Building Design and Construction

The design and construction of buildings should be a carefully supervised and coordinated process involving as much professional input as is possible at all phases, not only because of the financial input involved but, more importantly, the risk of loss of human life when natural hazards threaten. In the context of light frame (timber) residential buildings, which this document addresses, it is even more imperative—though contrary to popular opinion—that all aspects of design and construction be given careful consideration. These structures are some of the most vulnerable when exposed to the intense lateral, twisting and bending forces produced by a storm or hurricane.

Square or rectangle buildings are the most desirable building shapes, as they do not interrupt wind flow or create zones that restrict free wind flow around the building. Such interruptions and wind flow restrictions cause wind pressure to build up, which could cause failure of structural components, such as walls and roofs. Building orientation should take into account solar radiation, temperature and wind flow considerations.[1]

The importance of creating a sound load path to be evenly transmitted into the ground cannot be over emphasized. In addition, and just as important, is to ensure that all building components (from roof to foundation) are securely fastened to each other using metal straps and clamps, and that the building's foundation is firmly anchored into the ground.

Trenches for foundations (regardless of the foundation system used) must be excavated to a point below ground firm enough to sustain and distribute the building loads. Foundations must be constructed of adequately sized elements and properly reinforced. In the event that timber members are used, they must be of adequate cross sectional dimension, properly preserved and firmly anchored into the ground. Provision must be made to have framing anchors for the foundation elements (including foundation walls, piers, columns) to firmly secure floor beams to the foundation.

All floor joists must be firmly secured to beams, and materials of adequate cross-sectional strength must be used. Twisted metal straps should be used for securing these elements to each other. Appropriate joist spacing relative to beam sizes and spans is specified previously in this manual and in the National Building Code. Materials used for floor boarding must be securely fastened to floor joist using nailing patterns prescribed in the *Minimum Standards* manual, as the underside of a large number of homes in St. Lucia are exposed to winds which can create uplift. This is particularly true for homes built on hillsides.

The connections between exterior wall framing and flooring system must be sound. Bottom plates must be secured to the header or floor joists using appropriate metal straps and all studs must be connected at joints with wall plate and double top plates using T-shaped metal straps. Rafters must be securely fastened to wall plates with approved hurricane straps and built with the appropriate seat cut to ensure good vertical load distribution into the external walls and rafters. Framing around all opening must be doubled as openings create weak planes in a structure, and all corners of the building must be diagonally braced in the approved manner. Materials used as lath to receive the roof covering must toenailed into the rafters and twisted straps should be provided to adequately secure them to the rafters. Roof covering materials can finally be nailed to the laths in the approved manner.

During the design stage of a structure, which will be required to withstand high winds, the focus must be on the correct connections and where they are to be made. The areas that must be given most attention are the foundation, cladding, roof and roof covering.

[1] See Victor Olgay (1963) *Design with Climate* and Mazria (1979).

During construction, builders must be knowledgeable and well informed as to the importance of making appropriate and solid connections between all parts of the structure and must ensure that the best level of construction and construction practices are maintained. The following building tips and recommendation will serve as a guide.

Recommendations—Design and Construction

- Have all parts of the building (including doors, roofs and cladding) designed to withstand high wind pressure, including suction.
- Obtain the necessary permits for building from the local Authority.
- Have detailed drawings and specifications, which cover all aspects of construction.
- Ensure that persons involved in the construction are sufficiently experienced and qualified in hurricane- and flood-resistant construction.
- Secure all plates to foundation by means of bolts, straps, wood bracing or by using other special connectors to resist wind or water pressures.
- Secure all studs to sill plates and top plates with metal connectors or straps.
- Ensure that metal straps or connectors have been used to make a positive connection from the foundation through to the structural members of the roof.
- Make certain that all material used and techniques employed provide adequate strength for withstanding potential hazards.
- Use framing anchors where possible, as these anchors put shear stress on nails and screws, which is the highest efficiency connection. Toe-nailing must be avoided, unless the cladding is braced ad is of very rigid continuous sheeting (e.g. plywood).

Building Maintenance

The long-term durability of a structure is heavily dependent on the level of maintenance work that is carried out to prevent deterioration of the structure. Periodic checks and preventative maintenance can help prevent rot, termite infestation and uplift of roof covering during high winds. The recommendations given below should be used as a guide.

Recommendations—Building Maintenance

- Carry out regular maintenance work to ensure that the house is fit to offer resistance to high winds.
- The most important areas for regular checks in a house are:
    a. Roof covering: for rusty or damaged corrugated sheets and missing nails or screws.
    b. Rafters and laths: to ensure that they are sound.
    c. All joints in the structure: for signs of weakness or movement.
    d. Pillars, both concrete and wood: for sign of cracks, rot, movements or disconnection.
    e. Pillars, wooden: for any sign of termites; if termites are present, preservative should be applied immediately.

New Construction Methods for Low-Income Housing

Low-income housing in St. Lucia is predominantly timber frame construction on concrete pillars, with gable roofs covered with corrugated zinc sheets and claded with ½" T1-11 exterior grade plywood sheets.

The construction methods used are generally acceptable. In an effort to economize, however, low-income earners typically seek help from relatives and friends (who possess few or no building skills) during the construction process. This decision can seriously affect the quality of the finished product. Structural members used for flooring and roofing systems are usually undersized, which also compromises the structural integrity of the housing. New construction methods are available, however, which are both structurally sound and cost-effective.

Built-up Plywood Joists and Beams

The building up of members (e.g. joists and beams) using plywood is an emerging trend. The advantages of plywood beams include their strength and rigidity, the ease with which they can be built, their light weight and their relative economy. The use of joist hangers could also be employed, which can speed up the construction work. Roofing systems could be strengthened by using trusses. This method is economical, as smaller members can be used for their fabrication.

The building up of members and the employment of roof trusses in low-income housing will ensure that:

- strength is not compromised in an effort to economize
- members can span larger openings with fewer intermediate supports
- they can be spaced further apart thus reducing the number of joist or rafters needed.
- the structure would be erected much faster (speed of erection is a factor in low-income housing)

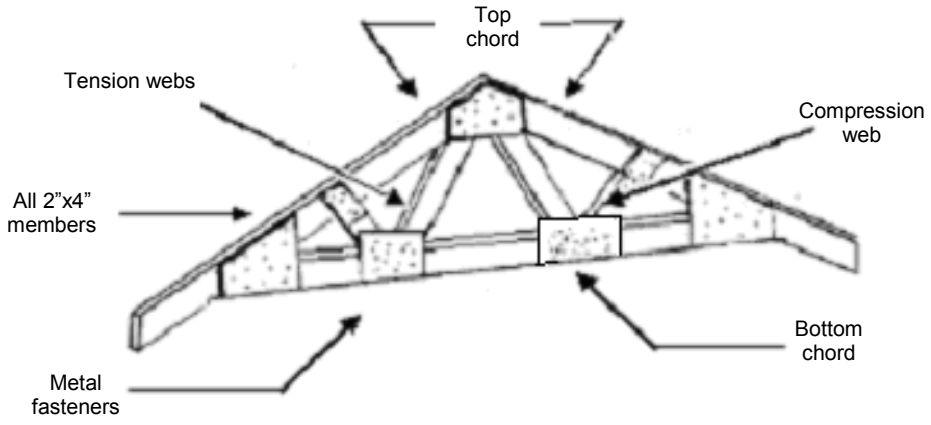
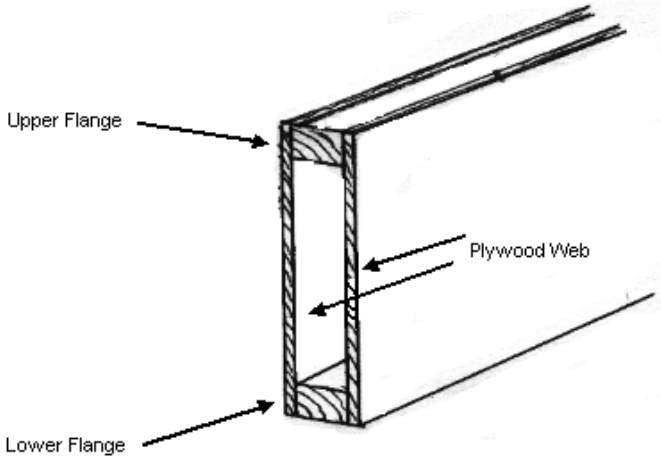


Figure 38 Roof Truss

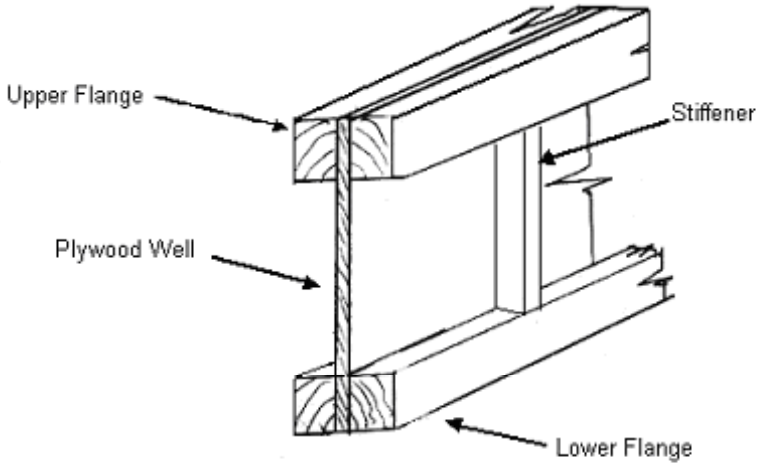
The employment of built-up members and roof trusses in the low-income housing sector means that the tradition of allowing relatives and friends exclusively to erect structures will have to change. A qualified carpenter must carry out the fabrication of these members. If this is not done, the structural integrity of the fabricated work cannot be guaranteed.

Cladding Protection

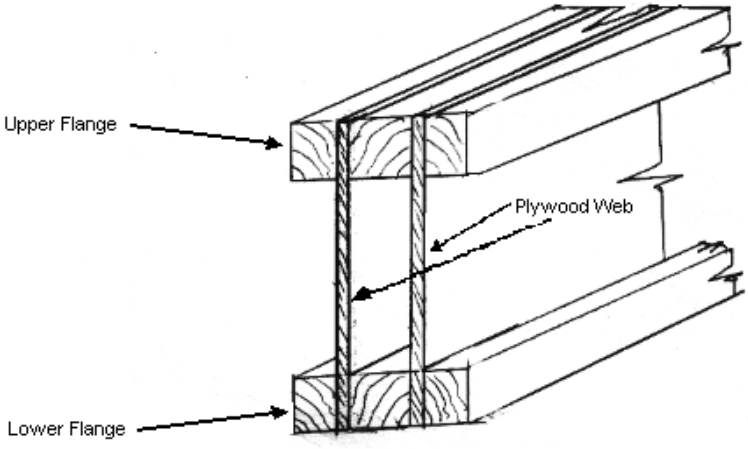
The exposure of external cladding materials to the elements in Caribbean conditions lead to severe deterioration of the materials (especially timber). Protection of exposed timber facades must be given a high priority, as it can significantly reduce replacement cost in the long term. [Reference: *St. Lucia Building Code,* Section 2.3, clauses (a) to (d).]



Box Beam



I-Beam



Double I-Beam

Figure 39 Examples of Plywood Box Beams

Lath and plaster, also known as cement render or stucco, could be applied to those facades of the building exposed to the weather (Eastern and Southern facades). Lath and plaster consist of bituminous roll felt, which is tacked on to the plywood cladding. Expanded metal sheets are fastened over the cladding, with two coats of sand/cement plaster (1:3 mix) ½" thick (each coat) applied as finished surface. Another option is the use of 'sand dash', which is the spraying of paint mixed with fine sand or powdered marl onto the wooden cladding.

Users Guide for Hurricane Straps and Other Framing Anchors

Hurricane Straps

Hurricane straps are galvanized metal angle plates drilled to allow them to be fixed with nails. There are two types available, left hand and right hand, which allows hurricane straps to fit either on the left or right side of the rafter. They are used to take shear, compressive and tension stresses. This offers resistance against up-lift of roofs at the eave during a hurricane.

The straps shown in Figure 40 and Figure 41can be manufactured very easily using 18-gauge zinc-coated sheets steel, a snip to cut out the strap and a hammer to aid in the bending of the strap. Note the dimensions are very important and must be measured accurately[2]. The holes should be well spaced and not too close to the edge and should be about 1/8 inch in diameter.

When manufacturing or using hurricane straps, it is essential that the two flat parts of the straps are exactly at right angles to each other. This ensures that the two faces are flush with the timbers, so that the nails (or preferably screws) are stressed in shear, where they are most efficient. If these two faces are not flat, uplift forces will dominate.

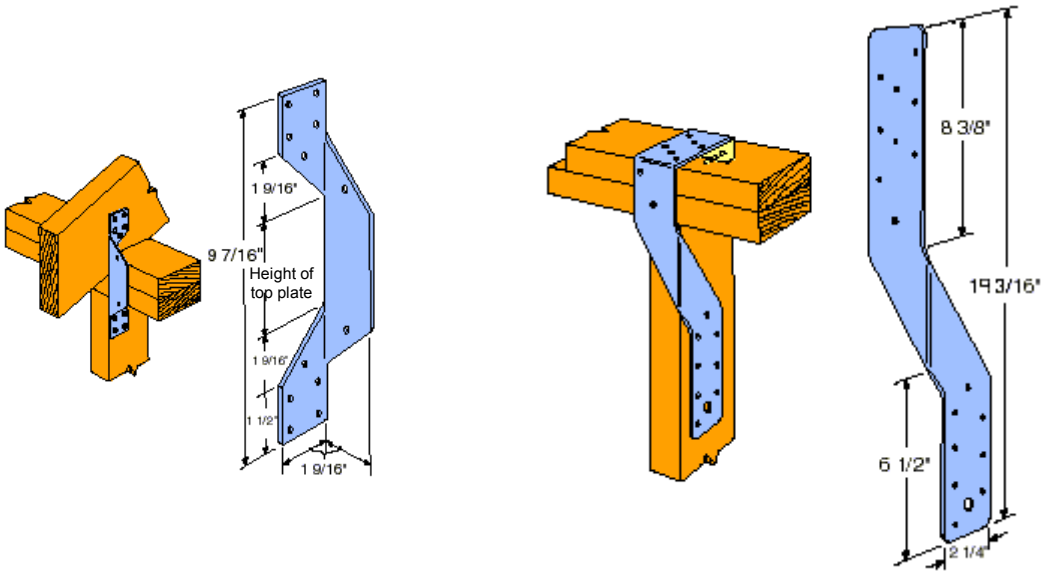


Image source: http://www.stormsurvival.homestead.com/Hurricane_Straps.html

Figure 40

The strap shown in Figure 42 is the example of a different design that can be just as effective as the ones shown in Figure 40.

Triple-L-Grip anchors are made in three basic types, A, B, and C, with left and right hand bends. One advantage of using hurricane straps over right angle L straps is that the nails are always loaded laterally, which makes the strongest connection. Note: Nails must be placed in all the holes of the strap; 1" nails are sufficient.

[2] Note: the height of the middle section of the clamp depicted on the left is a function of the thickness of the top plate to which this clamp is attached.

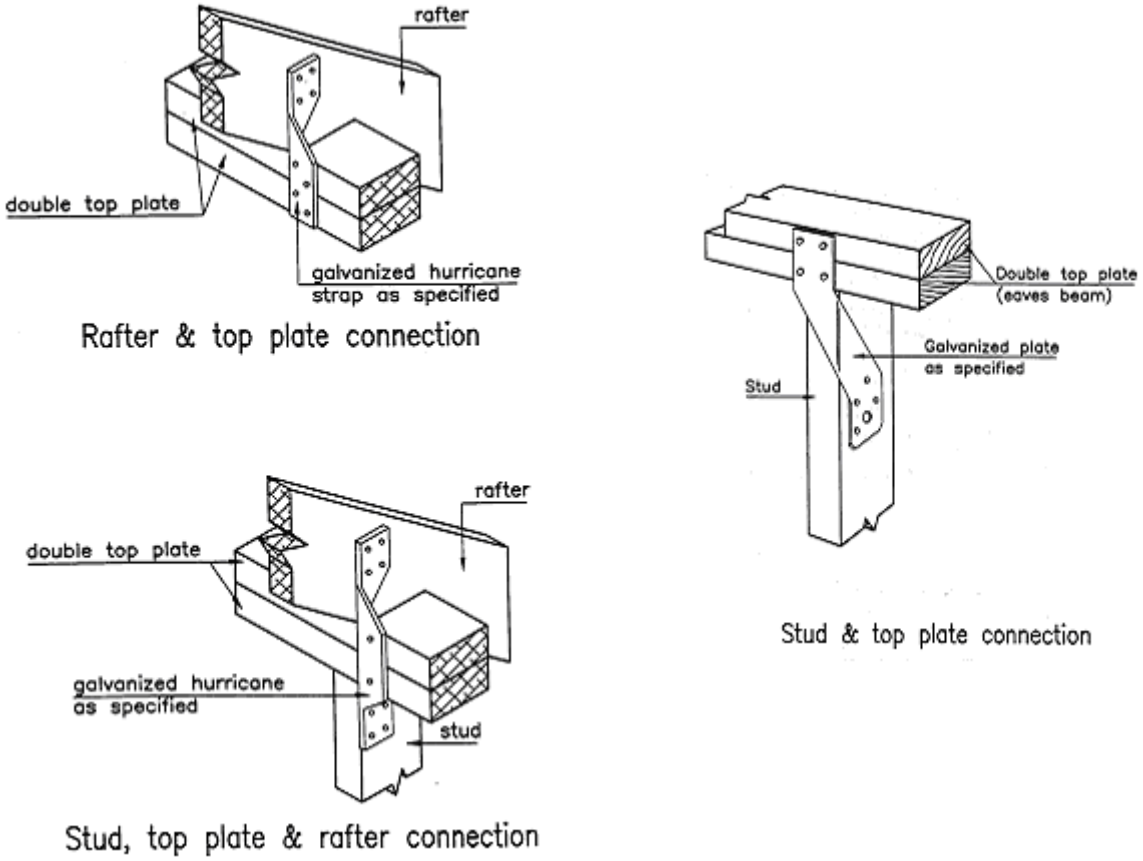


Figure 41 Examples of the Use of Straps shown in Figure 40

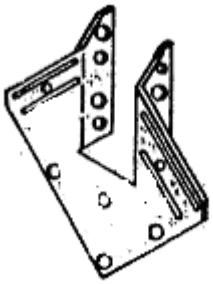


Figure 42

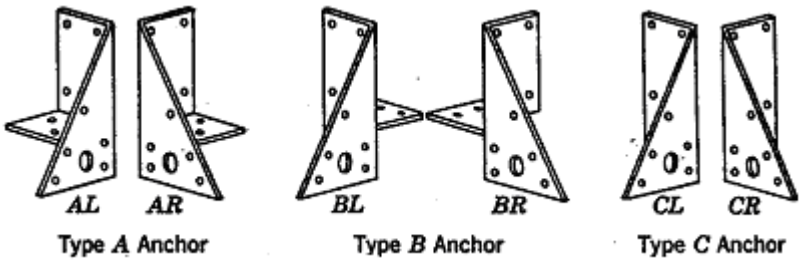


Figure 43 Trip-L-Grip Anchors

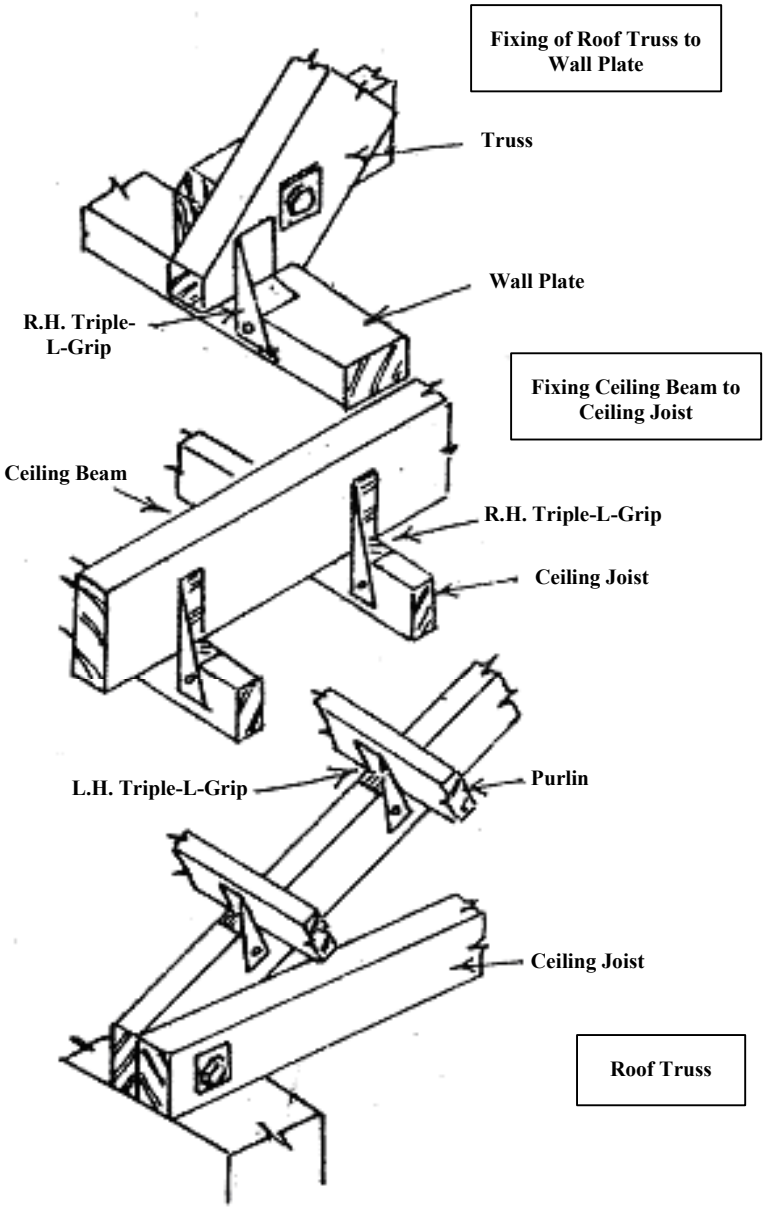
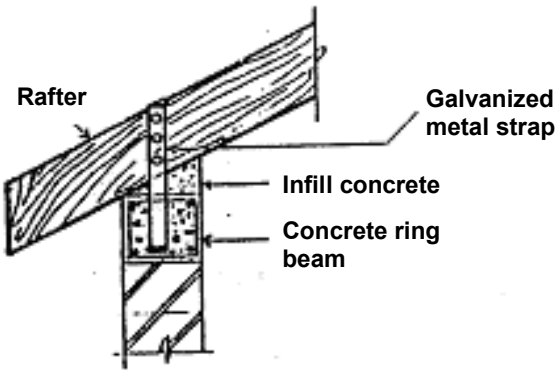


Figure 44 Use of Triple-L-Grip Anchors

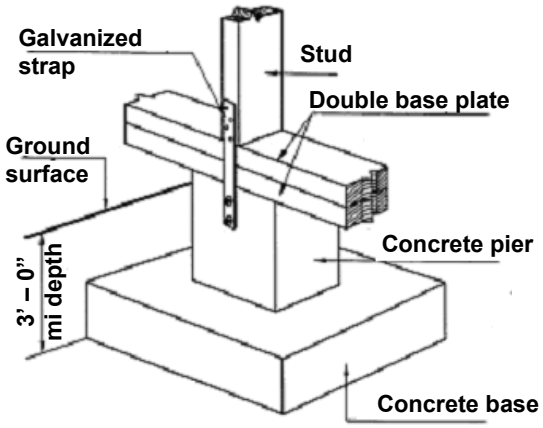
Securing the Load Path

Proper connections must be made between all parts of the structure, including the foundation and bottom plate, bottom plate and studs, studs and top plate, top plate and rafters, rafters and battens/lathes or purlin and roof covering and battens/lathes or purlin. Proper connections between all parts of the building, from foundation to roof, will make the difference between survival or loss of a structure.

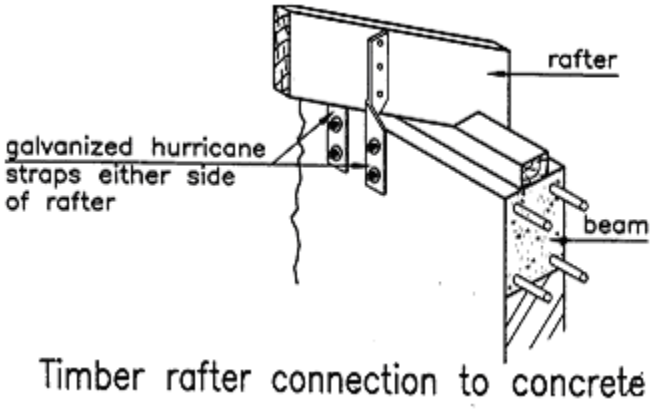
Once this has been achieved the structure's ability to withstand hurricane force winds would be improved significantly. Framing anchors and Hurricane straps when used as demonstrated in the sketches below to make the connections between the various members will afford homeowner better security during a hurricane.



Note: Ties or ceiling joists must be used in the cases depicted in these diagrams to counteract the effects of lateral forces on the external walls.



Stud to foundation connection
Foundation anchorage



Timber rafter connection to concrete

Figure 45

Health and Safety

Building sites can be very dangerous, both to the workmen and passers-by, especially when the following activities are being undertaken:

- Demolition works
- Working at heights
- Lifting or carrying heavy objects
- Operating electrical powered tools

Accidents on a building site can be reduced by workers' awareness of the root causes and adoption of safer working habits that can avoid endangering themselves and others. It must be noted that two of the most common factors which cause accidents on a work site (or elsewhere) are the attitude of individuals and the ignorance of the correct way machinery/ equipment work or are operated. The following are examples of dangerous attitudes:

- An inclination to take risk and behave recklessly.
- Believing that safety precautions are a waste of time.
- Thinking that if accidents are going occur, there is little anyone can do to stop them.

If workers change their attitudes and develop safer working habits, this would go a long way towards reducing accidents.

The second factor, the ignorance of persons as to the correct way machinery/equipment works or are operated, can be corrected by persons ensuring that they are knowledgeable and skilled in the safe use of machinery/equipment before attempting to use them. In the same manner, persons must be skilled in Carpentry or general building works before attempting to erect structures, because when the structure fails lives may be lost.

The following safety tips, if observed, can help reduce accidence and save the lives of workers and other people as well.

Safety on the Building Site

1. Keep work area clean. Clean up as you go, especially during demolition work.
2. Pull nails from boards at once. It is the odd piece of material with protruding nails that can cause serious injuries.
3. Wear thick-soled shoes with toe protection to protect your feet from protruding nails and heavy objects that may fall on your toes.
4. Use hard hats whenever you are working with persons above you or when you are below ground level (e.g. if you are digging a pit for a septic tank.)
5. Wear a respirator with changeable filters whenever you are working in a dusty environment
6. Do not operate machinery or sharp edged tools or climb ladders or scaffolds when under the influence of alcohol or other drugs that may impair your judgment.
7. When carrying out demolition/renovation work, make sure there are no children or other persons in the way before knocking out damage cladding.
8. Wear safety goggles whenever there is a chance that your eye would be endangered.

Electrical Safety

9. Always cut the power and check electrical outlets with a voltage tester.
10. When working in areas that you may cut into or otherwise disturb, keep in mind that there may be electric wires and pipes behind finished surfaces.
11. Power tools are commonly used; make sure, you know how to operate them. If it is raining, work should be stopped immediately as there is a chance that you will suffer an electric shock that could be fatal.
12. Check the electric cord of power tools to make sure that there are no cuts.

Scaffolding Safety

13. All supports for scaffolding must be solidly footed. Make sure they are checked every morning before you start work.
14. Platforms for scaffolding should be without twist or major cracks and they should be cleated (nailed) together.
15. Platform ends must not overhang more than l'-0" beyond their supports.

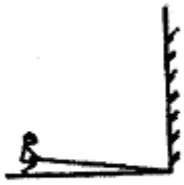
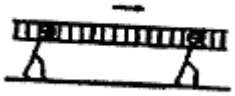
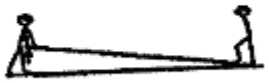
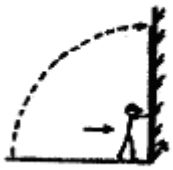
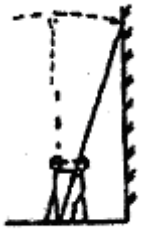
Safety while Working at Heights

16. Scaffolds that are higher than 3'-0" should have guard rails to protect workers from falling, and toe boards to stop objects from being accidentally kicked off the scaffold.
17. Working with ladders and scaffolds are dangerous as workers can fall from a height and injure themselves and persons below. They must be strongly built and well braced, as they have to carry heavy loads of persons and materials.
18. When working on a roof, erect scaffold up to the lower level of the roof to save anyone who slips down a roof slope.
19. Use roof ladders or crawl board to spread the load of the worker's weight when moving up and down the roof slope.
20. Roofs with zinc-corrugated sheets are not meant to support a person's weight between the timber frames. Walking on this type of roof covering requires extreme care because you need to move along the line of the nails or screws fixed to the battens/purling.
21. Do not use tools or do jobs requiring two hands while standing on a ladder.
22. Do not drop materials from a ladder.
23. Do not straddle from the ladder to a nearby foothold.
24. Do not allow more than one person up a ladder at a time.
25. Do not carry sheets of material, especially if it is windy.
26. Do not overreach.

Safety while Lifting or Moving Heavy or Awkward Objects

27. Protect your back muscles when lifting heavy objects. Get someone to help you. Lift with your arm and leg muscles, not your back.
28. Get help when carrying long boards or ladders, even if they are not heavy.

Manipulating and Maneuvering Ladders

Short Ladders	Long Ladders
Stage 1: Lift, bend knees and keep back straight 	Stage 1: Shoulder carrying 
Stage 2: Move forward and raise ladder 	Stage 2: Lifting – Assistant footing base of ladder 
Stage 3: Stand ladder up against a wall 	Stage 3: Move forward to raise ladder, assistant stationary 
Stage 4: Move out from wall 	Stage 4: Lean ladder against wall 
Stage 5: Carrying ladder 	

Note: When erecting and moving ladders over short distances, be aware of overhead cables and other obstacles. Metal ladders must not be used in areas where electric cables are present.

Ladder Safety

Ladders must be used correctly, if not, serious injury can result. The tips below should be a useful guide.

1. Do not erect on sloping ground.
2. Do not erect on movable objects.
3. Do not erect in front of a door that may be opened.
4. Do not erect against a slippery surface.
5. Do not erect at a shallow angle.
6. Do not erect horizontally as a plank or bridge.
7. Do not erect at too steep an angle.
8. Do not use a ladder that is too short.
9. Do not use a defective ladder.
10. Do not use a makeshift or 'home-made' ladder.
11. Do not overload a ladder or support it with a rung bearing on a board.
12. Do not slide down a ladder.
13. Do not carry a ladder while riding a bicycle.
14. Do not use an alloy or wet ladder near electrical conductors.
15. Always place a ladder on a firm level base.
16. Always set at an angle near to 75° from the horizontal (i.e. 4 in l).
17. Always tie the ladder in position, if possible at both the top and the bottom. (See pictures above.) If that is not possible, a worker should stand with one foot on the bottom rung holding the stiles to steady the ladder.
18. Always make sure the ladder projects above the climbing off level.

Relationship between the Minimum Standards Guide and the Building Guidelines

The St. Lucia Building Code was developed to ensure that homes and buildings constructed in St. Lucia are safe and sound. This Building Code was adapted from the OECS Model Building Code.

Building Code

The Building Code does not make a direct reference to hurricane resistant construction. Hazard-resistant building techniques are integral to the standards set forth in these documents. Section 14 of the Building Code (timber construction), for example, addresses quality, uses and sizes of structural timber and design parameters (e.g. allowable stresses) for various timber elements. Subsection 1406.1 provides timber construction details and reference information for material sizes required to span various distances.

The Building Code document is designed for use by Designers and Engineers. This information was re-presented in this document in a more accessible manner.

Building Guidelines

The information contained in the National Building Guidelines is based primarily on reports of the Construction Industry in the OECS and generally follows the customs and tradition in the design and construction practices. The Building Guidelines make use of the building traditions that lead to “safe” construction and introduced construction methods required for the proper use of contemporary materials. The Building Guidelines are to be used for design and construction of simple buildings such as private dwellings and small retail shops in St. Lucia of less than 2500 square feet gross area, and includes diagram and sketches of firm holding down mechanisms especially for light timber frame building, many of which are overturned or destroyed in high winds.

The Minimum Standards document addresses the same concerns of the Building Guidelines relative to light timber construction, but presents the information in a more graphic manner, and uses simpler terms and phrases which could be easily interpreted by untrained artisans and lay persons who are involved in the construction of dwellings in the vicinity of 1200 square feet or less.

References—Minimum Building Standards

The Construction Resource and Development Centre, (September 1988). 1st Ed. *Hurricanes and Houses* Kingston Jamaica.

The Construction Resource and Development Centre, *The Safe Roof Retrofit Project* Hyde, Held & Blackburn Ltd. Jamaica.

The Construction Resource and Development Centre, (October 1995) US AID/OAS *Caribbean Disaster Mitigation Project safe roof construction workshop*. Jamaica

Co-operative Housing Foundation (CHF) *Tool Kit: A Manual for the Implementation of the Hurricane Resistant Home Improvement Program*. International Cooperative Alliance

Farrag, M. (November 1991) *Hurricane - Resistance Construction Manual Are You Connected?*

The Federal Emergency Management Agency, (FEMA) (April 1990) *Construction Guide for Hurricane Resistant Housing in Puerto-Rico Revised Ed.*

Government of St. Lucia (November 1991). *Hurricane-Resistant Construction Manual—Are You Well Connected?* United Nations Centre For Human Settlements, United Nations Development Programme.

Mazria, E. (1979). *The Passive Solar Energy Book.* Rodale Press.

Miller, H.G. (1968) *Building Construction Materials and Methods.* The Macmillan Company of Canada Ltd.

Olgay, K. (1963). *Design with Climate,* Princeton University.

Organisation of Eastern Caribbean States and the Caribbean Community Secretariat (1997) *National Building Code (St. Lucia).*

Organisation of Eastern Caribbean States and the Caribbean Community Secretariat *National Building Guidelines (St. Lucia).*

Parker, Harry (1967) *Simplified Design of Structural Timber.* John Wiley & Sons, Inc, New York.