HURRICANE MARIA
LESSONS LEARNED

THE DOMINICAN EXPERIENCE AND
BEST PRACTICE RECOMMENDATIONS
FOR THE CONSTRUCTION INDUSTRY
FOREWORD

Developed by the Government of Dominica, Ministry of Planning, Economic Development and Investment and the Physical Planning Division.

Funded by the European Union through OCES/GCCA Project on Climate Change Adaption (CCA) and Sustainable Land Management in the Eastern Caribbean.
ACKNOWLEDGMENT

The creation of this booklet was made possible through technical assistance from the European Union OECS/ GCCA project on Climate Change Adaption (CCA) and Sustainable Land Management (SLM) in the Eastern Caribbean, along with the Ministry of Planning, Economic Development and Investment, and the Physical Planning Division.

Presentations from the following individuals, groups, and cross-sectoral associations at the one day consultation held on December 6th 2017, “contributed to the content of this document”.

- The executive of the Builders and Contractors Association of Dominica
- The executive of the Dominica Society of Architects.
- Local, regional and international Education & Training Management representatives from Simpsons strong tie.
- Dr. Lennox Honychurch, Historian
- Miguel St. Ville- Architect
- Representatives from the OECS GCCA project
- Staff of the Physical Planning Division
- This booklet was created by Delbert Paris, civil engineer and Steven Astaphan civil engineer
- Designed by Campbells Business Systems
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INTRODUCTION TO THE BOOKLET

This booklet is a combination of several best practice recommendations for roof construction following the devastating effects of Hurricane Maria on the Island of Dominica.

This document follows a one-day national consultation held in Dominica, funded by the European Union through the OECS GCCA Project on Climate Change Adaptation and sustainable land management in the Eastern Caribbean and hosted by the Physical Planning Division of Dominica.

Presenters at the consultation comprised of cross-sectoral representatives including architects, contractors, engineers, physical planners, development control officer, bankers, officers of the Bureau of Standards and Custom Department and a historian.

While much of the content of this booklet is supported by the recently revised, GUIDE TO DOMINICA HOUSING STANDARDS and is in line with a number of the following Documents. It does not form part of the National Housing standards, but rather seeks to make recommendations to general stakeholders in the industry.

- CODE OF PRACTICE FOR THE CONSTRUCTION OF HOUSES: AN INSTRUCTION MANUAL FOR FOREMEN AND EXPERIENCED ARTISANS PART 2: STUDENT’S MANUAL
MATERIAL RECOMMENDATIONS

Timber
- All Timber should be kiln-dried, grade 2 pressure-treated pitch pine, southern yellow pine or hardwood of equivalent or greater strength, free from splits, knots and other structural defects. Use rough instead of dressed timber where the structure is to be concealed.

Ties
- Hurricane straps to be obtained from your hardware dealer and used only with nails, screws & bolts supplied with these products. Use g185 zinc coated straps, installed as per manufacturer’s instructions, and stainless steel straps for coastal locations.
**Screws**

- Screws used in the roof framing and fastening, should be coated structural screws. At minimum 2.5” in length.
- Screws to be 2 ½ “ long x 12 gauge hex head wood screws with integral epdm washers driven to correct torque with power drill. Stitching screws to be similar but only 1” long.

![Correct compression of screws](image)

**Concrete**

- InSitu Concrete to be minimum 3000 psi @28days
- All cast InSitu concrete should employ proper curing methods to ensure the longevity and performance of structural or non-structural concrete elements.

**Reinforcement**

- All reinforcing steel to be corrugated or deformed high tensile bars
Sheeting

- All corrugated sheeting should be minimum 24 gauge or less.

<table>
<thead>
<tr>
<th>GAUGE</th>
<th>THICKNESS IN INCHES</th>
<th>THICKNESS IN MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>.0500</td>
<td>1.27</td>
</tr>
<tr>
<td>20</td>
<td>.0375</td>
<td>.95</td>
</tr>
<tr>
<td>22</td>
<td>.0313</td>
<td>.80</td>
</tr>
<tr>
<td>24</td>
<td>.0250</td>
<td>.64</td>
</tr>
</tbody>
</table>

Chart above shows the difference in gauge and thickness of roof sheetings

Diagram 1a show the Sheeting corrugation and distance between ribs
HOW TO READ A FRAMING SQUARE

1. Place the framing square on a table with the skinny length pointing right. You are looking at the face of the framing square.

2. The skinny length is called the **tongue**.

3. The thicker, longer section is called the **blade**.

4. The corner of the Framing Square is called the **Heel**.

5. On the face side, the **Tongue** reads the eight square scale. The **Blade** reads the rafter tables.

6. Flip the Framing Square. This is the back.

7. On the back side, the **Tongue** reads brace measurements. The **Blade** reads essex board measurements.
**HOW TO USE A FRAMING SQUARE**

1. Note the graduated scales. Generally, the framing square is broken down into fractions of an inch on top, and in centimeters on the bottom.
2. Measure a cut. Place one arm parallel against the edge of a piece of material that you wish to cut at a right angle.
3. Mark a line along the edge of the other arm and mark out a cut line.
4. The arm used for marking is generally determined by how long of a mark you need - use the **Blade** for a longer mark and vice versa.
5. Cut along the mark.

**HOW TO LAYOUT RAFTERS WITH A FRAMING SQUARE**

1. Figure the span of the Common Rafters. It’s the width of the building. Assume 30 feet, for this example.
2. Find the run of the Rafter. Let’s assume we want the Rafters to cover half the building. The run is 30’/2=15’.
3. Determine the roof’s pitch. Assume an 8”/15 pitch. There are 8” of rise for every 15” of run.
4. Place the Framing Square at the top edge of the rafter. The tongue on 8” and the **Blade** on 15”.
5. Make a mark along the **Tongue**.
6. Place a dot where the **Blades** meets the **Rafter Board**. In this case, at 15”.
7. “Step down” the Framing Square by lining up the Tongue at 8” on the square on the dot you just made.
8. Line up the Blade at 15” down the Rafter.
9. Make another mark alone the Tongue.
10. Repeat the process (steps 4-9) until you’ve run out of material. You won’t be able to make a final mark with a Framing Square once you’ve run out of enough board. You need to connect the last dot you made to the other edge of the board at the correct angle.
11. Measure the distance between any two points along the edge of the board.
12. Measure the distance from the last marked spot on the far end of the board and make a mark.
13. Connect this mark to the last dot you made using the Framing Square.
14. Use a straight edge to connect the dot to the mark.

15. To find the birds mouth, you’ll need to measure up 1/3 of the thickness of the **Rafter**. Let’s say we’re using a 2’x6’ that’s 5 1/2” thick. 1/3 of that is 1 7/8”.

16. Measure 1 7/8” up from your angled mark.

17. Line up the Framing Square Blade at 15” on the mark and ensure the Tongue reads 8” along the same edge.

18. Mark a line down the inside of the Blade to the edge of the near side of the board.

19. Repeat the process (15-18) on each remaining angled mark.

**PLEASE NOTE THAT THE SPEED SQUARE/ RAFTER SQUARE CAN BE USED FOR THE FRAMING OF A TIMBER ROOF. JUST AS EFFECTIVELY.**

*Diagram 2 shows the use of a Speed Square / Rafter Square*
Where Gable walls are required or are to be retained, they should be reinforced to prevent collapse due to wind loads as follows. Note that the height of the wall at the Ridge should preferably be no more than 8ft from the Ring Beam.

- **8”x10” RC CAPPING BEAM WITH 4 NO. 3/8” HIGH TENSILE RE-BARS AND 1/4” STIRRUPS AT 6” CENTERS TO SIT ON 6” BLOCK WORK WALLS.**

- **MIN 8”X12” DEEP RC RING BEAM**

- **3/8” DIAMETER HIGH - TENSILE RE-BARS TAKEN UP FROM RING BEAM BELOW AT 24” CENTERS AND SET INTO CONCRETE FILLED BLOCK WORK CORES.**

- **NOTE THAT RE-BARS TO BE TAKEN DOWN INTO RING BEAM BELOW**

- All reinforcing steel to be corrugated or deformed high tensile bars except for links or stirrups.

- Concrete strength to be a minimum of 3000P.S.I at 28 days.

- Timber framed external walls should be designed by a registered professional Engineer.

- Structural Epoxy for anchoring of re-bars into concrete must be supplied by approved manufactures such as Hilti, US Anchor, Fosroc, Sika, Sternson or Simpson.

- The Minimum Requirements given in this document must not be altered without the advice of a registered Engineer.

**Diagram 3 above shows the details of a reinforced Gable Wall.**
WIND FLOW ON GABLE ROOFS
Diagram 4 shows the members of a Hip Roof.
• The Hip Roof Design is more robust to withstand Hurricane Force Winds.

• The Hip and Ridge Rafters depth should be greater than Common and Jack Rafters in Roof design.

• The Roof pitch shall not be less than 25\(^\circ\) - 40\(^\circ\) (6:12 - 10:12).

• Minimum Rafter sizes for Ridge: 2”x8”, Hip Rafters: 2”x8”, Jack Rafters: 2”x6” and Common Rafters: 2”x6”.

• Depending on the size/span of the Roof a Truss system may be used in the place of Common Rafters.

• The Flow of the winds are less restrictive over the Hip Roof than in Gable.

• Eaves should be placed to a maximum projection of 18” from the wall. For exposed locations, Lean-to or Covered sunshades could be used over windows to protect them from the weather instead of relying on the main roof overhang.

• Open Eave Soffits are not recommended and should be boxed in with rigid timber framing and Soffit boarding fixed securely to the wall and.

• Gable ends should be converted to hips if possible by taking down part of the Gable wall and continuing the Ring Beam (if none present) horizontally along these walls.

• Eaves should be cut back to a maximum projection of 18” from the wall. For exposed locations, canopies over windows can be used to protect them from the weather instead of relying on the roof overhang.

**WIND FLOW AROUND HIP ROOFS**
ALLOW SPANS FOR Rafter & ROOF JOINT (based on 160 Mph Wind speeds)

Guides to Housing Standards in Roof Joist/Rafter Spans and Ceiling Joist span in terms of size and spacing

### Guide to Dominica’s Housing Standards

#### The Roof

**Dominica (160 mph wind speed)**

<table>
<thead>
<tr>
<th>SPACING</th>
<th>10’ or less</th>
<th>12’</th>
<th>14’</th>
<th>16’</th>
<th>18’</th>
<th>20’</th>
</tr>
</thead>
<tbody>
<tr>
<td>12” o.c.</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 10</td>
</tr>
<tr>
<td>16” o.c.</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 10</td>
<td>2 x 10</td>
</tr>
<tr>
<td>19.2” o.c.</td>
<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 10</td>
<td>2 x 10</td>
<td>None</td>
</tr>
<tr>
<td>24” o.c.</td>
<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 10</td>
<td>2 x 10</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

#### Ceiling Joist Span - Southern Pine #2 (no attic storage)

<table>
<thead>
<tr>
<th>SPACING</th>
<th>10’ or less</th>
<th>12’</th>
<th>14’</th>
<th>16’</th>
<th>18’</th>
<th>20’</th>
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</thead>
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<tr>
<td>12” o.c.</td>
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</tr>
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<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
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<td>2 x 6</td>
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<td>2 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 8/3 x 6</td>
<td>2 x 8/3 x 6</td>
</tr>
</tbody>
</table>

Tables above show guides to Housing Standards in Roof Joist/Rafter Spans and Ceiling Joist span in terms of size and spacing.
**RECOMMENDED**

**ROOF SHEETING**

- Roof sheeting should be a minimum 24 gauge steel base metal with galvanized or aluminum/zinc coating and be laid in continuous lengths from ridge to eave. Aluminum sheeting to be a minimum of 22 gauge.

- Aluminum sheeting may be used if plywood sheathing is installed over the rafters.

- Fixing of sheeting to be with Structural screws to penetrate a minimum of 1” into the timber laths below.

- Corrugated sheeting is to be fixed through the crown with a vertical spacing of no less than 3” spacing at the eaves, gables and ridges and 6” spacing in main roof “R” panel sheeting is to be fixed as shown below.

- Screws to be 2 ½ “ long x 12 gauge hex head wood screws with integral epdm washers driven to correct torque with power drill. Stitching screws to be similar but only 1” long.

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Diagram 5 above shows the Roof Sheeting with Screw orientation
Neoprene Washers allow screws to be attached securely to the covering material including at the Valley of the corrugation. Without the possibility of leaks.

At the Ridges, Eaves and Overhangs - min (2½”) Structural Screws should be used every 3”. All other locations, every 6”.

Diagram 6a shows the correct compression of screws onto Roof sheetings.

Diagram 6b shows installation of Structural Screws at Ridges, Eaves and Overhangs.
RECOMMENDATIONS FOR TYPICAL CONNECTION DETAILS WITH APPROPRIATE HURRICANE TIES

Diagram 7a shows the Hip Rafter connection details

Pressure - Treated Southern Yellow Pine
2”x 6” Hip Rafter

Pressure - Treated Southern Yellow Pine
3”x 4” Wall Plate

Recommended Hot - Dipped Galvanized Hip Connor Steel Straps

Diagram 7b shows the Common Rafter connection in a Timber building details

Pressure - Treated Southern Yellow Pine
2”x 6” Common Rafter

Pressure - Treated Southern Yellow Pine
Wall Plate 3”x 4” / 4” x 4”

Recommended Hot - Dipped Galvanized Plate Connector for Wooden structures

Diagram 7c shows the Ridge and Common Rafter connection details

Pressure - Treated Southern Yellow Pine

Recommended Hot - Dipped Galvanized Ridge Rafter Connector / Hanger

Pressure - Treated Southern Yellow Pine
Pressure - Treated Southern Yellow Pine
2” x 6” Rafter

Recommended Hot - Dipped Galvanize
Rafter / Wall Plate Connector

Diagram 8a shows the Rafter connection in Concrete building details

Pressure - Treated Southern Yellow Pine
2” x 8” Ridge Plate

Recommended Hot - Dipped Galvanize
Hip to Ridge Connector

Pressure - Treated Southern Yellow Pine
2’ x 8” Hip Rafters

Diagram 8b shows the Ridge Rafter to Hip Rafter connection details

Pressure - Treated Southern Yellow Pine
2” x 8” Hip Rafters

Pressure - Treated Southern Yellow Pine
2’ x 6” Jack Rafters

Recommended Hot - Dipped Galvanize Steel straps for
Hip to Plate and Jack Rafter to Hip Rafter connections
Jack Rafter Hanger/connector

Diagram 8c shows the Hip Rafter to Jack Rafter connection details
2” x 8” Ridge Board

2” x 6” Rafters at 24” Centers

2” x 6” Timber Collar fixed to Rafters with 2No. 1/2” Diameter Zinc Plated Bolts and Washers through centers of members and minimum of 6” from end of Collar

Recommended Hot - Dipped Galvanized Steel straps for Hip to Plate and Jack Rafter to Hip Rafter connections

Jack Rafter Hanger/connector

Diagram 9 above is a modified Rafter Trust System
Larger more, complexed Roofs with greater spans may require truss systems in order to maintain its structural integrity.

Diagram 10 above shows different variant types of Trust Systems.
Best Practice Recommendations For The Construction Industry

WINDOWS AND DOOR DETAILS

- It is necessary that the Masonry Wall on the perimeter of the window be a minimum of 6” of concrete and the window should be fixed with no less than 6” (six-inch) screws.
- All external doors should be minimum 1 -3/4” or 2” solid panel doors.
- All external wall openings should be constructed with the ability to be securely closed during Hurricane conditions, i.e. appropriate external door/window shutters.
CROSS VENTILATION

VENTS BETWEEN RAFTERS, VENTS UNDER EAVE SEALING AND DORMER WINDOWS

- Adequate Roof Vents in the Soffits and at the Ridge of the pitched Roof allow for the decrease in pressure build up during a Hurricane event which aids in preventing blow off or damage to the Roof.

Diagram 6a shows the Vents in the Soffits and at the Ridge of a pitched Roof.
POINTS TO NOTE AS IT RELATES TO ROOF & BUILDINGS IN DESIGN

- The design of the building **MUST** be carried out by a professional in the field of Architecture, qualified and trained with design competence.

- The implementation of the building design or actual construction must be done by a competent team of contractors with training and experience that will enable them to produce and maintain the required quality of construction.

- The material quality must also be of the highest standard, as this is required for optimal performance particularly in storm conditions.

- Reduce the complexity of the Roofing system; overly complexed Roofs seldom perform optimally in storms.

- Resilience in the face of a CAT 5+ Hurricanes will require greater investment in, better material and better construction practices that will mean a financial investment into building construction.
Best Practice Recommendations For The Construction Industry

Increase in competence training and development of local construction labor force.

It is our view that there was a failure in regulatory Responsibility of the Physical Planning Unit and Ministry of Housing to ensure that building connections, not only in Roofs, met code requirements for Hurricane and Lateral forces. Failure was in oversight not strictly in knowledge.

Mitigation is best achieved by increasing regulatory oversight with financial incentives.

Consider alternative solutions.

Mitigate by increasing:

- The presence of monitoring officers on sites at critical stages.
- Implement certification process, culmination with Certificate of Occupancy that is renewal every 5/10 years.
- Use of private sector professionals to certify compliance at critical stages - before the work is covered.

Involving financing and insurance companies.

Use certification to obtain financial benefits.

Increased Mortgage Tax rebates and lower insurance premiums.

Mitigate by:

- Mapping waterways after Maria
- Mapping extent of waterway intrusion into built areas.
- Establishing safe buffer zones, being cognizant of limited land.
- Land use re-zoning.

Establishing new regulation for location with proximity of wastewater structures - Septic Tank and Soak Pits - to water ways.

Implement simpler system of Environmental Impact Assessment for water way zones - checklist.

Use of private sector professionals to design mitigating and protective structure for building close to water ways.

Involve financing and insurance companies.
The publication of Guide to Dominica Housing Standard forms the Housing Standards for the Commonwealth of Dominica. All construction plans must be submitted to the Physical Planning Division for approval.

This project was developed with assistance from UNDP and Engineers without Borders-USA.

Much of the Guide to Dominica Housing Standard was from the publication from the Informal Housing Retrofit and Safe Construction Pilot Project administered in Dominica by the National Development Foundation of Dominica (NDFD) with technical input from Safe Shelter Initiative (SSI) with credit to USAID, OECS, OAS, CRDC, Severin McKenzie and Lennard Andre.

This booklet will be made available online or at the office of the physical planning division and should be used in conjunction with the following.


Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Source: The Brundtland Commission (1983)

Primary Goals of Sustainable Development
- Tackling the effects of Climate Change, Pollution and other Environmental Factors
- The end of poverty and hunger
- Better standards of Education and Healthcare, particularly as it pertains to water quality and better sanitation.
- To achieve Gender equality.
- Sustainable economic growth while promoting jobs and stronger economies.

Sustainable building integrates building materials and methods that promote Environmental Quality, Economic Vitality and Social benefits through the design, construction and operation of the built environment.
As with all construction projects, sustainable development projects must be planned and executed, with the guidance of qualified Architectural, Engineering and Construction Competencies, ensuring that the project accomplishes its sustainability objectives.
CONCLUSION

This creation of this document does not form part of the national housing standards and should not be referred to or used as such, it however serves as an indicator of some of the best practice methods that can be used during the reconstruction of timber roofs on the island of Dominica Post Hurricane Maria.

Points to remember:

• All Renovation and construction of houses in Dominica Must be submitted to and approved by the Physical Planning Division
• Designs of Timber roofs should be carried out by Certified Engineer, particularly larger roofs with Long spans
• Material Grade should meet minimum Requirements, especially Structural and exposed members.
• Timber members should be grade 2 pressure treated or better
• Metal sheeting Should be 24 gauge or better
• Screw should be structural screws 2.5” or longer with appropriate washers to prevent leakage.
• Hurricane ties should be Recommended hot-dipped galvanized steel straps or better.
• Building Design must take into consideration environmental factors that will affect the longevity and performance of the structural elements.
  • Roof design – Hip Versus Gable
  • Truss versus open rafter
  • Wind Direction
  • Seismicity
  • Coastal areas

It is important to note that while climate change has affected the way natural events occur, we can do more with the knowledge we have, to help save human lives.