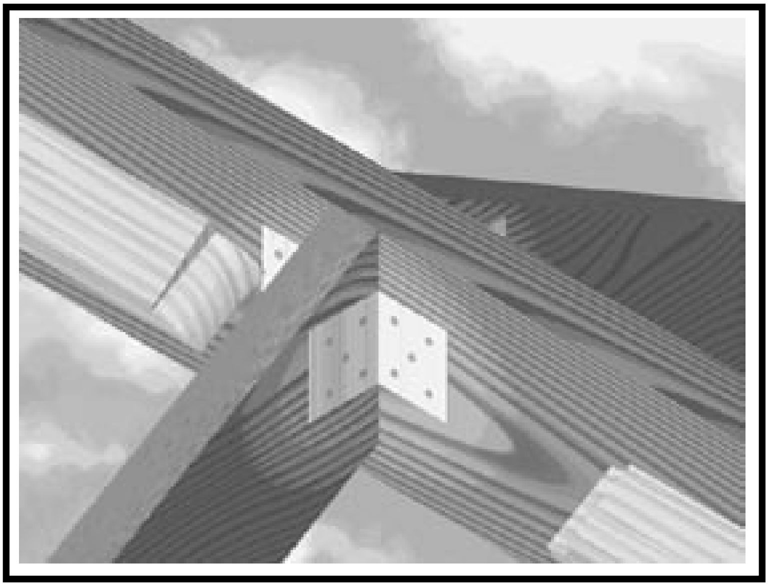
Hurricane Straps



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This Technical Manual on Hurricane Straps has been developed for

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SECTION 1

GENERAL INTRODUCTION TO WIND DAMAGE AND DESIGN AGAINST WIND

Hurricanes in the Caribbean

In recent times in the Caribbean there has been a heightened awareness of the damage potential of hurricanes. Such damage is done both by wind and by water. Damage by the wind can be either direct (i.e. due to wind pressures acting on the structures) or indirect, as in the case of flying debris impacting on vulnerable structures such as glazed windows. BRC Hurricane Straps are designed to address the problem of damage due to wind pressures acting on the structures.

Hurricanes in the Caribbean are formed when an organised system of anti-clockwise, revolving winds develop over the tropical waters. When the wind speeds near the centre of the system exceed 32 m/s 1 (sustained 1-minute average) the system is called a hurricane. In theory there is no maximum wind speed for hurricanes but conventional building design in the Caribbean would be limited to speeds less than 85 m/s (190 mph).

It is estimated that over 4,000 tropical storms have occurred in the North Atlantic region (including the Caribbean) in the 500 years since the advent of Columbus. About half of these have developed into hurricanes. The greatest of all recorded hurricanes occurred from 10th to 18th October 1780. Nearly 20,000 people perished as the storm hit virtually every island from Tobago in the south-east through the Windward and Leeward Islands and across to Hispaniola and Cuba. In the last 60 years in the Caribbean another 20,000 people have lost their lives because of hurricanes.

The pattern in recent times has been a reduction of deaths and injuries (because of better warning systems and other preparedness activities) and an increase in property damage (because of commercially-driven unsuitable building practices and locations).

Anyone who actually experiences a major hurricane, especially during daylight hours, would realise how inadequate and sterile are wind-loading standards. A quotation from Professor Joseph Minor, modified by Tony Gibbs, puts it this way:

"The real environment in a hurricane consists of strong, turbulent, winds (sustained for many hours), that change slowly in direction as the storm passes, and carry large amounts of debris while accompanied by torrential rains."

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1 Metres per second (1 m/s = 2.24 miles per hour) - 32m/s=72mph

The range of BRC Hurricane Straps has been tested recognising the characteristics of repeated, dynamic and fluctuating loads in such events.

During the past twenty years there have been several memorable hurricanes in the Caribbean. These events repeatedly illustrated the effects of such storms on buildings and other structures. They include Hurricane David in the Commonwealth of Dominica and the Dominican Republic in 1979; Hurricane Gilbert in Jamaica and Mexico (Cancun, Yucatan) in 1988; Hurricane Hugo in Dominica, Guadeloupe, Montserrat, Antigua, St Kitts, Nevis and The Virgin Islands in 1989; Hurricane Andrew in Cat Cay in the Bahamas in 1992; Hurricane Luis in Antigua and Sint Maarten / St Martin and Hurricane Marilyn in St Thomas in 1995.

The destructive potential of a hurricane is significant due to high wind speeds, torrential rains and occasional storm surge with heights of up to 8 metres (26 ft) above normal sea level, although such heights are unlikely to be experienced in most of the Caribbean islands. As suggested earlier, this document is limited to the wind aspect of hurricane damage.

Category	1-minute avrg (m/s)	1-minute avrg (mph)	3-second avrg (m/s)	Damage
HC1	33 - 42	74 - 95	42 - 53	Minimal
HC2	43 - 49	96 - 110	54 - 62	Moderate
HC3	50 - 58	111 - 130	63 - 74	Extensive
HC4	59 - 69	131 - 155	75 - 87	Extreme
HC5	> 69	> 155	>87	Catastrophic

Table 1: Wind Speed and the Saffir/Simpson Scale

The Saffir/Simpson scale is often used to categorize hurricanes based on wind speed
and damage potential. The following five categories of hurricanes are recognized:

Damage due to Hurricane Winds

The main types of damage to buildings and structures experienced in Caribbean hurricanes are:

Foundations

The uplift forces from hurricane winds can sometimes pull buildings completely out of the ground. In contrast to designing for gravity loads, the lighter the building the larger (or heavier) the foundation needs to be in hurricane-resistant design. Anchoring buildings to their foundations is critical for lightweight structures. Some of the BRC Hurricane Straps are designed to address this problem.

Structural — A common misconception is that the loss of cladding relieves the loads from building frameworks. There are common circumstances where the opposite is the case and where the wind loads on the structural frame increase substantially with the loss of cladding. The use of the BRC Hurricane Straps (and other products) facilitates the retention of cladding.

Usually the weakness in structural frames is in the connections. Convenient connection details in timber frames are possible with the use of the BRC Hurricane Straps.

Masonry Houses — These are usually regarded as being safe in hurricanes. There are countless examples where the loss of roofs has triggered the total destruction of un-reinforced masonry walls. Here again the use of the BRC Hurricane Straps can be used to hold roof rafters onto masonry walls.

Timber Houses — The key to safe construction of timber houses is in the connection details. The inherent vulnerability of light-weight timber houses, coupled with poor connections, is a dangerous combination which has often led to disaster. It is in timber construction that the BRC Hurricane Straps are most obviously valuable.

Other types of catastrophic failures such as those to reinforced concrete frames and to special structures such as telecommunication towers and masts are outside the scope of this document.

Roof Sheeting — This is perhaps the commonest area of failure in hurricanes. The causes are usually inadequate fastening devices, nadequate sheet thickness and insufficient frequencies of fasteners in the known areas of greater wind suction. In addition to Hurricane Straps, BRC provides products and services to solve these problems.


Roof Damaged in a Hurricane

Rafters Of particular interest in recent hurricanes was the longitudinal splitting of rafters with the top halves disappearing and leaving the bottom halves in place. The splitting would propagate from holes drilled horizontally through the rafters to receive holding-down steel rods. More satisfactory methods of securing rafters are available through the use of BRC Hurricane Straps.

Prevention of Damage

Hurricanes are not natural disasters; they are natural events which sometimes lead to manmade disasters. In these days of widespread technological education, sophisticated research, reliable building materials, computer-based geographical information systems and satellite-assisted warning programmes, hurricanes in the Caribbean should not lead to disasters.

One of the first steps which must be taken by the construction industry is the use of appropriate standards addressing the effects of wind on buildings. Two of the documents in current use in the region are CUBiC2, Part-2, Section-2 "Structural Design Requirements, Wind Load" and the previously mentioned BNS CP283.

Apart from formal and mandated standards, the most effective influence on the improvement of the security of buildings against hurricanes can be wielded by the general insurance industry. Insurance companies have a vested interest in this subject and could provide a strong incentive for the improvement of standards of design and construction.

Most insurance companies provide hurricane cover at the same rates for most buildings, irrespective of their relative abilities to withstand natural hazards. In this system "Peter pays for Paul". Graduated premiums, based on design type, materials and quality of construction would be a meaningful step in the right direction. There is some evidence that Caribbean insurance companies are moving in this direction.

So what can be done for new construction as well as for the large existing stock of buildings? Quite a lot! Listed below, in very general terms, are some issues which should be addressed for new construction and then for the strengthening of existing buildings.

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2 Caribbean Uniform Building Code

3 This was originally a code "Wind Loads for Structural Design" sponsored by the Council of Caribbean Engineering Organisations (CCEO) first published in 1970 and substantially revised in 1981. This was prepared by the Barbados Association of Professional Engineers (BAPE). This CCEO/BAPE Wind Code sets out the basic wind parameters for the design of buildings in the Commonwealth Caribbean. The normal requirement is the 1-in-50-year wind, i.e. a wind speed which on average is not expected to be exceeded more than once in 50 years. In the Caribbean this produces a basic 3-second gust wind speed of between 45 m/s in Trinidad in the south-east and 64 m/s in the north and west. This represents hurricanes of categories 2 and 3. For a category-4 hurricane, a wind speed is experienced which on average is not expected to be exceeded more than once in 100 years in most of the Caribbean. The 1-in-200-year wind is experienced in a category-5 hurricane.

Location The location of the building is important. We often have little choice in the matter, perhaps because of financial constraints. It is as well, therefore, to recognise when a building is being located in a more vulnerable area. The rational response would be to build a stronger-than-normal house. Such vulnerable areas include open-ended valleys, which act as funnels for the wind, and exposed hill crests. Both conditions lead to acceleration of wind speeds with the corresponding increase in damage potential.

Shape We do have control over the shape of new buildings and shape is the most important single factor in determining the performance of buildings in hurricanes. Simple, compact, symmetrical shapes are best. The square plan is better than the rectangle. The rectangle is better than the L-shaped plan. This is not to say that all buildings be square. But it is to say that one must be aware of the implications of design decisions and take appropriate action to counter negative features.

Even more important than plan shape is roof geometry. For lightweight roofs it is best that they be of hipped shape (sloping in all four directions, usually), steeply pitched (30 to 40 degrees), with little or no overhangs a the eaves (with parapets if possible) and with ridge ventilators where these are practicable.

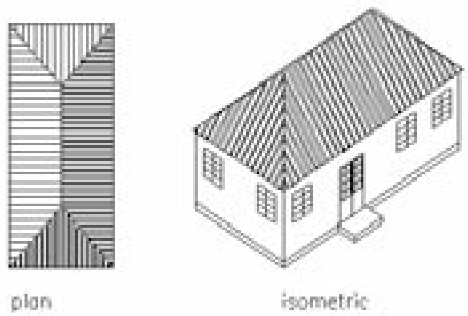

Figure 1: Hipped-roof, Rectangular House

Materials The strengths of materials are important characteristics as would be expected. Durability is equally important, especially in the corrosive environments prevalent in coastal situations which are commonplace in all Caribbean islands. BRC Hurricane Straps are available both in galvanised steel and in stainless steel.

Forces Although the determination of wind forces on buildings is not a precise exercise, it is nevertheless desirable to use the information in standards documents such as CUBiC and BNS CP28 to get better approximations of the forces and the patterns of forces than mere guesswork can provide.

Windows and Doors

Apart from roofs, the elements requiring the most attention are windows and doors. Sadly, these are often neglected, even when buildings are formally designed by professionals. Glass windows and doors are, of course, very vulnerable to flying objects. And there is much flying debris in hurricanes. These issues are outside the scope of this document.

Connection Details

The famous German architect, Mies van der Rohe, used to preach to his students that "God is in the details". For anti-hurricane construction this could be rewritten "God is in the connections". It is imperative that all the components of a building envelope be securely interconnected. The BRC range of Hurricane Straps satisfies the requirements of this subject.

Retrofitting

We must also address the huge stock of existing buildings. Any improvement is worthwhile. It won't be easy (it may not even be possible) to protect many existing buildings from major damage in another David, Gilbert, Hugo or Andrew. But all hurricanes are not great ones. The more severe the storm the less frequent its occurrence. Conversely, the less strong the hurricane the greater the likelihood of it visiting any particular community. Small improvements would be needed more frequently than major strengthening so, at least, a start should be made with the small things.

Add to and improve the connections of lightweight roofs to purlins, purlins to rafters and rafters to walls; invest in storm shutters; add bolts to external doors; increase the connections of door and window frames to walls; pay attention to the maintenance of buildings.

Costs

The good news is that using BRC Hurricane Straps is affordable to all building owners.

GUIDANCE ON THE USE OF THE MANUAL

This Manual covers the use of BRC Hurricane Straps for many common situations. Reference should be made to Appendix B for limitations on the applicability of this document. Reference may also be made to the worked example in Appendix C.

The steps to be taken in using this Manual are:

1. Identify need for connectors.
2. Select suitable connectors from Section 2.
3. Determine basic wind speed, design wind speed and design wind pressure from Section 3.

4. Determine design wind load from Section 4.
5. Determine the number of connectors (or the frequency of connectors) required to resist the wind load using the appropriate part of Section 5.
6. Adjust the spacing of timber members and/or connectors to achieve a regular and convenient set of construction details.

SECTION 2

GENERAL INTRODUCTION TO BRC HURRICANE STRAPS

Range of Products

The current range of BRC Hurricane Straps includes:

RAFTER-TO-PURLIN CLIPS

As the name implies, these are used to connect purlins (or battens) to the main supporting rafters in roof construction. They may be used either singly or doubly at each rafter/purlin crossover.

These may also be used to connect the ends of rafters to timber wall plates. Between one and four clips may be used per junction, depending on the uplift force.

Photo 2: Rafter-to-purlin Clip

RAFTER CONNECTORS

These may be used to connect the ends of rafters to sides of ridge boards. When bent at angles other than right angles they may be used to connect the ends of orthogonal rafters to hip rafters in hipped-roof construction.

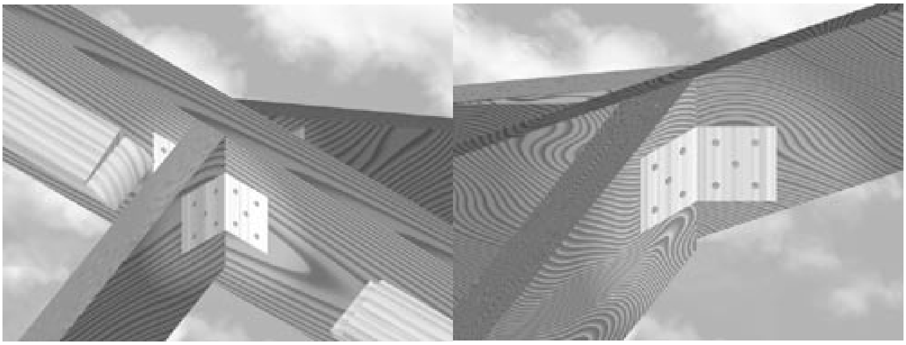

Photo 3: Rafter Connector

TRUSS ANCHORS

These are used where roof trusses or main rafters are supported by concrete belt beams (also known as ring beams)

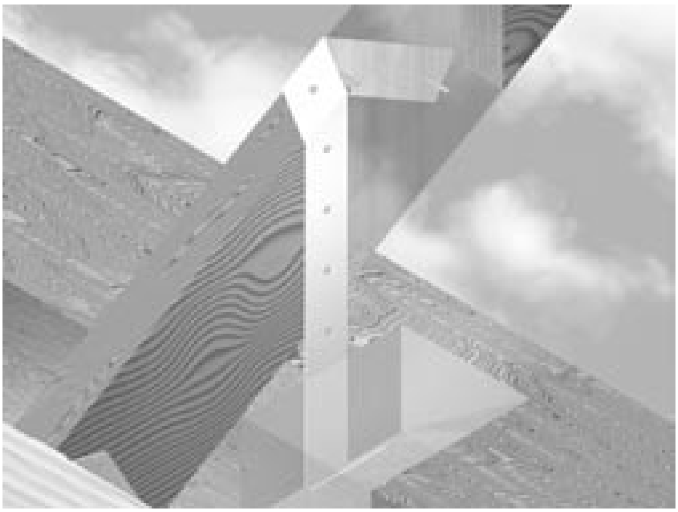

Photo 4: Truss Anchor

MULTI-PURPOSE STRAPS

As the name suggests, these items have many uses. They may be used to hold down lightweight buildings onto their foundations, to connect timber stud walls to sill plates, to connect upper storeys to lower storeys in timber construction and to supplement dedicated roof-member connections.

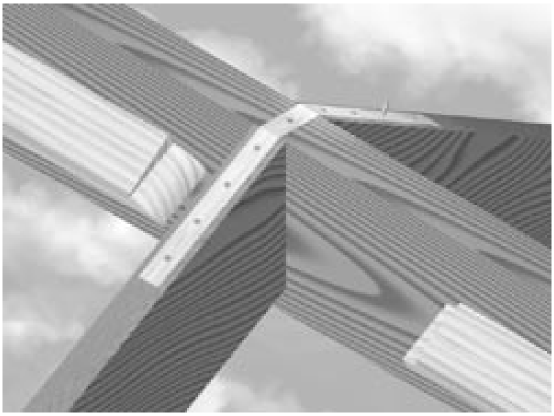

Photo 5: Multi-purpose Strap

MENDING PLATES

These are used at splice junctions. They are not very efficient in transferring direct loads and bending moments. Their appropriate use is as an economical connector where the loads or moments to be transferred are much less than the potential capacities of the connected members.

Photo 6: Mending Plate

MOMENT CONNECTORS

These are used in pairs at butt junctions in beams where it is necessary to transfer significant bending moments.

Photo 7: Moment Connector

Quality of Materials

BRC Hurricane Straps are supplied in two materials and two thicknesses as follows:

* Galvalume coated steel sheet to ASTM A792M, Grade 345A, AZ180, in thickness 1.0mm. Minimum Tensile Strength of 450 MPa, Minimum Yield of 345 MPa with Elongation of 12%.

* Stainless steel sheet to ASTM A240-S31603 with Minimum Tensile Strength of 485 MPa in thickness 1.0mm. Minimum yield of 170 MPa with elongation of 40%.

The testing of **BRC** Hurricane Straps (see Appendix A) has been carried out using two gauges of galvanised nails - 3.75 mm (0.148 in) and 3.15 mm (0.124 in). The length of the smaller nail was 35 mm (1.378 in) and the minimum length of the larger nail was 40 mm (1.575 in).

The tests used F8 seasoned slash pine (P. elliottii) with a nominal density of 625 kg/m^3 (39 lb/ft^3) at 12% moisture content and a mean modulus of elasticity of 12,000 N/mm2 (1.74x106 lbf/in^2).

SECTION 3

WIND SPEED, PRESSURE AND LOAD

Basic Wind Speed Table of the Caribbean (V)

This information is based mainly on the research and analysis undertaken by H C Shellard in 1970 and revised by B. A. Rocheford in 1981. Both of these meteorologists were attached to the Caribbean Meteorological Institute.

The wind speeds are 3-second gusts at 10 metres above ground in an open situation and likely to be exceeded not more than once in 50 years..

Place	Metres per Second	Miles per Hour	Notes
Guyana	22	49	
Trinidad	45	101	
Tobago, Grenada	50	112	
Grenadines, St Vincent, Barbados, St Lucia	58	130	Based on studies for Barbados only
Dominica, Montserrat	61	136	Interpolated
Antigua, Barbuda, St. Kitts, Nevis, Anguilla, BVI, Turks & Caicos	64	143	Based on studies for Antigua only
Turks & Caicos, Bahamas, Jamaica, Cayman Islands, Northern Belize	58	130	Shellard-Rocheford-Davenport[4]
Southern Belize	50	112	Shellard-Rocheford-Davenport

Table 2: Basic Wind Speeds (V) of the Caribbean

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4 The University of Western Ontario (Prof Alan Davenport) undertook a study of the hurricane hazard in 1985. This information has been used directly in CUBiC. It is not exactly comparable with the Shellard-Rocheford studies. However, the Davenport information has been used comparatively in conjunction with the Shellard-Rocheford studies to derive these figures.

Factors for Topography (S_1)

Recent hurricane events in the Caribbean have demonstrated the significant influence of topography on the levels of damage caused by the wind. Although most modern wind-load standards provide guidance and procedures for addressing this issue, the adjustment factors given in these documents do not fairly represent the range of effects experienced in the dramatic topographies of many Caribbean islands.

Research work is ongoing in this area and it is expected that much better guidance will be available in the near future. In the meanwhile the factors in the following table may be used, although they do not represent the maximum range likely to be experienced in practice.

Topography Condition	Topography Factor
Very exposed hill slopes and crests	1.1
Valleys shaped to produce a funnelling of the wind	1.1
Steep-sided enclosed depressions	0.9
All other situations	1.0

Table 3: Topography Factor

Factors for Ground Roughness and Height (S_2)

Since the BRC Hurricane Straps are used typically for connecting individual building components, only Class A structures are considered in the Table below. Class A structures include all units of cladding, roofing and their immediate fixings.

Height in Metres (and Storeys)	Open Country Coastlines	Suburbs Wooded Areas	Town Centres
4 (1 storey)	0.86	0.76	0.67
8 (2 storeys)	0.95	0.92	0.75
12 (3 storeys)	1.01	0.96	0.82

Table 4: Ground Roughness and Height (S_2) Factor

Design Wind Speeds (V_s)

$V_s = V \times S_1 \times S_2$

Wind Pressures (q)

Design Wind Speed (m/s)	Design Wind Pressure (N/m^2)	Design Wind Speed (mph)	Design Wind Pressure (lbf/ft^2)
20	245	45	5
25	383	56	8
30	552	67	12
35	751	78	16
40	981	89	20
45	1240	101	26
50	1530	112	32
55	1850	123	39
60	2210	134	46
65	2590	145	54
70	3000	157	63

Table 5: Speed-to-pressure Conversions (see also Appendix D)

SECTION 4

WIND PRESSURE COEFFICIENTS FOR DIFFERENT ROOF SHAPES AND SLOPES

Hipped Roofs

This is the most favourable shape for a roof from the point of view of resisting wind forces. Although the theoretical maximum pressures (and suction forces) are not very different from those for gable roofs, the practical performance of hipped roofs in hurricanes is demonstrably superior to that of gable roofs. The reasons are:

- slightly lower maximum values of pressures and suction forces;
- more even distribution of pressures and suction forces over the roof surface;
- more favourable structural form leading to better (and less onerous) distribution of the loads from the roof to the walls;
- the practical need for better quality of workmanship for fabricating and erecting hipped roofs.

The following table gives external pressure coefficients (C_{pe}). In most cases it would be necessary to add an upward internal pressure coefficient of 0.2 to these figures.

Roof Angle in Degrees	Maximum Uplift Pressure Coefficient on Interior of Roof	Maximum Uplift Pressure Coefficient on Hip Ridges	Maximum Uplift Pressure Coefficient at Horizontal Ridge
5	0.64	0.89	0.62
15	0.64	1.43	1.31
30	0.78	1.40	0.78
45	0.88	1.35	0.88

Table 6: Pressure Coefficients for Hipped Roofs

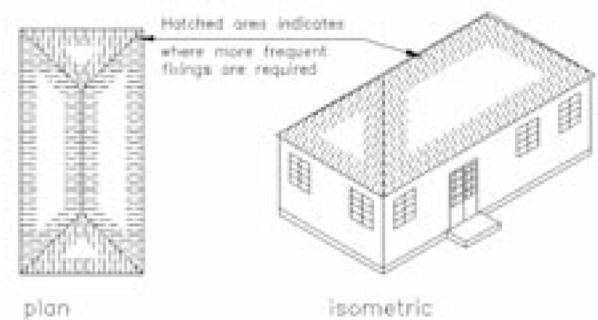


Figure 2: Edge Areas where the Higher Forces Apply

Note: The hatched areas in Figure 2 extend approximately 15% of the relevant dimensions of the sections of the roof.

Gable Roofs

The table below gives external pressure coefficients (C_{pe}). In most cases it would be necessary to add an upward internal pressure coefficient of 0.2 to these figures.

Roof Angle in Degrees	Maximum Uplift Pressure Coefficient on Interior of Roof	Maximum Uplift Pressure Coeff. on Eaves and Gable Edges	Maximum Uplift Pressure Coefficient at Ridge
5	0.9	1.4	1.0
10	1.2	1.0	1.2
20	0.7	0.8	1.2
30	0.7	0.7	1.1
45	0.7*		1.1

Table 7: Pressure Coefficients for Gable Roofs

* There is also the possibility of a downward pressure coefficient of 0.3 in this case.

Unit wind load = Design wind pressure x pressure coefficient

= q x C_p

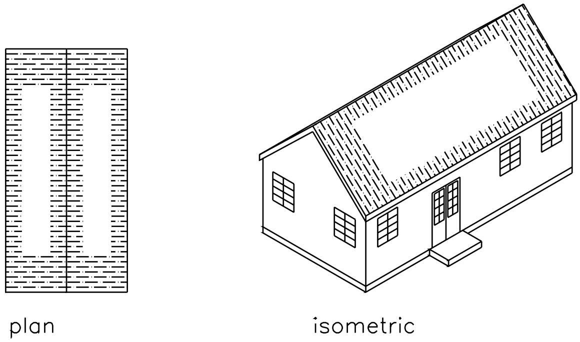


Figure 3: Edge Areas where the Higher Forces Apply

Note: The hatched areas in Figure 3 extend approximately 15% of the relevant dimensions of the sections of the roof.

Mono-pitch Roofs

For these roofs the maximum external pressure coefficient (C_{pe}) on the interior of the roof is 1.0 and at the edges 2.0. In most cases it would be necessary to add an upward internal pressure coefficient of 0.2 to these figures.

Unit wind load = Design wind pressure x pressure coefficient

= q x C_p

Eaves Overhangs

For these areas an upward pressure coefficient of 0.7 should be added to the appropriate external pressure coefficient (C_{pe}).

Unit wind load = Design wind pressure x pressure coefficient

= q x C_p

Balcony Roofs

Where the roof is at the same level as the main roof of the building, use an overall pressure coefficient (C_p) of 1.8 upward.

Where the building extends a storey or more above the balcony roof, use an overall pressure coefficient (C_p) of 0.9 upward.

For all cases, use an overall pressure coefficient (C_p) of 3.0 upward for the edges of the roof.

Unit wind load = Design wind pressure x pressure coefficient
= $q \times C_p$

SECTION 5

ALLOWABLE LOADS

Rafter Purlin Clip

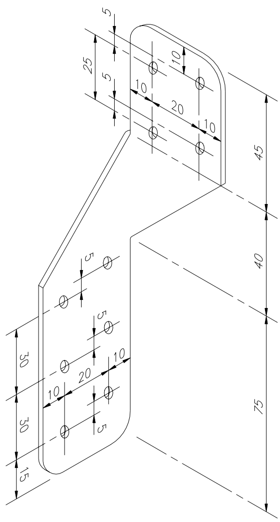


Figure 4: Rafter-purlin Clip

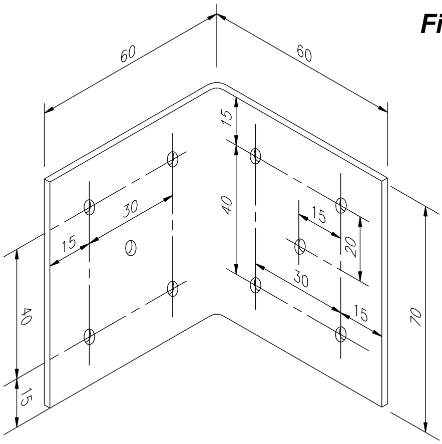
The permissible design load (unfactored) is 3 kN (670 lbf) using 3.75 mm nails and 2.8 kN (630 lbf) using 3.15 mm nails.

Notes:

1. It is important to use 4 nails per leg and to place nails in the holes closes to the inside corner of the clip.
2. Although both the stainless steel and the galvanised steel clips satisfy the requirements for the stated permissible design loads, the stainless steel clips have greater reserve capacity (about 10%).

Rafter Connector

Figure 5: Rafter Connector 90º



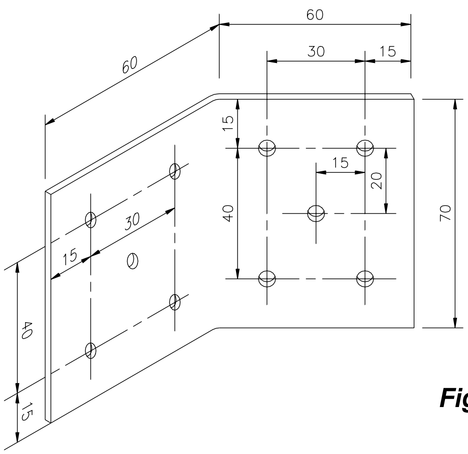


Figure 6: Rafter Connector 135º

The permissible design load (unfactored) is 3 kN (670 lbf) using 3.75 mm nails and 2.4 kN (540 lbf) using 3.15 mm nails.

Note:

1. Both the stainless steel and the galvanised steel clips satisfy the requirements for the stated permissible design loads.

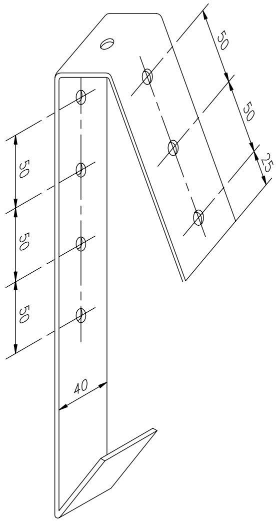
Truss Anchor

The permissible design load (unfactored) is 8.2 kN (1840 lbf) using 3.75 mm nails with the 0.87 mm stainless steel and 2.0 mm galvanised steel anchors. The permissible design load (unfactored) is 7.8 kN (1750 lbf) using 3.15 mm nails with the 1.0 mm galvanised steel anchors.

Notes:
Although both the stainless steel and the galvanised steel clips satisfy the requirements for the stated permissible design loads, the 2.0 mm galvanised steel clips have greater reserve capacity (over 20% generally). However caution should be exercised in relying on this extra capacity since the test results showed significant variation.

BRC normally supplies the truss anchor in 1.0 mm galvanised steel. For 1.0 mm galvanised steel in conjunction with 3.75 mm nails the designer may use a permissible design load (unfactored) of 8.0 kN (1795 lbf).

Figure 7: Truss Anchor



Multi-purpose Strap

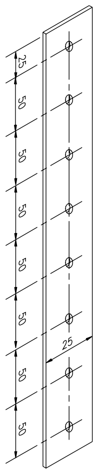


Figure 8: Multi-purpose Strap

The permissible design load (unfactored) is 2.6 kN (584 lbf) using 3.75 mm nails.

Note:
1It is intended to supply an amended version of this strap with a greater edge distance for the nails closest to the butt joint. This would increase the capacity of the multi-purpose strap.

Mending Plate

The permissible design moment (unfactored) is 0.88 kNm (7800 lbf-in) using 3.75 mm nails.

Note:
1This should only be used for nominal connections because the connection has much less capacity than the main members.

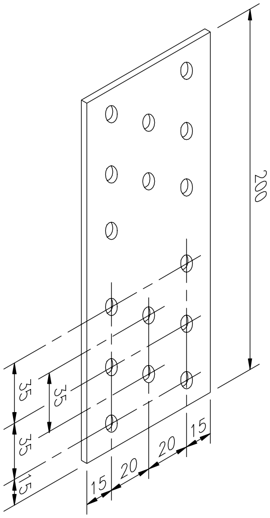


Figure 9: Mending Plate

Moment Connector

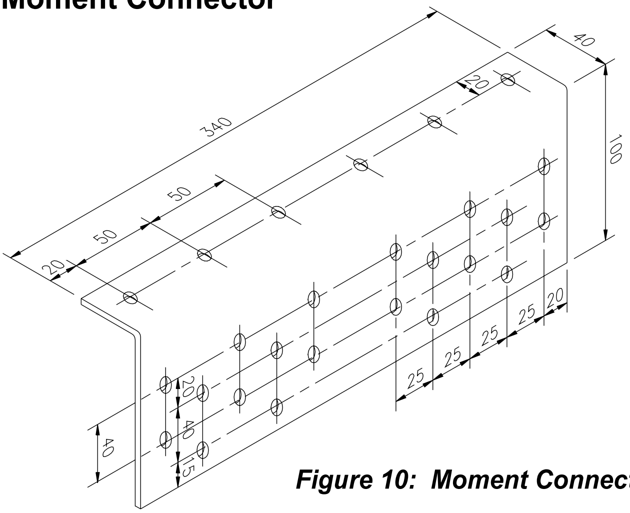


Figure 10: Moment Connector

The permissible design moment (unfactored) is 2.5 kNm (22,000 lbf-in) for a 140 mm ($5^{1}/_{2}$ in) deep beam.

Note:
With this connector, the deeper the beam the greater the permissible design moment.

APPENDICES

A - HISTORY OF THE CSTS TESTING PROGRAMME

Damage to lightweight roofs is a common feature when hurricanes strike. Loss of roof sheeting is one form of failure. Loss of roof structure is the other form of failure. On Christmas Day in 1974 Cyclone Tracy devastated the city of Darwin in Northern Australia. In particular, the 24-gauge, arc-tangent profile, galvanised roof sheeting commonly used in that city suffered almost 100% losses. Because of that dramatic event, an exhaustive programme of testing was initiated and carried out in Australia. Coming out of that initial programme was the establishment of the Cyclone Structural Testing Station (CSTS) in Queensland, Australia. The CSTS is now regarded as one of the foremost research centres for hurricane-resistant structural components in the world.

In the 1980s the IBRD/IDB Phase II Schools project was in progress in Barbados. The structural engineer for Government's project office, Dr Prevala Sivaprakasapillai of Sri Lanka, encouraged BRC West Indies Limited to arrange for a series of tests at CSTS on roof sheeting fasteners. That initial programme was completed in 1988. A further series of tests was conducted in 1993-4 by CSTS for BRC. Loads for this programme were provided by Consulting Engineers Partnership Ltd (CEP). In the meanwhile BRC had also consulted with the UWI[5] Civil Engineering Department with a view to getting that institution involved in a similar testing programme.

Other initiatives in hurricane-resistant construction which came out of BRC included hurricane shutters in 1994.

BRC held preliminary discussions with CEP on hurricane straps starting in June 1994. Negotiations between BRC and CSTS started from December 1995. CEP was appointed to advise BRC on the testing programme in January 1996.

Throughout the testing programme there was interaction between CSTS, BRC and CEP in order to resolve problems with materials (timber and nails), loads, adjustment of connectors and hole locations.

Of particular interest is the cyclic testing procedures used in this programme. The research carried out after Cyclone Tracy demonstrated clearly that traditional static load tests do not give reliable information on the performance characteristics of lightweight building components in hurricanes. Regrettably, the vast majority of tests worldwide still use static procedures rather than cyclic-dynamic loading.

The Cyclone Structural Testing Station completed its testing, and its reporting thereon, in August 1997. The Report TS496 "Cyclic Loading of BRC Timber Connectors" is available for examination, on request, at BRC West Indies Limited.

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5 The University of the West Indies, St. Augustine, Trinidad

B - GUIDANCE FOR SITUATIONS NOT COVERED IN THE MAIN SECTIONS OF THE DOCUMENT

Of necessity this document cannot cover the full range of situations likely to be met in practice. It is hoped that it can be seen to cover the use of BRC Hurricane Straps in the more common applications.

For complex situations such as:

- unusual or dramatic topography eg cliff edges
- unusual ground roughness eg middle of cities
- temporary structures or, on the other hand, critically important structures
- buildings or structures of irregular shape
- very flexible structures

guidance should be sought from a "wind engineer" or a structural engineer with specialist knowledge in wind forces on structures. Also, the standard BNS CP28 "Code of Practice for Structural Design"[6] provides comprehensive guidance on most situations likely to be met in practice. The appendices in BNS CP28 contain valuable background material to assist the interested practitioner in understanding the specific provisions in that standard.

Note:

This Manual covers design, selection and detailing when using BRC Hurricane Straps. It should be remembered that any structure or building, however well designed and built, needs maintenance if it is to perform adequately throughout its intended life. In particular, it is recommended that annual inspections of structures and connections be carried out in advance of the hurricane season so that incipient deterioration may be nipped in the bud.

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6 This is an official document of the Barbados National Standards Institute (BNSI). It is not currently on sale by the BNSI but photocopies are available from Mr. Tony Gibbs, Consulting Engineers Partnership Ltd, Tel:(246) 426-5930, Fax (246) 426-5935, Email concept@caribsurf.com

C - WORKED EXAMPLE

Reference should be made to Section 1, Guidance on the Use of the Manual, Page 10.

Single-storey house on a suburban ridge in Barbados
Symmetrical gable roof spanning a total of 11 metres (36 feet) with no overhang Roof pitch 20°
Rafters at 1.2-metres (4-ft) centres
Purlins at 0.9-metres (3-ft) centres

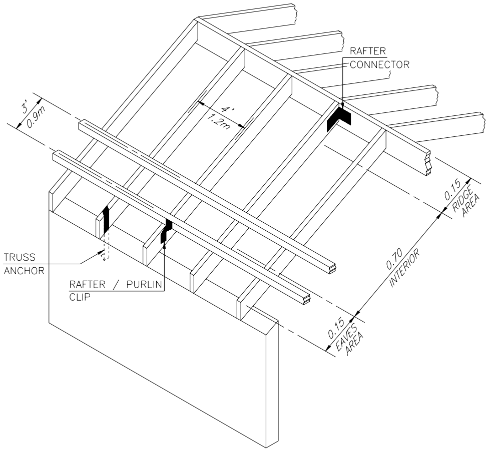


Figure 11: Roof Members Showing Connectors

Step 3 Basic wind speed (Barbados) = 58 metres/sec (130 mph)

- For ridge location Topography Factor (S_1) = 1.1
- For suburbs Factor for Ground Roughness and Height (S_2) = 0.76
- Design wind speed = 58x1.1x0.76 = 48.5 metres/sec (108 mph)
- Design wind pressure (q) = 1441 N/m^2 (30 lbf/ft^2)

Step 4 Uplift pressure (interior 70% of roof - see Figures 3 & 10) = 0.7x1441 = 1009 N/m2 (21 lbf/ft^2)

- Uplift pressure (eaves 15% of roof - see Figures 3 & 10) = 1.0x1441 = 1441 N/m^2 (30 lbf/ft^2)
- Uplift pressure (ridge 15% of roof - see Figures 3 & 10) = 1.2x1441 = 1729 N/m^2 (36 lbf/ft^2)
- Add internal pressure of 0.2x1441 = 288 N/m^2 (6 lbf/ft^2) to each of the above three figures

- Anchorage force at eaves end of rafter:

  [{(0.15x11/2) x (1441+288)} + {(0.7/2x11/2) x (1009+288)}] x1.2 = 4707 N (1058 lbf). This is less than permissible Truss Anchor load (one anchor is sufficient **(Step 5)**

- Anchorage force at ridge end of rafter:

  [{(0.15x11/2) x (1729+288)} + {(0.7/2x11/2) x (1009+288)}] x1.2 = 4992 N (1122 lbf). This is less than permissible Rafter Connector load (one connector is sufficient **(Step 5)**

- Anchorage force at rafter-purlin junction (at eaves):

  (1441+288) x0.9x1.2 = 1867 N (420 lbf). This is less than permissible Rafter-purlin Clip load (one clip is sufficient **(Step 5)**

- Anchorage force at rafter-purlin junction (at ridge):

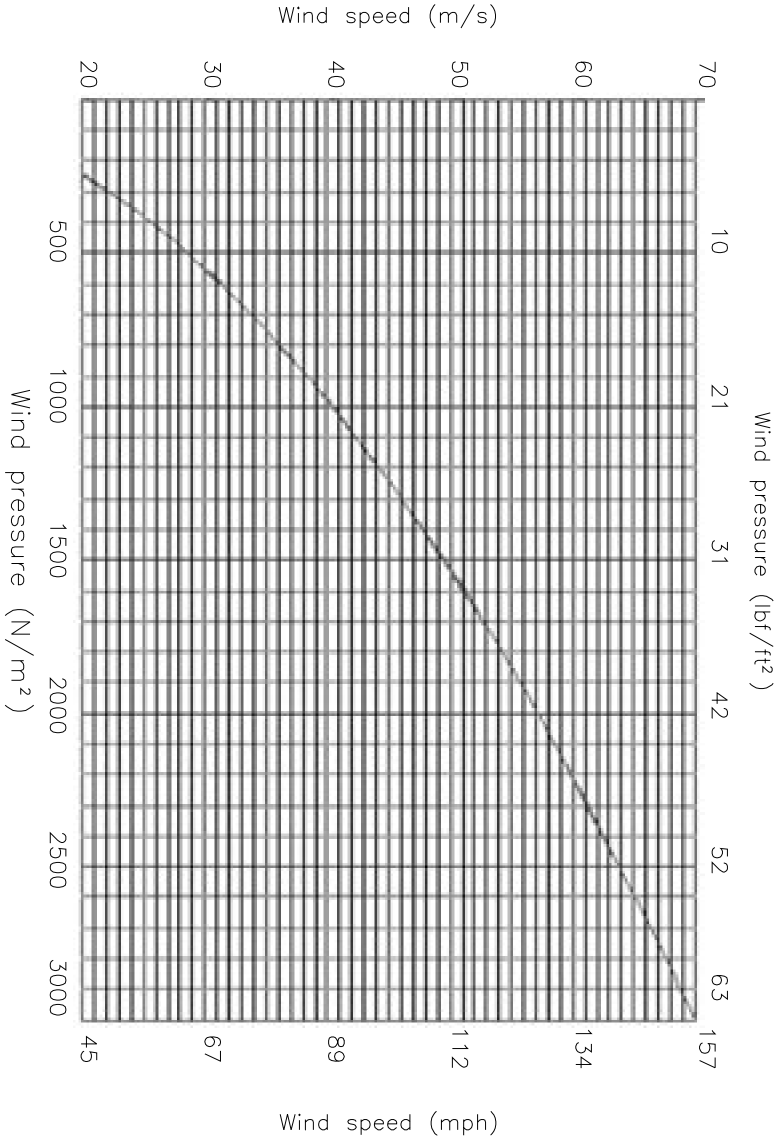
  (1729+288) x0.9x1.2 = 2178 N (490 lbf). This is less than permissible Rafter-purlin Clip load (one clip is sufficient **(Step 5)**

- Anchorage force at rafter-purlin junction (at interior):

  (1009+288) x0.9x1.2 = 1400 N (315 lbf). This is less than permissible Rafter-purlin Clip load (one clip is sufficient **(Step 5)**

D - WIND PRESSURES FROM WIND SPEEDS

For values of wind speed between the values given in Table 5, the graph which follows may be used to facilitate interpolations.



Graph 1: Wind Pressures from Wind Speeds