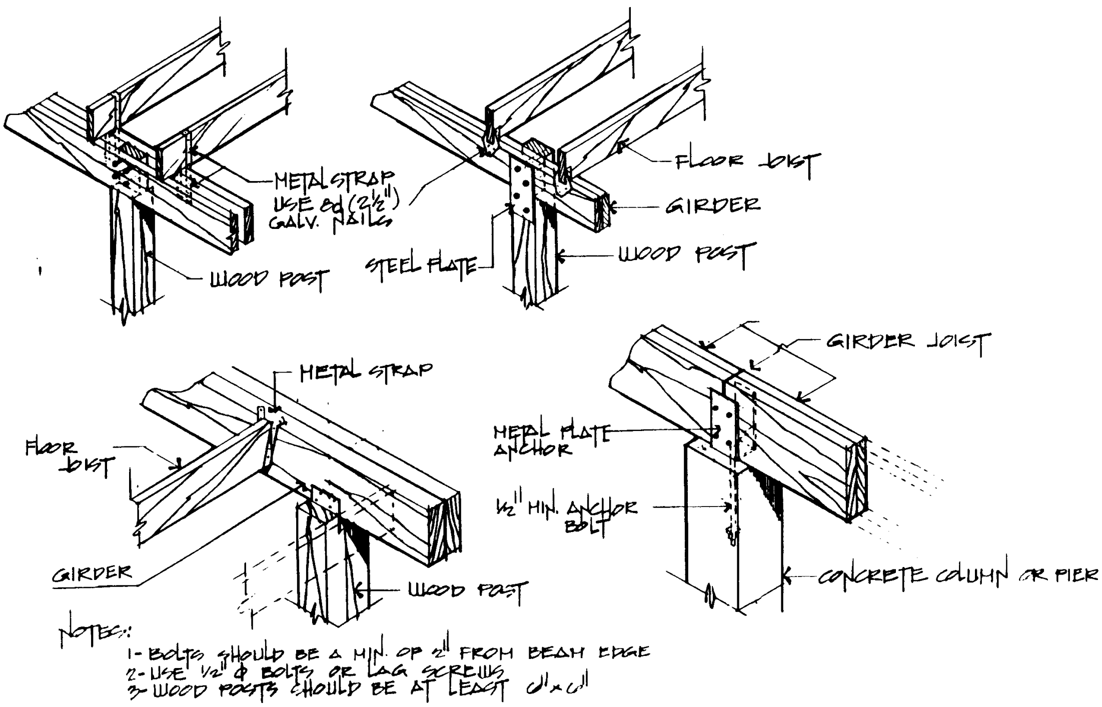
Inadequate sizing of floor joists results in excessive deflection (bending) of the members and floors, causing a springing or bouncing action when walked on. The common, but inadequate, practice of using four by four inch (4" x 4") beams and two by four inch (2" x 4") joists, spanning dimensions in excess of ten feet, often has this result. [Reference: *OECS Building Guidelines,* Section C, clauses 3.1(a), (b), (c)]

Recommended Minimum, Spans & Sizes for Pitch Pine Joists at 2 ft. centres

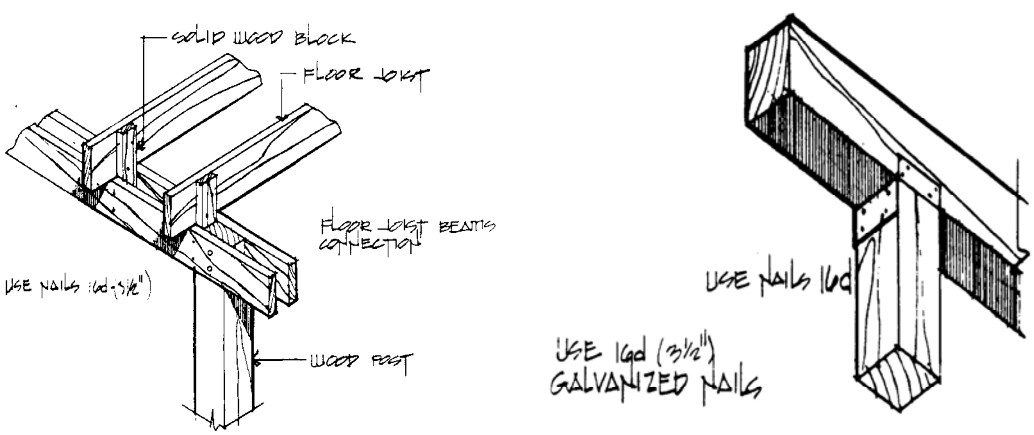
Span Range (feet)	Joist size (nominal inches)
6 – 8	2 x 6
8 – 10	2 x 8
10 – 12	2 x 8
12 – 15	3 x 8
15 – 20	3 x 12

Note: For more precise joist sizes and spans see St. Lucia Building Code, *Table C-1, Section 3.1.*

Wind or water forces could lift the wooden floor from the foundation if the connection between the two is not adequate. Figure 15 shows ideal details for the connection of floor framing members to ensure adequate resistance against separation during high winds.



Beam to Floor Joist Connection



Girder to Wood Post Connection

Figure 15 Connections

When flooring members must be spliced, ensure that splices conform to dimensions shown (Figure 16) and make certain that splices are constructed over a support. The length of the splice should be at least three times the depth of the joint on either side of the juncture.

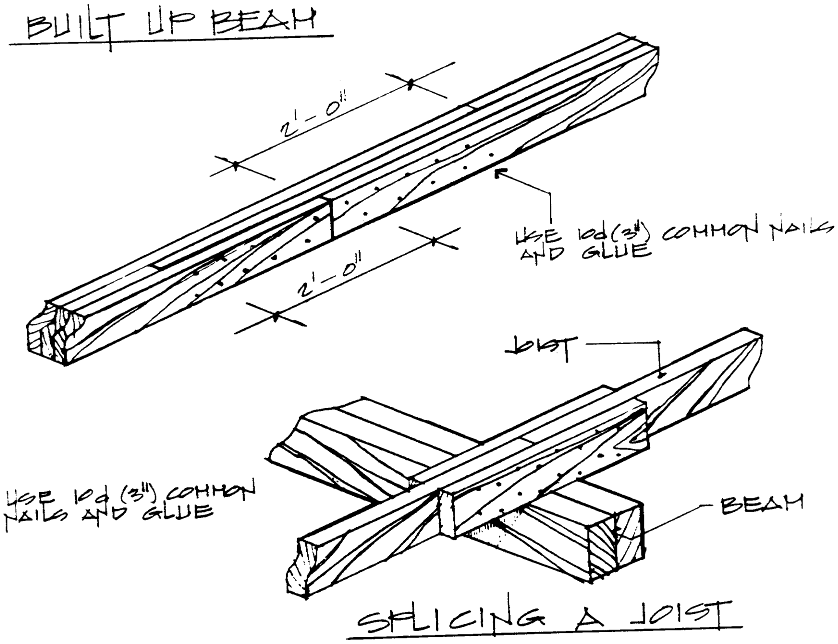


Figure 16 Splicing a joist

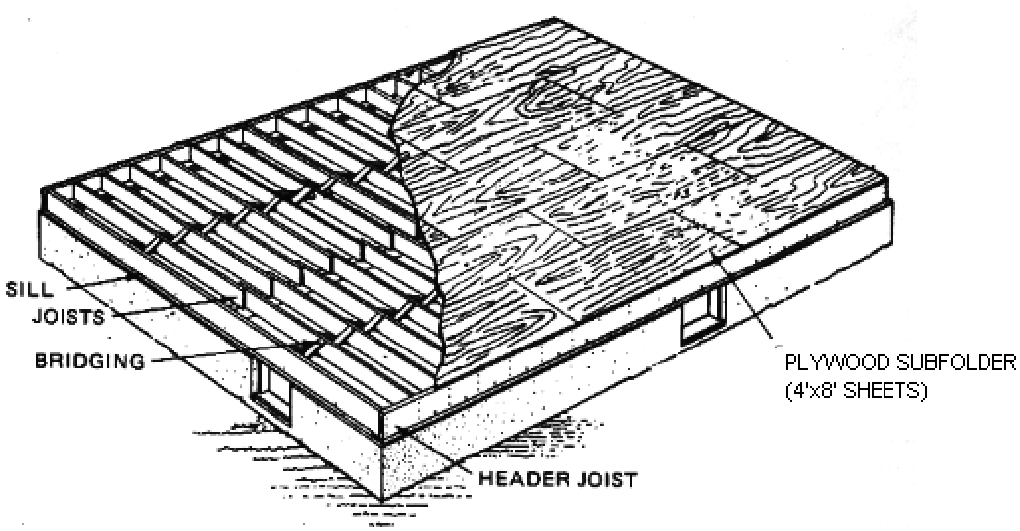
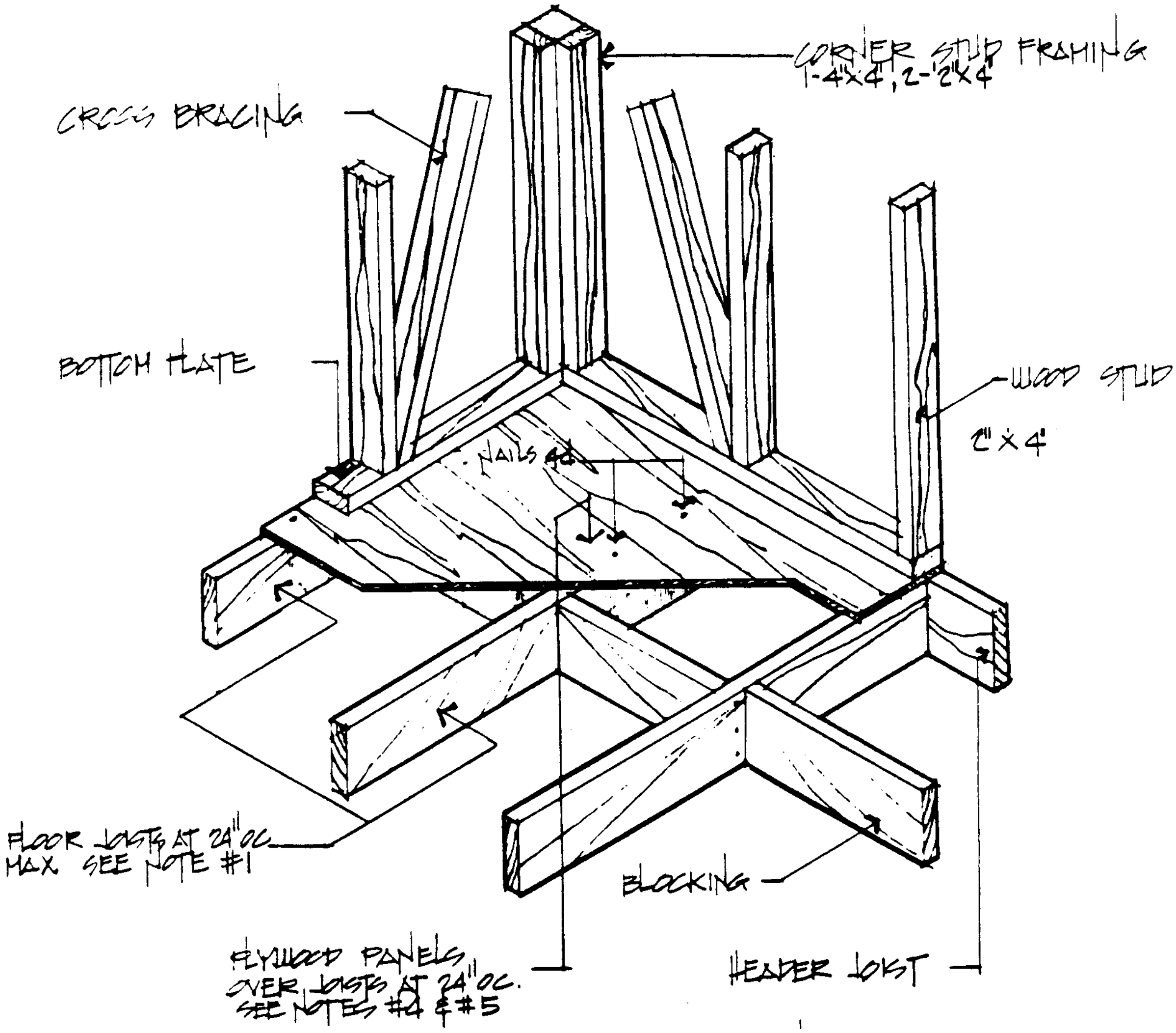


Figure 17 Sub-flooring installation

When spacing the joists for flooring, it is important that they are exactly on 12", 16" or 24" centres. Incorrectly spaced joists will not accommodate standard 4'-0" and 8'-0" sheets, which then must be cut to fit. With properly spaced joists, there is no need for cutting and, as a result, the job is completed much faster. When laying flooring, the initial flooring sheet should be placed such that the square or grooved edge of the sheet is flush with the outer edge of the beam and ends of the sheets rest on the joists.

The thickness of the plywood used for the floor covering depends on the spacing of the joists. The most common thickness is 5/8", which can be placed on joists spaced at 16" centres. The sheets must be laid with the surface grain of the plywood at right angles to the joist. They should be fastened down with 2” galvanized nails at 6” intervals along the edges of the sheet and 12” intervals along intermediate supports. The end joints of the sheets should be staggered so that no two joints are adjacent on the same joist.

When square-edged plywood is used as sub-flooring, 2” x 4” bridging must be nailed between the joists to support the edges of the sheets. If tongue and groove plywood sheets are used, this is not necessary as the edges of these sheets are self-supporting. Figure 17 shows proper installation procedures for installing plywood flooring. Figure 18 provides further details for correct installation of flooring components.



Notes:

1. Use 2”x 4” joist for a distance of 6’-0” between supports; 2”x 6” joist for a distance of 13’0” between supports; or 2”x12” joist for a distance of 15’-0” between supports.
2. Metal connectors or straps should be used.
3. Joist and stud spacing should be the same for structural efficiency and economy of material.
4. Floor panels should be nailed on all edges with 4d (1 ½”) nails at 6” intervals and at 12” on the center of the panels.
5. Use ring-shank or screw-shank nails.

Figure 18 Floor details