# ROOF ANCHORAGE

## Table of Contents



## List of Figures



## List of Tables

## 1.0 SCOPE

This data sheet provides recommendations for (a) anchoring roof members and columns of wood roof buildings; and (b) fastening steel, aluminum, plastic and corrugated cementitious panels to roof purlins of older style steel-frame buildings. For recommendations on the construction of modern metal roof systems, refer to Data Sheet 1-31, *Metal Roof Systems*.

This data sheet applies geographically to the United States, Canada and Puerto Rico.

### 1.1 Changes

June 2009. Editorial changes were made for this revision.

## 2.0 LOSS PREVENTION RECOMMENDATIONS

### 2.1 Construction and Location

2.1.1 Design the roof and anchorage for all new construction in accordance with FM Global Loss Prevention Data Sheets (See Section 4.0).

2.1.2 Where perimeter nailers are secured to concrete block walls, fill all cores and voids in the concrete block walls with concrete grout down to the depth of the anchor bolt (see Fig. 11).

## 3.0 SUPPORT FOR RECOMMENDATIONS

### 3.1 General

Insufficient roof anchorage has been the major reason for wind damage to plank-on-timber and, to a lesser extent, board-on-joist buildings. Though few plank-on-timber buildings are being constructed today, a large number are still in service.

Some board-on-joist buildings are still being constructed today for various purposes. Wood frame buildings are continually being built for dwellings, apartments, shopping centers, educational buildings and so forth. In some cases, the roof is anchored by toenailing its framing members to the eave plate. Stronger anchoring devices such as shear connectors, steel straps or other connectors in which the fasteners are in shear rather than in tension, are needed when the wind design pressure in the field of the roof exceeds 30 psf (1.44 kPa) per Data Sheet 1-28, *Wind Design*. Even wood roofs in the fringe area of a tornado may be kept from lifting if anchored as recommended in this data sheet.

Many buildings have a steel frame to which a ‘‘skin’’ of corrugated metal, plastic or asbestos sheets is attached. In some cases, the sheets are not attached with a sufficient number of fasteners, and strong winds can cause the fasteners to fail.

For the purposes of this document only, Zone 2 is defined as having field of roof wind pressures greater than 30 psf (1.44 kPa) and less than or equal to 45 psf (2.14 kPa). Zone 3 includes pressures greater than 45 psf (2.14 kPa).

#### *3.1.1 Plank-On-Timber Buildings*

An unanchored roof is easily discovered by inspecting of the places where roof loads are transmitted to the walls and columns. These bearing points will show no sign of hardware, such as steel straps, through bolts and lag screws. Nails and spikes toenailing heavy members to each other do not provide adequate anchorage.

The roof is secured at the perimeter on many plank-on-timber buildings by a brick parapet or timbers attached to the wall. Elsewhere, the designers may have relied on the dead load of the thick wood planking, built-up roof covering and gravel to hold the roof down. The members merely rest on the ones below or on cast-iron hardware such as a column cap or pintle (Fig. 1).

Recommended anchorage for plank-on-timber buildings is illustrated in Figs. 2 through 8 and Table 1. These details may not be adequate for all buildings, however.

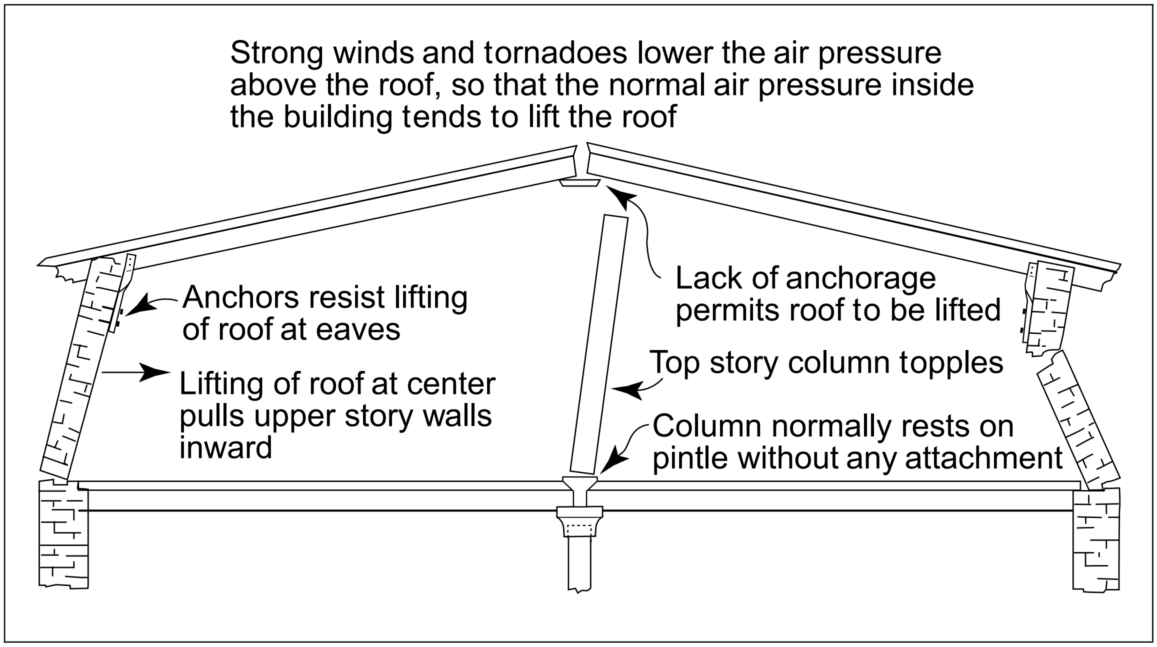


*Fig. 1. Roof anchored at walls, but not at columns*

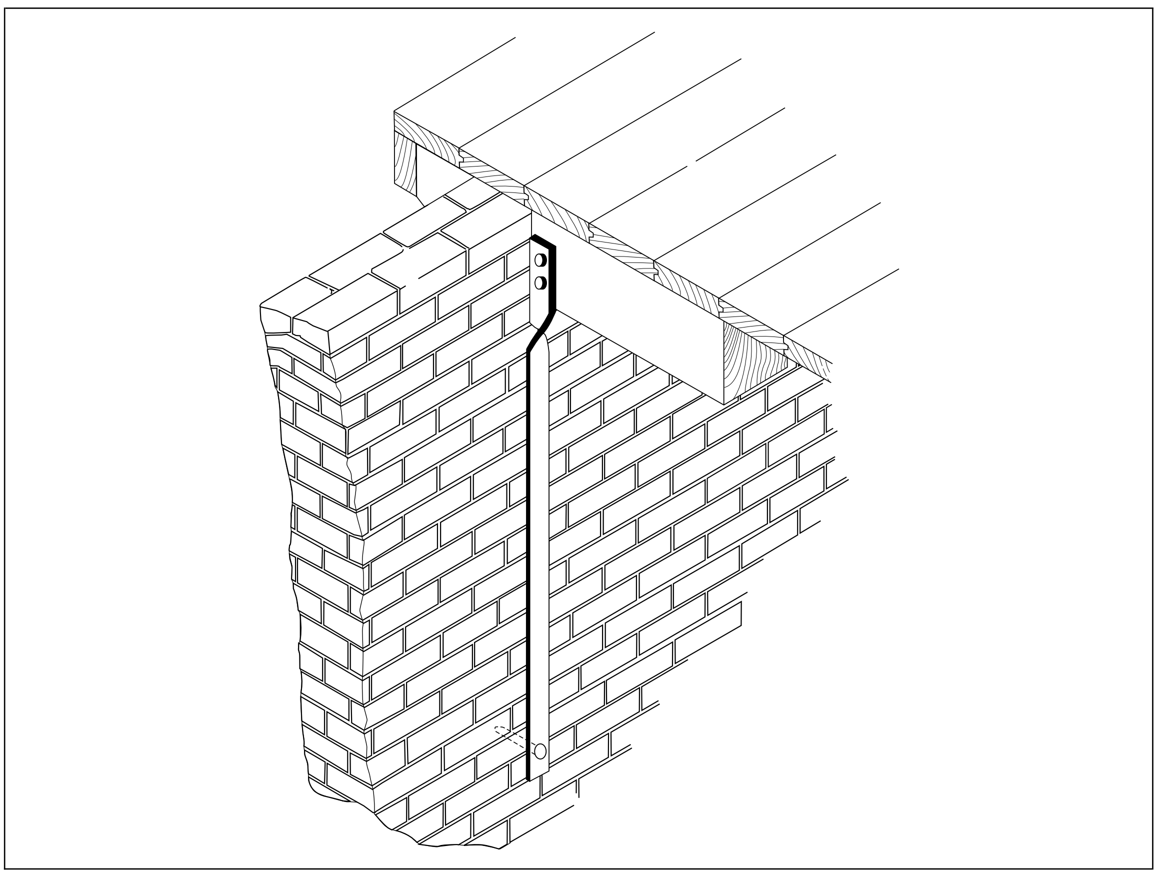

*Fig. 2. Plank-roof timber anchored to solid wall*

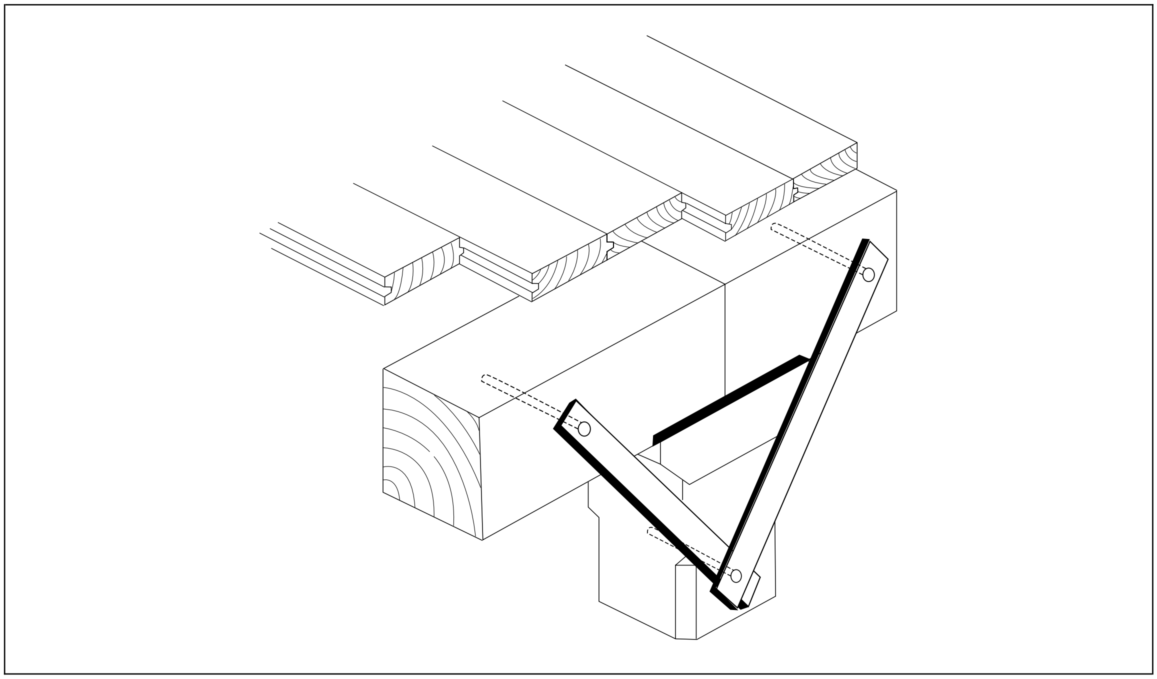

*Fig. 3. Roof timber anchored to column, plank-on-timber construction*

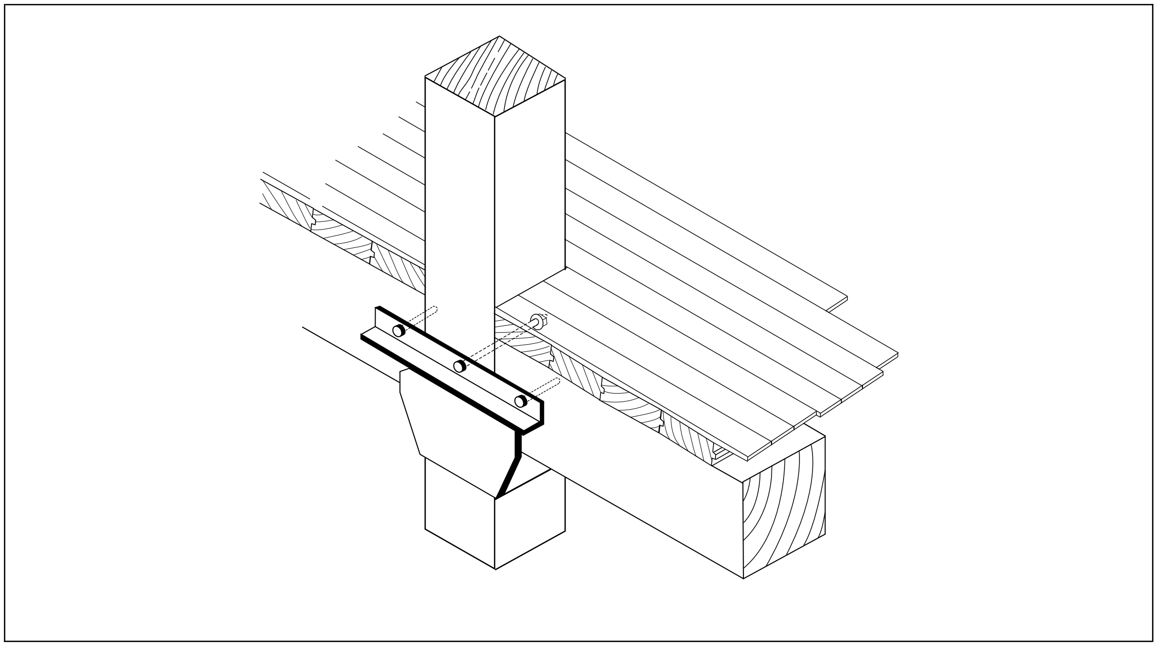

*Fig. 4. Base of roof column anchored to floor timber, multistory plank-on-timber construction*

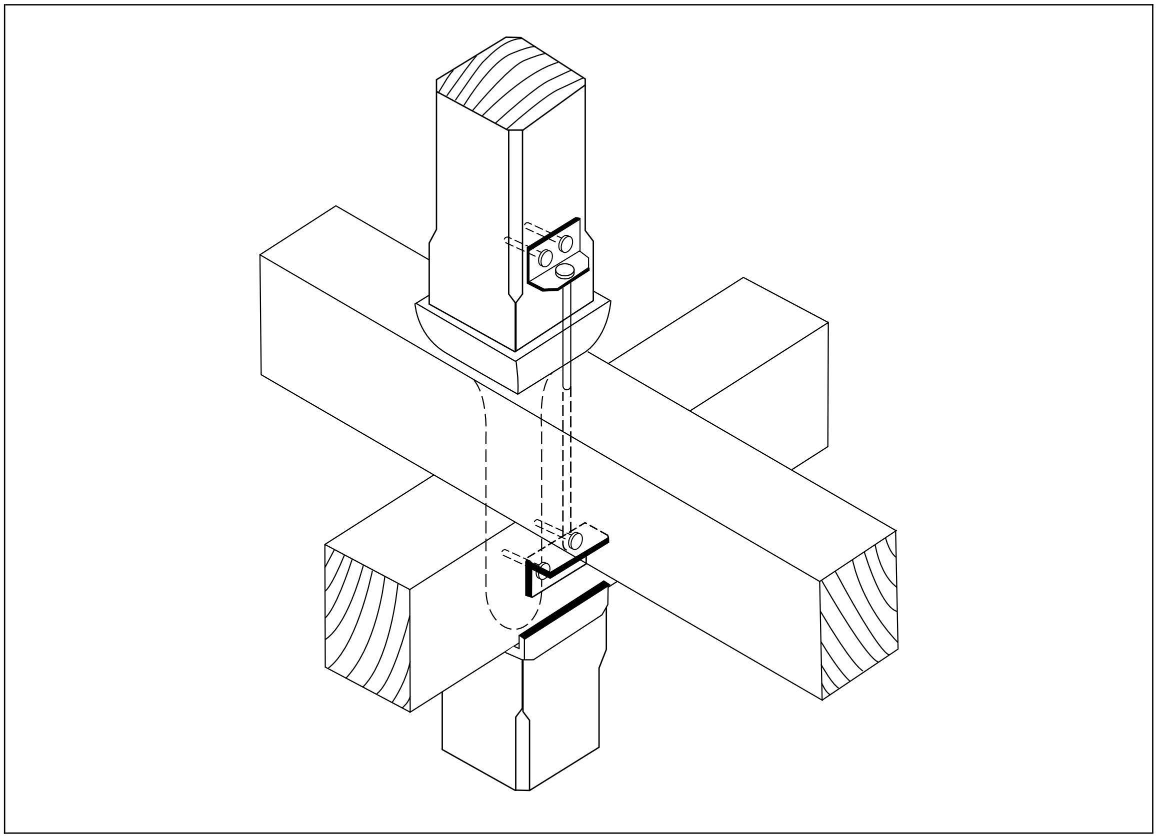

*Fig. 5. Anchorage of base of roof column with pintle, multistory plank-on-timber construction*

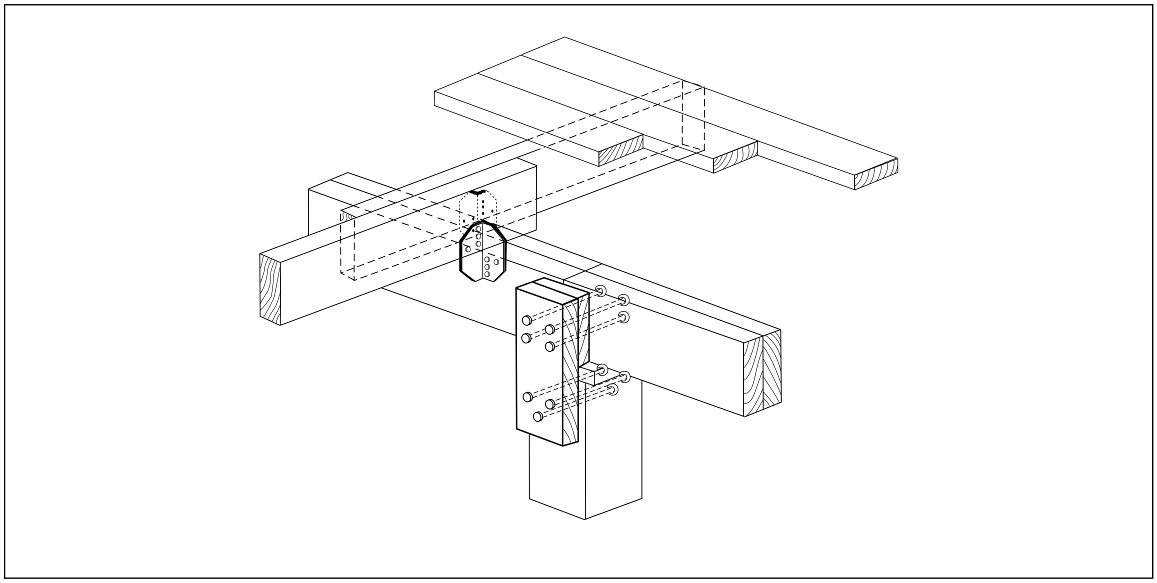

*Fig. 6. Roof joists anchored to girder, and girder anchored to column*

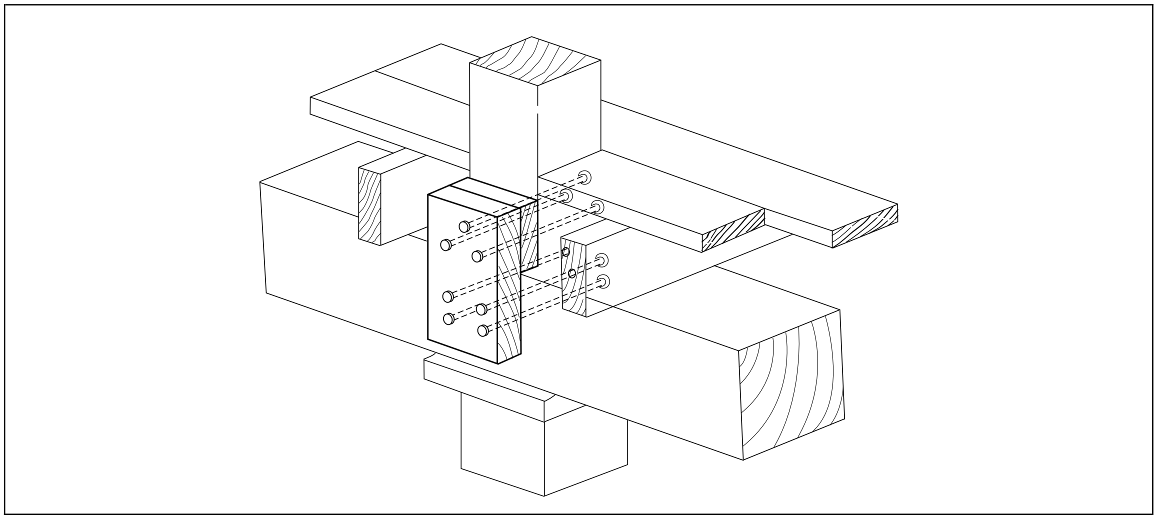

*Fig. 7. Anchorage at base of roof column in multistory building with joisted floors*

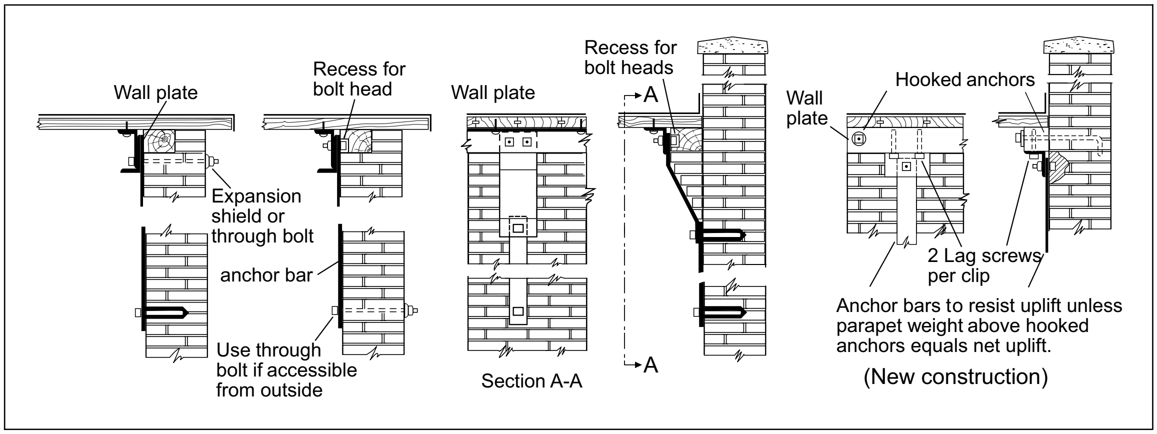


*Fig. 8. Endwall anchorage for plank-on-timber roofs*

*Table 1. Type and Size of Hardware to be Used in Figs. 2–8*

| *Fig.* | *Anchor (Top & Bottom) No. & Type* | *Size (in.)* | *t (in.)* | *Upper Fastener* | | | *Lower Fastener Fig.* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Dia (in.)* | *Lag Bolts** | *Through Bolts* | *Dia (in.)* | *Lag Bolts* | *Through Bolts* | *Expansion Shield* |
| 2 | 1 strap | 2-½ | ⅛ | ⅝ | 2 | | ⅝ | | | 1-½ in |
| 3 | 2 straps | 2-½ | ⅛ | ⅝ | 2 | | ¾ | 1 | | |
| 4 | 2 angles | 2-½ × 2-½ | 3⁄16 | 6 lag screws (end — ⅝ in. dia center - ¾ in. dia.) or 3 through bolts | | | | | | |
| 5 | 4 angles 2 rods | 2-½ × 2-½ ⅝ | 5⁄16 | ⅝ | 4 | | ⅝ | 4 | | |
| 6 | wood plank | | 2-3 | ⅝ | | 4 | ⅝ | | 3 | |
| 7 | wood plank | | 2-3 | ⅝ | | 3 | ⅝ | | 4 | |
| 8 | lag screws ⅝ in. dia expansion shields ½ in. dia straps 2-½ × ⅛ in., angles 2-½ × 2-½ × 5⁄16, hooked anchors ⅝ in. dia. | | | | | | | | | |
| in. ⅛ 3⁄16 5⁄16 ½ ⅝ ¾ 2 2-½ 3 | | | | | | | | | | |
| mm 3.2 4.8 7.9 13 16 19 51 64 76 | | | | | | | | | | |

*Through bolts may be used in lieu of lag bolts or expansion shields.

Note: Alternate details for anchoring the roof are acceptable providing they are strong or stronger than the details shown in this data sheet in Figs. 2 through 8.

''Through bolts'' pass through a wall or beam and have angles, straps or washers on each side to reduce bearing pressures. They make a better connection than lag screws and are necessary when filler blocks are used to build out the face of one member to make it flush with the attached member (Figs. 6 and 7). Lag screws may not be effective when filler blocks are used because they are likely to pull out.

All unanchored bearing points, such as at sidewalls, end walls and beam-to-column junctures, should be anchored. Omission of anchorage in any one place may result in overstressing and failure.

Sidewall anchorage is shown in Fig. 2. Straps are placed at each roof timber, and connection to the masonry wall can be by an expansion shield or through bolt. At the end wall of the building, straps may be secured to the wood timber and wall in a similar manner (Fig. 8). If the wood timber shown is missing, an auxiliary one may be provided. Anchors can be spaced the same as for side-walls or 8—10 ft (2.4—3.0 m) apart. Anchorage to the wall is not needed when the building has a masonry parapet at least 2 ft (0.61 m) high. When the columns are cast iron or steel (Figs. 3 through 7), anchors may be connected by drilling through the metal and tapping or, if steel, by welding.

When steel anchorage members will be subjected to a corrosive atmosphere, they may be galvanized or similarly treated to prevent corrosion.

When the building contains heavy, vibrating machinery, expansion shields attached to masonry may pull out. This can be prevented by the use of through bolts. If sizable holes have been made through floors to install anchors at columns and walls, they should be filled with wooden plugs or oakum to prevent the passage of fire or leakage of water.

### *3.1.2 Board-On-Joist Buildings*

The roof-carrying members are trusses, arches, etc., that span the building width, or wood beams that rest on intermediate columns. Joists or purlins generally are parallel to the longest building dimension. Wind uplift forces on the roof are restrained mainly by the roof's dead load and the connections where carrying members are attached to the building wall. Small credit may be given to resistance (if any) by the intermediate columns, provided the beams are anchored to the columns and the columns to the floor below. Anchorage is needed where velocity pressures exceed 30 psf (1.44 kPa) (see Data Sheet 1-28) and may be in accordance with Table 2 and Figs. 9 and 10.

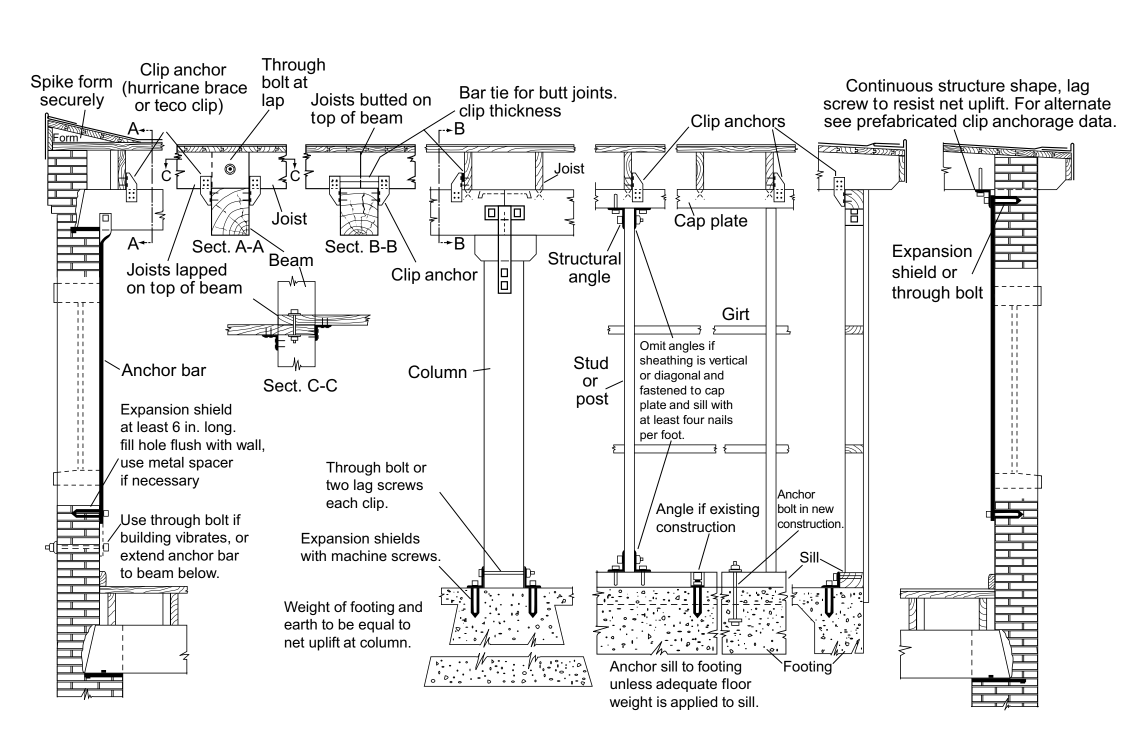


*Fig. 9. Anchorage for board-on-joist roof (roof slope 0°-10°)*

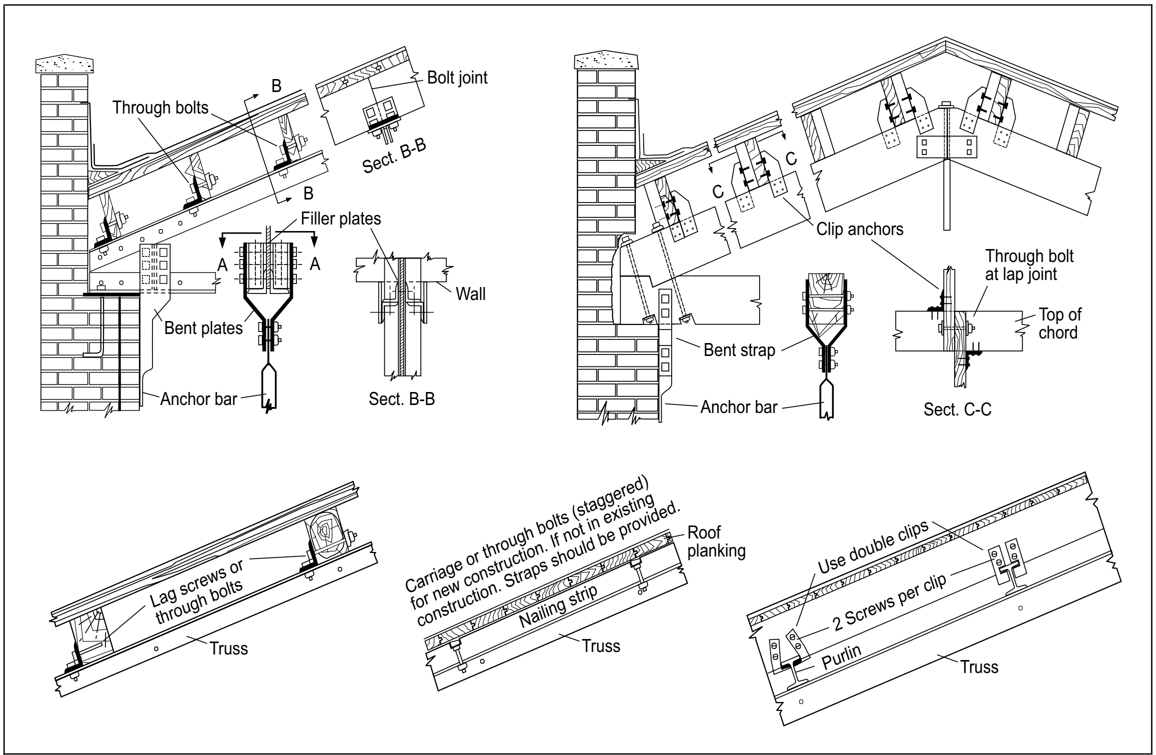


*Fig. 10. Anchorage for board-on-joist roof (roof slope 10°-30°)*

*Table 2. Roof Anchorage—Board-on-Joist Buildings*

| *Roof Slope* | *Zone** | *Eave and Ridge* |
|---|---|---|
| 0°–10° | 2 & 3 | Special anchorage (Fig. 9) |
| 10°–30° | 2 & 3 | Special anchorage (Fig. 10) |

*Data Sheet 1-28, *Wind Design*.

### *3.1.3 Connection to Concrete Block Wall*

In new construction, the roof may be anchored by setting the bolts and filling the cores of the blocks to the bolt depth with concrete (Table 3 and Fig. 11). When a bond beam (see Appendix A for definition) is installed at the top of the wall, anchorage may be obtained by hooking the bolt around one of the lower reinforcing bars in the beam. In existing construction, if no bolts are present, a deficiency exists. This can be corrected by concreting in new bolts or connecting the roof to the wall in a manner similar to that shown in Fig. 2.

*Table 3. Length of Anchor Bolt Embedment for Buildings With Concrete Block Walls—in. (mm). See Figure 11.*

| *Building Width* | *20 - 40 ft (6.1 - 12.2 m)* | | | *40 - 60 ft (12.2 - 18.3 m)* | | |
|---|---|---|---|---|---|---|
| *Roof Slope* | *Zone 1 ($P_h$ = 10-20 psf)* | *Zone 1 ($P_h$ = 20-30 psf)* | *Zone 2* | *Zone 1 ($P_h$ = 10-20 psf)* | *Zone 1 ($P_h$ = 20-30 psf)* | *Zone 2* |
| 0° - 10° | 16 (400) | 16 (400) | 24 (600) | 16 (400) | 24 (600) | 24 (600) |
| 10° - 30° | 16 (400) | 16 (400) | 24 (600) | 16 (400) | 16 (400) | 24 (600) |
| 30° - 45° | 16 (400) | 16 (400) | 16 (400) | 16 (400) | 16 (400) | 16 (400) |

Note: Lengths of anchor bolts are based on ¾ in. (19 mm) steel bolts with 2 in. (51 mm) by ¼ in. (6 mm) steel washers and 6 ft (1.83 m) spacing.

### *3.1.4 Wood Frame Buildings*

The roof and walls are constructed of wood although there may be a stucco or masonry veneer on the exterior. In industrial construction, the roof may be similar to that of a board-on-joist building. Anchorage is needed where velocity pressures exceed 30 psf (1.44 kPa) and may be in accordance with Table 2 and Figs. 9 and 10. Appropriate hardware is needed to resist uplift where the roof meets the wall.

In residential and commercial buildings, the roof- carrying members are closely spaced wood rafters, generally at right angles to the longer building dimension. Because there are usually numerous interior partitions to which the ceiling joists may be attached (usually by toenailing), anchorage is more easily built into the structure than in the industrial type. In addition, partitions and vented attic spaces reduce interior pressure. Anchorage may be in accordance with Table 4.

*Table 4. Roof Anchorage—Wood Frame Buildings*

| *Roof Slope* | *Zone** | *Eave (Rafter to Plate)* | *Ridge (Rafter to Rafter)* |
|---|---|---|---|
| 0° - 15° | 2 & 3 | Straps or clips | Straps or clips |
| 15° - 45° | 2 & 3 | 3-16 d nails (4.1 mm)** | Straps or clips |

* Data Sheet 1-7, *Wind Forces on Buildings and Other Structures*.
**Based on 2 ft (0.61 m) rafter spacing. Increase of nails for greater spacing.

### *3.1.5 Steel Buildings With Corrugated Roof Panels*

The strength of the fastener usually determines the windstorm resistance of corrugated roofing. Most commonly used are self-tapping screws, welded studs and hook clips (Figs. 12 and 13).

Adequacy of fastening arrangements may be determined by comparing the wind uplift load to be carried by a single fastener with the safe strength of the fastener. Where the strength equals or exceeds the load, the arrangement is adequate (Table 5).

Wind uplift load is determined by multiplying the fastener spacing by the purlin spacing by the wind uplift force. Fastener spacing between 8 and 12 in. (200 and 300 mm) is common. Purlin spacing is normally between 4 and 6 ft (1.2 and 1.8 m).

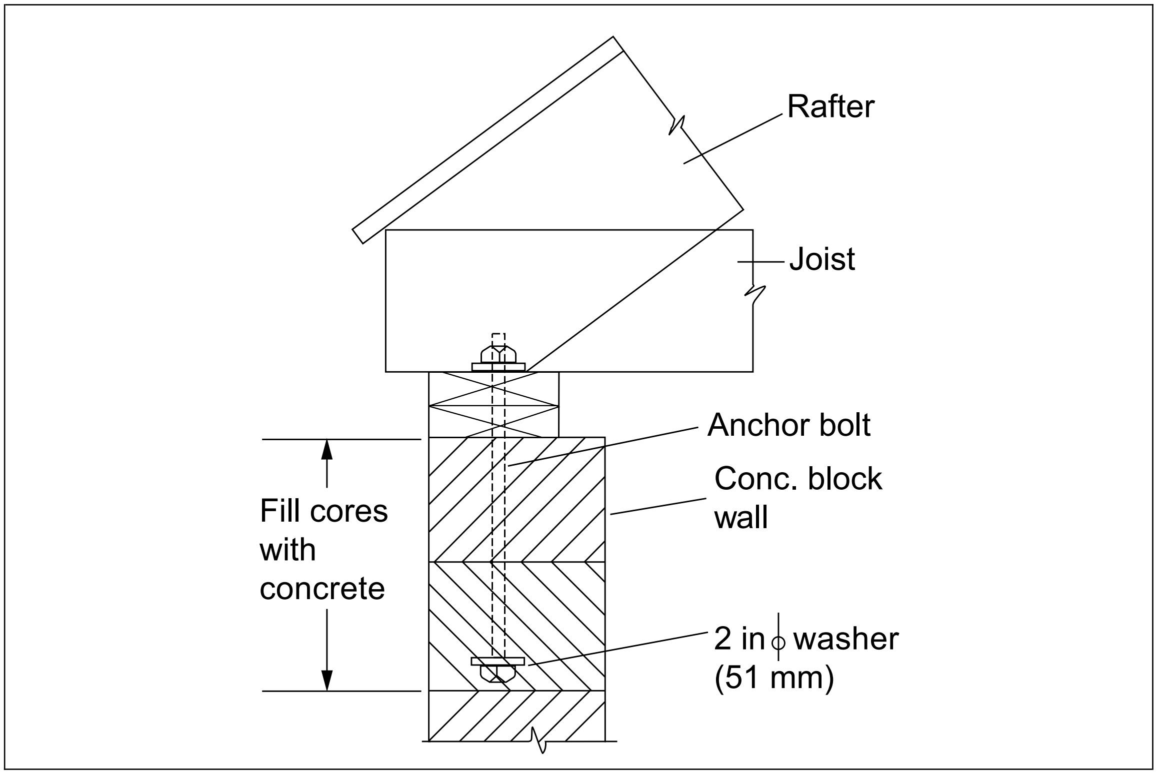


*Fig. 11. Anchorage of wood roof to masonry wall (see Table 3 for anchor bolt length)*

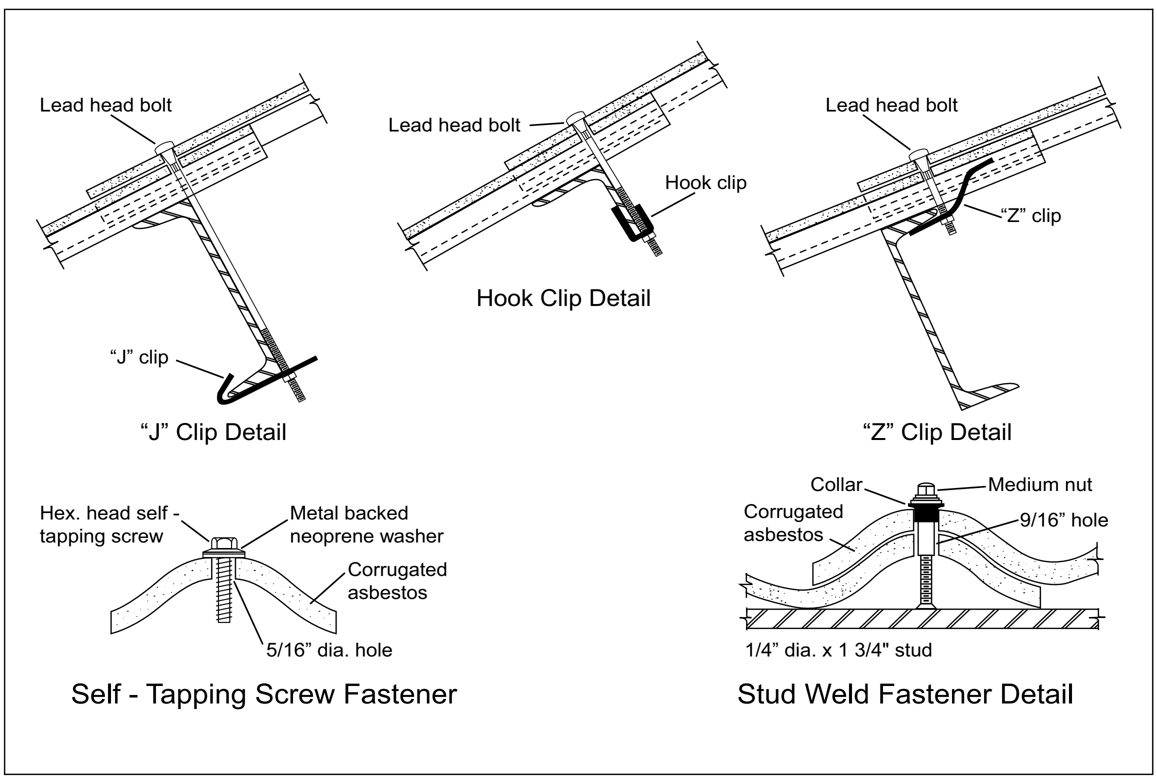


*Fig. 12. Fasteners for corrugated asbestos*

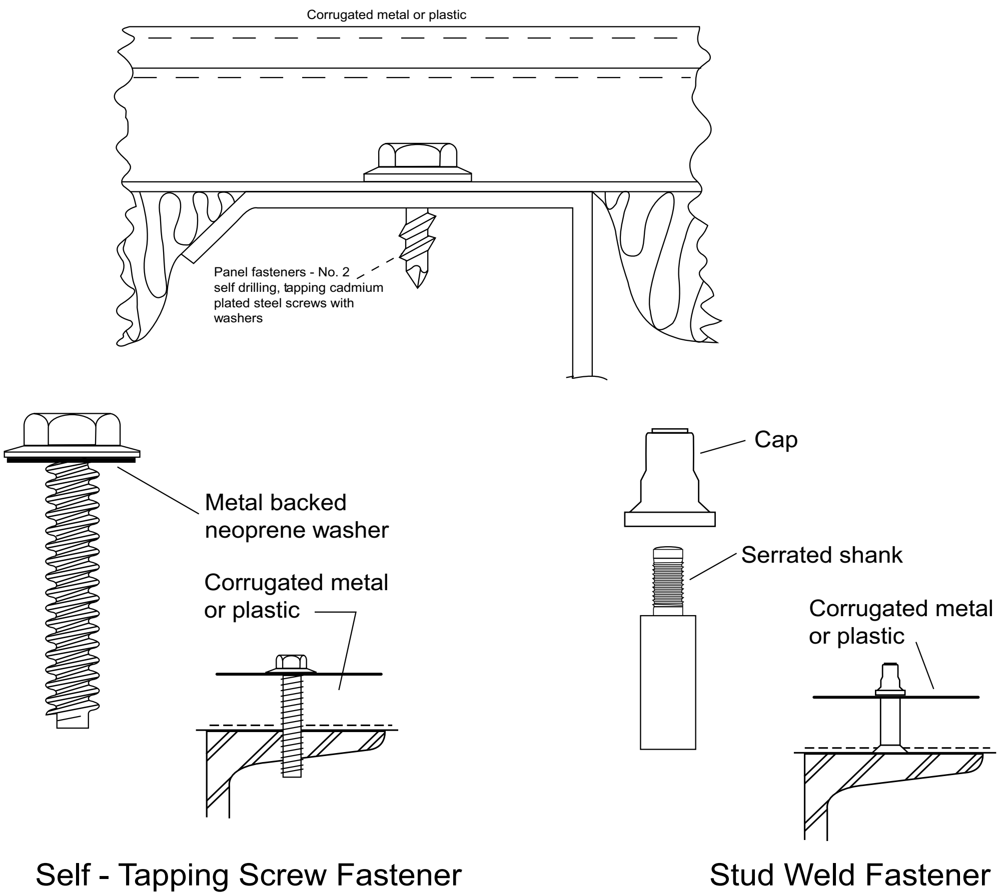


*Fig. 13. Fasteners for steel, aluminum, and plastic panels*

The wind uplift force on a roof may be determined from Data Sheet 1-28. (All tables and figures in this paragraph refer to Data Sheet 1-28). The wind isotach is shown in Figures 6 or 7. The building height is known. The velocity pressure ($P_h$) may be determined from Tables 2, 3 or 4. The uplift may then be determined by multiplying the velocity pressure by the pressure coefficient $C_p$ (Tables 5 and 6). This value is considerably higher for the eave and ridge strips than for the area of the roof between (Table 6). Stronger fastening should be provided there.

[2]All tables and figures in this paragraph refer to Data Sheet 1-28.

*Example:*

What uplift force can be expected on the fasteners securing steel roof panels to purlins on a 35 ft (10.7 m) high (to eave) building to be located in eastern North Carolina? Ground roughness is ''C.'' Roof slope is 15°, panel fastening is 8 in. (200 mm), purlin spacing 5 ft (1.5 m). Dead load of panels is ignored.

*Solution:*

The wind isotach (from Data Sheet 1-28) shows 120 mph at the location. Table 3 of that document shows a velocity pressure ($P_h$) of 56 psf (2.68 kPa) at the eave. The ridge is no higher than 50 ft (15.2 m). Unit uplift forces are as shown in Figure 14.

The load per fastener equals the uplift pressure times area of the panel held down by the fastener (spacing of purlins times spacing of fastener).

In eave and ridge strips:

Load = $0.667 \times 5 \times 134.4 = 450$ lb (204 kg).

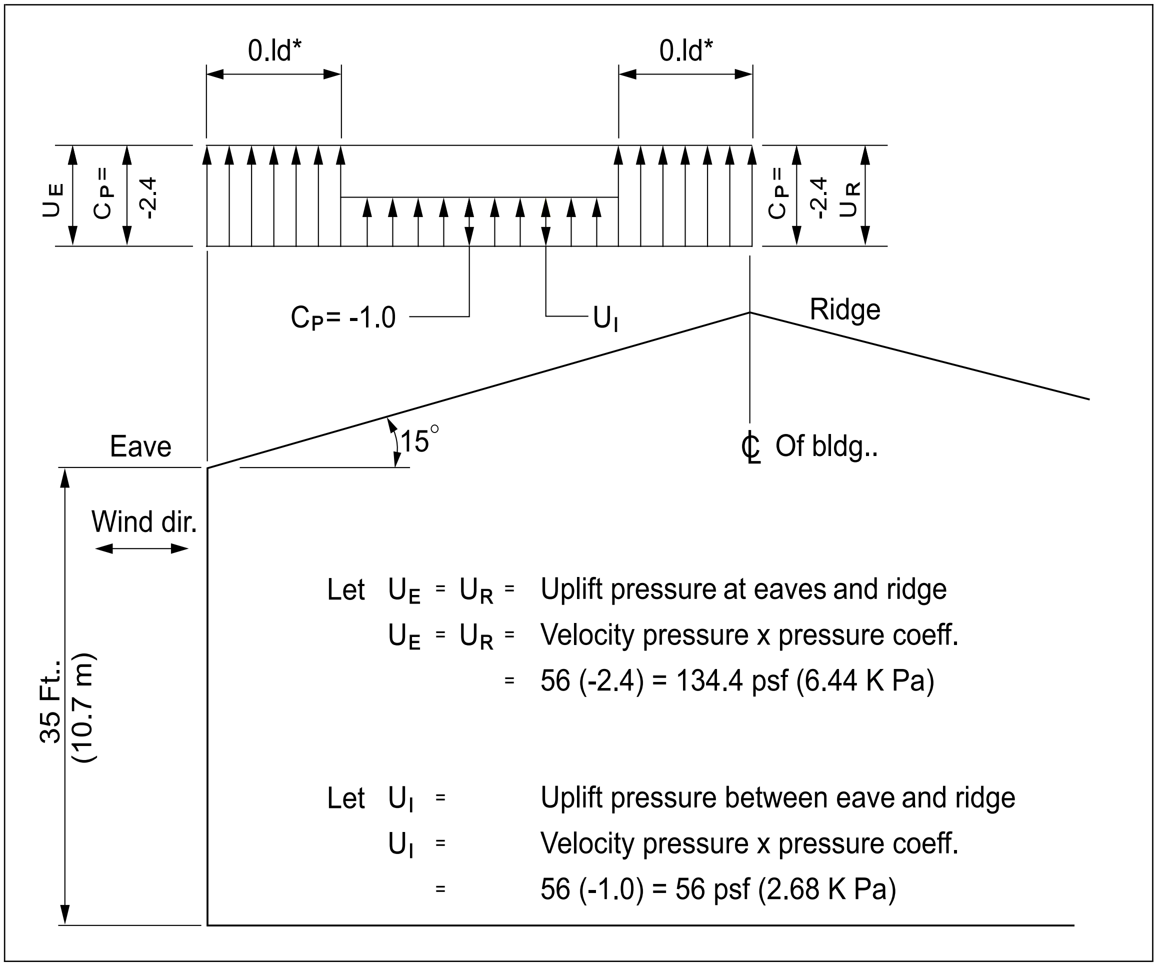


*Fig. 14. Wind uplift forces. d* = least roof dimension*

In area between eave and ridge strips:

Load = 0.667 × 5 × 56 = 187 lb (85 kg).

*Table 5. Allowable Fastener Strength Securing Single Panels*

| *Sheet Description* | *½ in. (13 mm) dia. Head or Washer, lb (kg)* | *⅝ in. (16 mm) dia. Head or Washer, lb (kg)* |
|---|---|---|
| 20 gauge (0.91 mm) steel | 350 (159) | 500 (227) |
| 22 gauge (0.76 mm) steel | 300 (136) | 400 (181) |
| 24 gauge (0.61 mm) steel | 225 (102) | 300 (136) |
| 26 gauge (0.45 mm) steel | 150 (68) | 200 (91) |
| 0.025 in. (0.64 mm) aluminum | 100 (45) | 125 (56) |
| 0.032 in. (0.81 mm) aluminum | 150 (68) | 200 (91) |

When heads must pull through two thicknesses, tabular values may be increased by 70%.

For four thickness, triple tabular values.

From Table 5, 20 gauge (0.87 mm) steel and ⅝ in. (16 mm) diameter head (or washer) fasteners are needed to prevent the steel sheet from pulling over the fastener head at the eave and ridge. Unless the building is large, metal thickness is not reduced in the area between the eave and ridge strips. Fastener size and/or spacing can be changed in this area while the building is in the design stage.

If the ridge elevation exceeded 50 ft (15.2 m), uplift forces on the ridge strip would then be based on a velocity pressure ($P_h$) of 63 psf (3.02 kPa) (Data Sheet 1-28).

*3.1.6 Permanently Open Buildings*

A special anchorage problem is created when one side of a wood roof building is almost, if not entirely open. The roof on the open side is supported by wood (or steel) columns, so there is very little dead load in the open wall to help resist wind forces that tend to lift the roof. Well designed, very strong anchorage of the columns to the eave plate and floor is needed. Hurricane anchorage or clips should be of a special design and used to attach all rafters, joists or purlins to their supporting members. These members meeting at a ridge should be tied to each other by a steel plate.

The same problem, to a lesser degree, is encountered when large doors or windows in one of the building walls are left open. Sufficient pressure may be built up inside the building to lift the roof if it is poorly anchored. However, openings in the opposite wall will allow air to flow through the building and minimize uplift on the roof.

The above considerations should be given to open sided buildings everywhere, because winds of only 60-70 mph can lift the roof unless it is strongly anchored. Uplift forces on the roof may be determined from Data Sheet 1-28.

Openings or slots built into the wall opposite the open side will lower the pressure by allowing the air to flow through and decrease uplift on the roof.

### 3.2 Illustrative Losses

For illustrative loss information, refer to Data sheets 1-28, 1-31 and 1-49.

## 4.0 REFERENCES

Data Sheet 1-1, *Firesafe Building Construction and Materials*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-31, *Metal Roof Systems*
Data Sheet 1-49, *Perimeter Flashing*

## APPENDIX A GLOSSARY OF TERMS

Brief descriptions of some terms are provided below.

*Board-on-joist roof:* Constructed of wood roof decking supported by narrow, closely spaced wood joists.

*Bond beam:* A beam of reinforced concrete block or reinforced concrete at eave height and supported by the block wall below

*Perimeter nailer:* Wood blocking that is anchored to the exterior wall or frame of the structure.

*Plank-on-timber roof:* Heavy wood planking supported by ‘‘heavy timbers’’ spaced several feet apart.

## APPENDIX B DOCUMENT REVISION HISTORY

June 2009. Editorial changes were made for this revision.

May 2000. This revision of the document has been reorganized to provide a consistent format.

This document was last revised in May of 1998.