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Design And Practical Application Considerations For Woodblocking Attachment

Perimeter woodblocking serves a number of purposes, depending on the type of roof system. Its primary purposes are to provide (1) a secure termination point for roof membrane and (2) a solid surface for termination of metal flashings.

Some types of roof systems depend on perimeter woodblocking more than others. As an example, a ballasted thermoplastic system depends on woodblocking performance to a greater extent than an adhered thermoplastic bonded throughout.

Depending on the roof system, perimeter woodblocking experiences a number of different load combinations:

1. Wind striking a building on the windward side exerts a lifting load on perimeter flashings. These flashings are secured to the woodblocking and to the roof membrane. The lifting is transferred to the woodblocking attachment as a clockwise moment[1] which 'rolls' the woodblocking inward to the roof.
2. Wind passing over a roof system creates varying uplift pressures at the building perimeter. Woodblocking is situated at the building perimeter at the junction between to the roof deck and the vertical walls. Often times a gap exists at this point. Air blowing into the building can infiltrate this gap, creating internal pressure on the woodblocking, the roof membrane and flashing system. This internal pressure, coupled with the wind uplift influence, exerts a lifting force on the woodblocking securement points. The combined 'internal' and 'external' pressures attempt to lift the woodblocking from its point of attachment.
3. As ambient temperatures increase and/or decrease, roof membranes change dimension, creating a tensile load throughout the membrane. Depending on the building's structural configuration, this tensile load is transferred and absorbed a number of ways.

With varying wind speeds, membrane types, and wind gusts, the load conditions at perimeter areas are dynamic, creating particular concern for the mechanical securement of woodblocking. Moreover, air can infiltrate the underside of a roof membrane, either under a flashing component or at an exposed membrane edge, violating its bonds or attachment points. All of these factors play a part in the load conditions that are transferred to the woodblocking.

Factory Mutual Loss Prevention Data Sheet 1-49:

The most comprehensive document detailing woodblocking construction and securement is the Factory Mutual Loss Prevention Data Sheet 1-49[2], which states:

> "The majority of roof covering failures resulting from windstorms involve improperly designed or constructed perimeter flashings. A study of 145 Factory Mutual losses involving BUR showed that 85 (59%) occurred because the perimeter failed. Damage occurred at the edge of the roof in 29 additional cases, with no specific mention in the loss report of flashing failure."

The 1-49 document lists various recommendations for the attachment of woodblocking to concrete and metal decks.

Factory Mutual Research Corporation's (FMRC) primary woodblocking attachment recommendation for attachment to concrete is a minimum 1/2" diameter anchor bolt with a minimum 1" diameter bearing washer properly embedded into a structural substrate and recessed into woodblocking having a minimum 1 1/2" thickness. Anchors should be staggered if the blocking is wider than 6". Anchors should be spaced a maximum of 48" o.c., except at corner areas where the spacing is reduced to 24" o.c.

As an alternate, FMRC recommends 3/8" diameter anchor bolts spaced 32" o.c., and 16" o.c. at corner areas.

For steel decks, FMRC recommends 3/4" diameter bolts tapped into a structural steel member or into bar joists between 48" and 72" o.c., depending on existing perimeter conditions. As an alternate, FMRC recommends two rows of minimum #10 (0.183") diameter carbon steel fasteners with 5/8" o.d. bearing washers spaced 24" o.c.[3].

If the deck is neither structural concrete nor steel, FMRC recommends attachment with anchors of equivalent strength (See Table 1).

Of course, the pull-over value of the woodblocking over the fastener head and bearing washer must exceed the design load.

Manufacturers' Recommendations:

Manufacturers' guideline specifications reference a variety of attachment methods. The most common phrase found in guideline specifications is "attachment of woodblocking to resist a minimum pull-out resistance of 175 lbf/ft in all directions". This phrase has been subject to many interpretations. Some specifications have recently increased the minimum pull-out resistance value from 175 to as much as 350 lbf/ft in all directions. No safety factor relating to specific deck types is noted in any of the guide specifications reviewed.

The phrase "in all directions" is commonly interpreted as a force exerted on the woodblocking from any side or multiple sides. This could be the uplift force created by wind passing over the roof in combination with the rotation force created by the membrane's loss of dimension or it could be rotation caused by wind entering behind the fascia metal. The woodblocking anchors must withstand vertical tensile load, shear and shock loads, and an oblique load induced by the moment imposed on the woodblocking (See Figure 1).

Inspection of roof systems over the past fifteen years has revealed an upgrading of perimeter attachment, especially on ballasted systems. However, recent hurricanes and major windstorms have highlighted the damage potential of those systems without adequate woodblocking attachment.

It should be noted that the design velocity pressure calculations for ballasted roof systems are different from adhered or mechanically attached systems[4]. An averaging method for ballast applications allows for lighter ballast loads in the field and perimeters. Ballooning of the membrane could occur during ballast scour, creating a reliance on the woodblocking to hold the membrane in place.

This article proposes a woodblocking attachment formula for all deck types, utilizing an upgraded load force of 250 lbf per lineal foot of woodblocking. The upgraded load figure of 250 lbf is supported by recent FMRC proposals and data obtained from long term observations of roof systems subjected to high winds for 10 years or more.

1-49 Interpretations:

The 1-49 recommendations confirm a number of numeric resistance values relating to the various attachment options. The minimum recommended thickness of woodblocking is 1 1/2". Based on a recess of 1/2" to countersink the bolt and washer, the failure, in concrete decks, could be

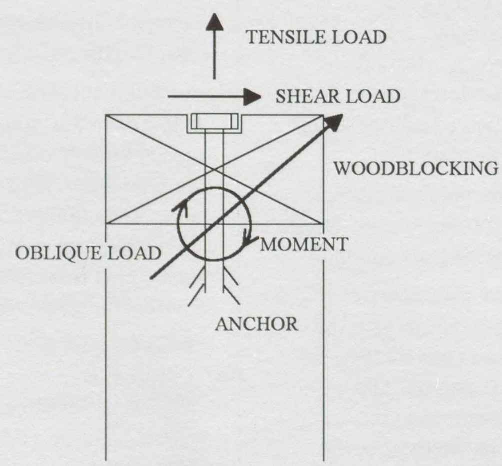

Figure 1. Loads which woodblocking anchors must withstand.

Fastener Type	Avg. Withdrawal Resistance (lbf)	Safety Factor	Fastener Spacing (inches)	Linear Uplift Resistance (lbf/ft)
½" Anchor Bolt	3,200	4 : 1	48	200
3/8" Anchor Bolt	2,400	4 : 1	32	225
¾" Steel Bolt	2,000	1.5 : 1	72	222
#10 Decking Screw	340	1.5 : 1	24	226

Table 1. Tensile withdrawal resistance of FMRC recommended fasteners for woodblocking attachment.

either the pull-out value of the fastener or the pull-over value of the wood over the bearing washer and fastener. This failure takes place in the region of 700 lbf, depending on the species of wood. The minimum attachment option for concrete decks is 1/2" diameter expansion anchors spaced 48" o.c. apart. Based on a 3,200 lbf average withdrawal resistance and a 4 : 1 safety factor, the design load of the anchor is 800 lbf. The pull-over value is then 88% of the withdrawal resistance design load.

Calculating the alternate steel deck method of attachment with a #10 (0.183") diameter steel deck fastener, the average withdrawal resistance value in 22 ga. decking is 340 lbf. Applying a 1.5 : 1 safety factor, the design value is calculated at 226 lbf — well below the 500 lbf pull-over value of the 5/8" bearing washer recessed 1/2" into southern yellow pine.

Both the pull-out and pull-over values are important in the design calculation. Typically, thin woodblocking, such as 3/4" to 1" x 4" wide woodblocking, is installed with 1/4" expansion anchors or concrete screws placed 18" to 24" o.c.. The head of the anchor is typically .450" to .500". The pull-out value is 1,000 lbf (±250 lbf) and the pull-over value is virtually identical.

Advances in the fastening industry have generated a number of options that were not available at the time of writing the LPDS 1-49. These options can provide the same degree of security outlined in the LPDS 1-49 if an appropriate safety factor is applied to all fasteners and deck combinations.

The type of roof system applied should also play a roll in the withdrawal resistance design value of woodblocking fasteners. It is reccommended that all ballasted and mechanically attached thermoplastic roof systems increase the fastener's design withdrawal resistance value by 20% to compensate for the additional load conditions that are placed on these systems. Long term system observation indicates that a higher number of woodblocking failures occur in these types of systems.

This recommendation is based on the observation of 92 systems of various types installed for a period of not less than 10 years[5]. Observed failures were caused by:

- deck and fastener corrosion;
- loss of deck integrity due to water infiltration;
- inferior fastener installation;
- poor quality lumber; and
- improper woodblocking placement.

The following recommendations are based on laboratory and field testing. Pull-over values have been calculated taking an average of pressure treated, southern yellow pine and Douglas fir. Recesses were drilled with a flat "paddle bit and electric drill motor".

Concrete:

The fastener design load should not be less than 250 lbf/foot after application of a 4 : 1 safety factor. This value should be increased by 20% (to 300 lbf/foot) for ballasted systems. The pull-over value should be not less than 125% of the design load. If less, a larger bearing washer should be added to the assembly to meet this requirement.

A number of fasteners can be used to achieve these requirements. The fastener spacing should be reduced by one-half at corner areas. The dimensions of corner areas should be calculated in accordance with FMRC Loss Prevention Data Sheets or American Society of Civil Engineers (ASCE) 7-88, but should not be less than 10 feet (See Table 2).

If the compressive strength of the concrete is less than 2,500 psi or the concrete thickness is less than 2 1/2", an on-site test should be carried out to confirm fastener performance.

The thickness of the woodblocking should be not less than 1 1/2" if a bearing washer is required. If the woodblocking thickness is greater than the insulation thickness, a tapered edge may be installed to match the height of the woodblocking height.

Power Actuated (PAT) fastening is not recommended for woodblocking attachment. The industry accepted safety factor of 8 : 1 would require a large quantity of fasteners to meet the design criteria. Moreover, the PAT industry does not recommend the application due to the dynamic load conditions expected at woodblocking attachment points and the potential safety issues that arise should the woodblocking come loose, allowing blocking, sheet metal and, possibly, ballast to fall to the ground.

Anchor Type	Diameter	Spacing	Ballasted / Thermoplastic
Wedge Anchor	½"	40" o.c.	32" o.c.
Sleeve Anchor	⅜"	30" o.c.	24" o.c.
Threaded Concrete Anchor	¼"	12" o.c.	9" o.c.
Drive Anchor	¼"	12" o.c.	9" o.c.

Table 2. Anchor types, sizes and spacing criteria for concrete decks.

Steel Deck:

Standard diameter roofing fasteners are #12 (0.209") and #14 (0.240"). These fasteners have an average withdrawal resistance from 22 ga. steel of 425 lbf and 480 lbf, respectively. These values are based on average withdrawal resistance values recorded by Factory Mutual Research in new metal decking. The industry accepted margin of safety of 1.5 : 1 and the design load requirement for applications without an additional bearing washer is 125%. Following the LPDS 1-49 attachment pattern, standard "roofing screws" will provide adequate attachment in 18-22 ga. decking. The pull-over value of a 0.45" diameter head through 3/4" southern yellow pine is 400lbf.

Using a #12 fastener, the average withdrawal resistance is 425 lbf. Dividing by the industry accepted safety factor and multiplying by the additional bearing washer design requirement yields:

$$(425 \div 1.5) \times 1.25 = 354 \text{ lbf}$$

This design withdrawal resistance value is less than the pull-over value of 400 lbf noted above (354 lbf ≤ 400 lbf); therefore, the #12 fastener has sufficient withdrawal resistance to be used on 22 ga. steel decking.

Similarly, using a #14 fastener, the withdrawal resistance is 480 lbf.

$$(480 \div 1.5) \times 1.25 = 400 \text{ lbf}$$

This design withdrawal resistance value is equal to the pull-over value of 400 lbf noted above; therefore, the #14 fastener also has sufficient withdrawal resistance to be used on 22 ga. steel decking.

Where woodblocking is attached perpendicular to the deck flute, it is recommended that the attachment be staggered in the high flanges of the deck at spacing of 12" o.c., and 6" o.c. in corner areas. Similar spacing should be followed when woodblocking runs parallel to the flutes with the addition of a minimum 1/4" diameter self-tapping screw, through the woodblocking and metal deck, into the bar joist or a steel angle with spacing not greater that 7' o.c.. Since the quality of weld is not known, especially in re-roof applications, it is possible that the deck is poorly attached to the structural members. Loads transferred to the woodblocking from the membrane could lift the decking from the bar joists. As a solution, the decking can be mechanically attached to the bar joists with a self-tapping fastener or a #5 pt. self-driller with a minimum 7/8" bearing washer. This is good precaution in new construction as well as re-roof projects.

If the steel deck thickness is less than 22 ga., an on-site test is needed to determine accurate withdrawal resistance values. A field test is recommended in all retrofit applications to confirm the average withdrawal resistance value.

The following formula is suggested for light gauge metal decks:

Xmn x FS = Xfst ÷ MS

where:

Average fastener withdrawal resistance = Xfst = known;
Margin of Safety = MS = 2;
Fastener Spacing = FS = unknown; and
Minimum withdrawal resistance = Xmn = known[6].

FMRC does not recommend the use of plastic fasteners for attachment of woodblocking.

Available for use are lightweight metal deck fasteners that can achieve withdrawal resistance values as high as 500 lbf. As an alternate or supplement to deck fastening, self-tapping fasteners or bolts can be installed into bar joists or steel angles. Nuts and bolts should be minimum grade 5, hot dipped galvanized, installed with flat and lock washers. Self-tapping screws should be stainless steel or coated with a corrosion resistant process in compliance with the FMRC 4470 protocol.

Since the bar joist spacing on a lightweight metal deck is usually 48" o.c. or less, sufficient attachment points are available for securement to the bar joists only. All woodblocking ends should be secured into the deck to avoid lifting.

As with standard metal decks, woodblocking attached parallel to the ribs should be secured to bar joists or to steel angles or the decking should be mechanically secured to the bar joists with self-tapping or self-drilling fasteners.

"Lightweight" Decks (Gypsum, Tectum, Lightweight Insulating and Cellular Concrete):

Lightweight decks present a difficult challenge. The low density of the deck and the load variations create the need for careful consideration of attachment methods.

In general, the deck should not be used as an attachment substrate unless the chosen anchor can clamp to the underside of the deck or attach to a structural member, and will achieve not less than 425 lbf ultimate load. A margin of safety of 4 : 1 should be used in the formula:

Xmn x FS = Xfst ÷ MS

where:

Average fastener withdrawal resistance = Xfst = known;
Margin of Safety = MS = 4;
Fastener Spacing = FS = unknown; and
Design withdrawal resistance = Xmn = 250 lbf/lineal foot

As an example, consider a fastener with an average withdrawal resistance of 425 lbf. Inserting appropriate values into the above equation yields:

$$\left(\frac{250 \text{ lbf}}{\text{lineal foot}}\right) \times (?) = \left(\frac{\frac{425 \text{ lbf}}{\text{fastener}}}{4}\right)$$

Solving this equation for (?) yields:

$$(?) = \left(\frac{106.25 \text{ lbf}}{\text{fastener}}\right) \times \left(\frac{\text{lineal foot}}{250 \text{ lbf}}\right) =$$

$$\frac{0.425 \text{ lineal feet}}{\text{fastener}} = \frac{5.1 \text{ lineal inches}}{\text{fastener}}$$

The fastener spacing would be one fastener every 5 inches. Fasteners should be staggered along the blocking to avoid a single stress line. As an alternate, self-tapping fasteners can be installed into the steel angle, bar joists or bulb T's.

Toggle bolts are not recommended due to the large hole required for installation and the reliance on a small trunion nut holding the toggle rod to the wing. The large holes create a potential for horizontal movement of the woodblocking if the membrane transfers any tensile load to the perimeter areas. They also allow greater initial internal pressure to the underside of the blocking. While some trunion nuts are strong, many others are weak, significantly reducing anticipated withdrawal resistance.

A second alternative is to attach the woodblocking to the vertical wall (See Figure 2). The blocking should have a minimum thickness of 1 1/2" and should be attached not less than 12" o.c.. Each anchor should have a minimum 800 lbf withdrawal resistance. Threaded concrete anchors are preferred since the blocking will be drawn tight to the substrate. "Hammer-in" expansion anchors such as drives or spikes may also be effective in high density concrete or masonry. Expansion anchors are static anchors holding the blocking in place; however, they will not draw the blocking to the substrate.

Pull-over values of 1/4" diameter threaded fasteners, in combination with the threading of the wood, is usually well in excess of 125% of the withdrawal resistance value of the fastener. The placement of the woodblocking, as well as the type of anchors used, can play a significant role in its performance.

For an example, consider that a building's structural roof top termination point is at the same level as the wall termination. The tensile load created by the membrane's dimensional changes is transferred directly to the woodblocking attachment points, pulling the woodblocking towards the center of the roof (See Figure 3).

If structural roof top termination sits below the wall termination, the woodblocking is commonly attached through a top course of masonry block. An anchor bolt is used to attach the woodblocking through the filled cavity of a masonry block along the top course of block. In this case, the tensile load is transferred through the length of the anchor bolts using the bolts as levers. This creates a moment at the base of each anchor bolt.

Cases have arisen in which the

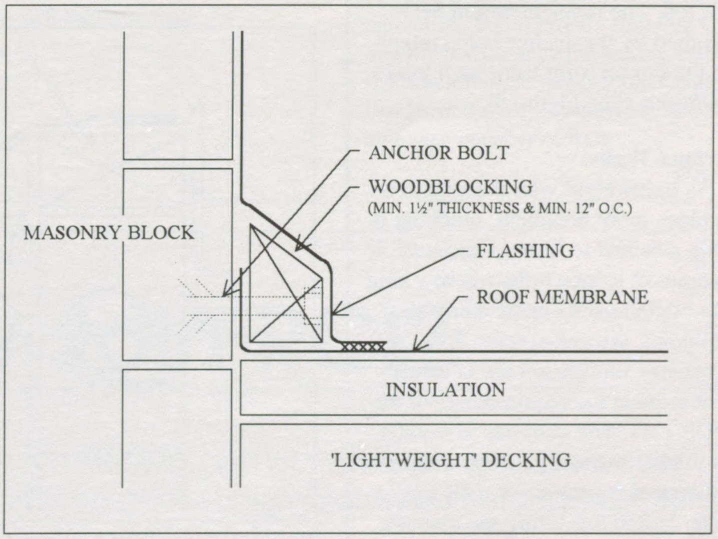

Figure 2. Woodblocking attachment to vertical wall.

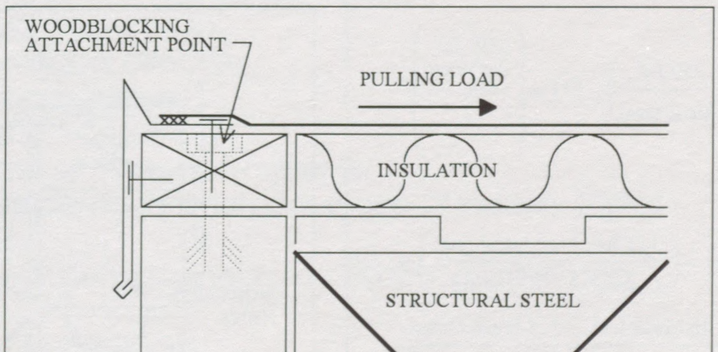

Figure 3. Tensile load transferred directly to woodblocking attachment point.

anchor bolts used to attach the woodblocking did not extend below the structural roof deck. The moment described above is transferred from the base of the anchor bolt to the mortar joint between the first and second course of masonry block. This joint is unable to absorb and resist this moment and the joint fails, creating a gap at the mortar joint (See Figure 4).

It has been recommended that, in these situations, the anchor bolts used to attach the woodblocking through the top course of masonry block extend below the structural roof top. The moment would be absorbed by the anchor bolts, relieving the mortar joint from such load conditions (See Figure 5).

Parapet Walls:

As lightweight wall construction becomes more prevalent, blocking is being attached to light gauge steel. It is common to attach the top blocking with buglehead #7 or #8 diameter, drill point, drywall screws. Even at 6" centers, this anchorage is insufficient to meet the requirements of the LPDS 1-49. The steel cap is usually not thicker than 24 ga.. The average withdrawal resistance of a #8 self-driller is 230 lbf. Using the formula noted above with a margin of safety of 2 yields the following results.

$$\left(\frac{250\text{ lbf}}{\text{lineal foot}}\right) \times (?) = \left(\frac{\frac{230\text{ lbf}}{\text{fastener}}}{2}\right)$$

$$(?) = \left(\frac{115\text{ lbf}}{\text{fastener}}\right) \times \left(\frac{\text{lineal foot}}{250\text{ lbf}}\right) =$$

$$\frac{0.46\text{ lineal feet}}{\text{fastener}} = \frac{5.5\text{ lineal inches}}{\text{fastener}}$$

The fastener spacing would be one fastener every 5.5 inches.

General Recommendations:

1. All woodblocking should be pre-drilled prior to attachment. Metal deck fasteners will thread the wood prior to penetrating the deck. A 13/64" pre-drilled hole will clear the threads of a #14 (0.240") deck screw and provide optimum pull-over of the fastener head.
2. A 1/4" gap should be left between each section of woodblocking.
3. A fastener should be placed within 3" of the end of each section of woodblocking.
4. Woodblocking should not overhang the deck any more than 2". In such cases, a nominal 2" x 8" block should be used to allow for a double row of staggered fasteners.
5. All woodblocking should be salt pressure treated to Wood Preservatives Institute LP-2, or better.
6. Nails used to secure multiple nailers should be long enough to penetrate the base woodblocking 11/4". Double rows spaced 24"

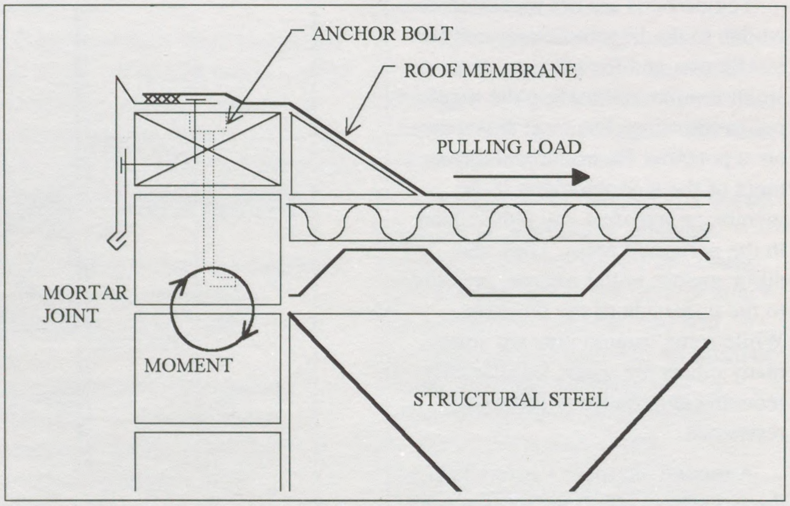

Figure 4. Tensile load transferred through length of anchor bolts creating moment at base of anchor bolts.

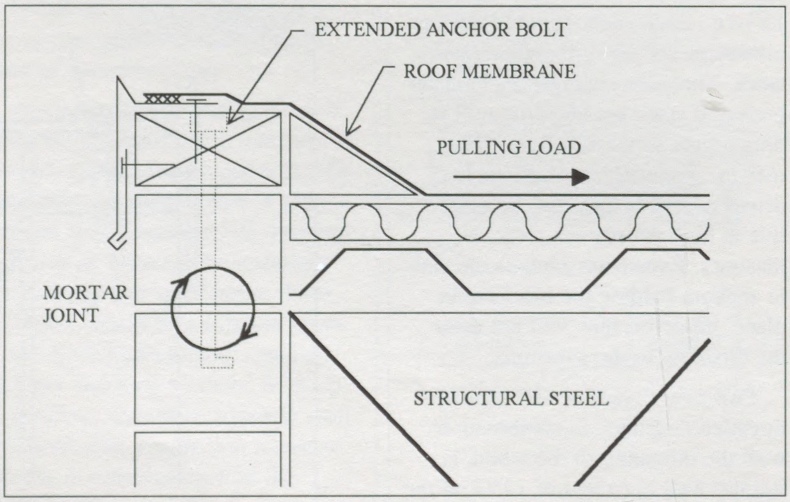

Figure 5. Extended anchor bolts of sufficient length to absorb moment created by tensile load.

o.c., staggered are recommended. Nails should be installed at an angle to increase withdrawal resistance. Minimum #12 diameter wood screws or roofing screws are recommended for ballasted or thermoplastic systems and parapet applications.

7. Woodblocking should be examined for warpage and splits prior to installation.

Properly installed woodblocking will provide security for both the roof and flashing systems. Hurricanes Hugo and Andrew confirmed that perimeter protection is essential to the performance of the roof and flashing systems in high winds. In addition to wind induced forces, the forces exerted by the roof system components need to be considered.

[1]The measure of a force with reference to its effect in producing rotation.

[2]Factory Mutual Research Corporation, Norwood, Mass., June, 1985.

[3]Carbon steel fasteners should be coated to meet corrosion resistance minimums published in the FMRC 4470 protocol.

[4]Kind, R.J., *Loss Prevention Data Sheet 1-29*, FMRC and Wardlaw, R.L., *Design of Rooftops Against Gravel Blow Off*, FMRC

[5]Murphy, Colin, "A Long Term Evaluation of Mechanical Attachment of Thermoplastic Systems", *Interface*, Nov., 1992.

[6]For Standard Roof Systems:
Xmn = 250 lbf/lineal foot
For Ballasted or Thermoplastic Systems:
Xmn = 300 lbf/lineal foot

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Colin Murphy, a Registered Roof Consultant, has been involved in the roofing industry for over 18 years. He is currently a principal of Trinity Engineering, Inc., a firm specializing in roof system design; systems testing and forensic analysis of roof systems and components. Mr. Murphy has been published in most of the national roofing publications, including *Interface* and *Proceedings of the Ninth Conference on Roofing Technology*. He is presently retained by Dade County for the revision of the South Florida Building Code and methods of material testing within the South Florida jurisdiction. Colin resides in Seattle, Washington, and is an active member of RCI.