Wind Design Standard For Ballasted Single-ply Roofing Systems

1.0 INTRODUCTION

The following standard is intended as a reference for those individuals who design, specify, and install ballasted single-ply roofing systems. It shall be used in conjunction with the installation specifications and requirements of the manufacturer of the specific products used in the ballasted single-ply roofing assembly.

2.0 GENERAL DESIGN CONSIDERATIONS AND DEFINITIONS

The following factors shall apply when designing a ballasted single-ply roof assembly.

2.1 Conventional Ballasted Roof Assemblies: A conventional Ballasted Roof assembly consists of a membrane or membrane and substrate material (insulation, fleece, etc.) looselaid over a deck with assembly held in place with ballast.

2.2 Protected Membrane Ballasted Roof Assemblies: A protected membrane ballasted roof system consists of a roof deck with or without insulation over which the membrane is installed. The membrane is either loosely laid, mechanically attached or adhered to the substrate. Insulation is then installed over the membrane. The insulation is then covered with a water-and air-pervious fabric over which ballast is applied.

2.3 Protected Membrane Ballasted Roof Assemblies Using A Cementitious Coating Which Has Been Attached To the Insulation As Ballast: The insulation panels with an attached cementitious material act as both insulation and ballast. The panels shall be interlocking and weigh a minimum of 4.0 psf. A water-and air-pervious fabric is not required in this construction.

2.4 Roof Structure: The building structure shall be examined by the owner who shall secure competent advice for verifying that it will support the ballast load in combination with all other design loads.

Approved as an American National Standard by ANSI

DISCLAIMER

This standard is for use by architects, engineers, and owners of single-ply roofing systems. SPRI, AND **ITS** MEMBERS AND EMPLOYEES DO NOT WARRANT THAT THIS STANDARD IS PROPER AND APPLICABLE UNDER ALL CONDITIONS. PLEASE SEE EXPLANATION OF A “STANDARD” ON PAGE 22.

[1] The wind speed map shown as Attachment II is an element of the ANSI/ASCE 7-95 document, “Minimum Design Loads for Buildings and Other Structures”, an American National Standards Institute Standard, copyrighted in 1995 by the American Society of Civil Engineers. Copies of this standard may be purchased from the American National Standards Institute at 11 West 42nd Street, New York, NY 10036 or American Society of Civil Engineers at 1801 Alexander Bell Drive, Reston, VA 20191

2.5 Slope: The roof slope design shall not exceed 2" in 12".

2.6 Wind Speed: The Basic Wind Speed is the 3-second gust speed at 33 ft (10 m) above the ground in Exposure C and associated with an annual probability of 0.02 of being equaled or exceeded (50 year mean recurrence interval). The Basic Wind Speed value to be used in the design calculations shall be taken from the ANSI/ASCE 7-95[1] document or the local authority having jurisdiction when local values exceed ASCE 7-95. The intensifying effects of valleys on wind speed as well as unique topographic features such as hills or escarpments, shall be accounted for in the design (See Commentary 2.6 and Attachment II). A local authority having jurisdiction shall be contacted for verification of the wind data and shall, if necessary, adjust the values given in Attachment II to account for higher local wind speeds.
When the wind speed exceeds 140 miles per hour 3-second gust wind speed after all adjustments are applied, the roof design shall be based on an expert's design method and approved by the authority having jurisdiction.

2.7 Building Height: The building height shall be measured from ground level to the roof system surface at the roof edge. If more than one roof level is involved, each shall have its own design per Sections 4.0 and 5.0. (See Commentary 2.6)

When building height exceeds 150 feet, the roof design shall be based on an expert's design method and approved by the authority having jurisdiction.

2.8 Roof Areas: Different areas of the roof surface are affected by wind in different ways. For design and installation purposes, the roof surface is divided into the following areas:

2.8.1 Corners
The space between meeting walls forming an angle greater than 45 degrees but less than 135 degrees (See Figure 1).

2.8.2 Corner Areas
The corner area is defined as the roof section with sides equal to 40% of the building height. The minimum length of a side is 8.5 feet (See Figure 1).

2.8.3 Perimeter
The perimeter area is defined as the rectangular roof section paralleling the roof edge and connecting the corner areas with a width measurement equal to the lesser of 10% of the roof plan lesser dimension, or 40% of the building height, but no less than 8.5 feet (See Figure 1).

2.8.4 Field
The field of the roof is defined as that portion of the roof surface which is not included in the corner areas or the perimeter area as defined above (See Figure 1).

2.9 Edge Condition:

2.9.1 Metal Edge Flashing (Gravel Stop)
If an edge flashing is used at the building perimeter, the top edge of the flashing shall be higher than the top surface of the ballast, but not less than 2 inches above the top surface of the roof membrane (See Figure 6).

2.9.2 Parapet Height
The parapet height for conventional ballasted roof assemblies (See Section 2.1 for definition) is the distance from the top of the roof system membrane to the top of the parapet (See Figure 5A, C, and D).

For Protected Membrane Ballasted Roof Assemblies (See Section 2.2 & 2.3 for definition), the parapet height is the distance from the top of the insulation to the top of the parapet (See Figure 5B).

If the lowest parapet height is outside of the defined corner area of the roof, and is less than 70% of the height of the parapet within the defined corner area, then this lower parapet height shall be used for the design. If the lowest parapet is located outside the defined corner area of the roof and is equal to or greater than 70% of the height of the parapet within the defined corner area, then the minimum parapet height within the corner segment shall be used for the design (See example in Figure 7).

2.10 Building Location: The terrain surrounding a building will influence the degree of exposure of that building to the wind. The building shall be classified into one of the following exposures:[2]

2.10.1 Protected Exposures

Exposure B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single family dwellings or larger. Use of this exposure category shall be limited to those areas for which terrain representative of Exposure B prevails in the upwind direction for a distance of at least 1,500 ft (460 m) or 10 times the height of the building or other structure, whichever is greater.

2.10.2 Unprotected Exposures

Exposure A: Large city centers with at least 50% of the buildings having a height in excess of 70 ft (21.3 m). Use of this exposure category shall be limited to those areas for which terrain representative of Exposure A prevails in the upwind direction for a distance of at least 0.5 mi (0.8 km) or 10 times the height of the building or other structure, whichever is greater. Channeling effects or increased velocity pressure due to the building or structure being located in the wake of adjacent building shall be taken into account.

Exposure C: Open terrain with scattered obstructions having heights generally less than 30 feet. This category includes flat open country and grasslands.

Exposure D: Flat, unobstructed areas exposed to wind flowing over open water for a distance of at least 1 mi (1.61 km). This exposure shall apply only to those buildings and other structures exposed to the wind coming from over the water. Exposure D extends inland from the shoreline a distance of 1,500 ft (460 m) or 10 times the height of the building or structure, whichever is greater. Such conditions shall be designed in accordance with Section 5.5.

2.11 Large Openings In A Wall: For buildings having openings in a single exterior wall that in total exceed 10% of the exterior wall area, in the story located immediately below the roof, the roof shall be designed to resist the pressure created when the opening(s) are in their full, open, position. Such conditions shall be designed in accordance with Section 5.1 (See Commentary 2.11).

2.12 Positive Pressure Building Systems: When HVAC equipment generates a positive pressure inside a building greater than 0.5 inches of water, the roof system shall be designed to resist the pressure by increasing the wind load requirements in accordance with Section 5.2.

2.13 Rooftop Projections: The roof area at the base of any rooftop projection which extends more than two feet above the top of the parapet and has one side longer than 4 ft shall be designed in accordance with Section 5.3.

2.14 Overhanging Eaves & Canopies: By their design, overhanging eaves and canopies are subject to greater uplift forces than the roof surface because of the impact of the air flow up the wall. Such conditions shall be designed in accordance with Section 5.4.

2.15 Impervious Decks

A roof deck structure that will not allow air to pass through it. Some examples are poured concrete, gypsum, poured light weight concrete (See Commentary Section 2.15).

2.16 Pervious Decks

A roof deck structure that allows air to move through it. Some examples are metal, cementitious wood fiber and wood plank.

2.17 Importance Factor

Importance factor accounts for the degree of hazard to human life and damage to property. For buildings fitting Category III or IV (see page 4), the roof shall be designed in accordance with Section 5.6.

[2] The definitions below are based on those of ANSI/ASCE 7-95, with modifications to suit the needs of this document.

Classification of Buildings and Other Structures for Wind, Snow, and Earthquake Loads

Nature of Occupancy	Category
Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Categories I, III, IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with elementary school, secondary school, or day care facilities with capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities • Jails and detention facilities • Power generating stations and other public utility facilities not included in Category IV • Buildings and other structures containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released	III
Buildings and other structures designated as essential facilities including, but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities • Fire, rescue and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Communications centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Buildings and other structures having critical national defense functions	IV

From ASCE 7/95

3.0 SYSTEM REQUIREMENTS

All single-ply ballasted roof systems shall comply with the following:

3.1 Membrane Requirements: The membrane specified for use in the ballasted system shall meet the recognized industry minimum material requirements listed below for the generic membrane type, and shall meet the specific requirements of its manufacturer.

<u>EPDM</u>	<u>PVC</u>
ASTM D-4637	ASTM D-4434
ASTM D-4811	
ANSI/RMA RP-1	<u>Hypalon/CPE/PIB</u>
ANSI/RMA RP-2	ASTM D-5019
ANSI/RMA RP-5	
ANSI/RMA RP-6	

3.2 Single-Ply Membrane Perimeter Attachment: The perimeter attachment used to terminate a roofing system shall be designed for a minimum load of 100 pounds per linear foot. This termination system shall be located at the roof perimeter and at the base of any angle change (See Attachment I, Figure 5 and Figure 6). The substrate into which the termination system is anchored shall be capable of withstanding a minimum of 100 pounds per linear foot. The procedure outlined in Attachment I shall be used to measure pull-out strength.

3.3 Ballast Requirements: Ballast shall be in accordance with the manufacturer's specification and not less than the following:

3.3.1 #4 Ballast: Nominal 1-1/2 inch smooth river bottom stone of ballast gradation size #4, or alternatively, #3, #24, #2, or #1 as specified in ASTM D-448, "Standard Sizes of Coarse Aggregate" spread at a minimum rate of 1000 pounds per 100 square feet; standard concrete pavers (minimum 18 psf); or interlocking, beveled, doweled, or contoured fit lightweight concrete pavers (minimum 10 psf).

3.3.2 #2 Ballast: Nominal 2-1/2 inch smooth river bottom stone of ballast gradation size #2 or alternatively #1, as specified in ASTM D 448, "Standard Sizes of Coarse Aggregate" spread at a minimum rate of 1300 pounds per 100 square feet; concrete pavers (minimum 22 psf); or approved interlocking, beveled, doweled or contoured fit, lightweight concrete pavers (minimum 10 psf) when documented or demonstrated as equivalent.

3.3.3 Crushed stone, when the gradation requirements for 3.3.1 and 3.3.2 above are met. A protection layer meeting the membrane manufacturer's specifications shall be installed between the membrane and the crushed stone.

4.0 DESIGN OPTIONS

The ballasted roof wind designs include, but are not limited to, the generic systems shown below. Other systems when documented or demonstrated as equivalent with the provisions of this standard shall be used when approved by the authority having jurisdiction (See Commentary Section 4.0). The designs listed in Sections 4.1 and 4.2 are the minimum specifications.

4.1 Conventional Single-Ply Assemblies: See Section 2.1 for definition.

4.1.1 System 1
The installed membrane shall be ballasted with #4 ballast (See Section 3.3.1).

4.1.2 System 2
The installed membrane shall be ballasted as follows:

4.1.2.1 Corner Area (See Section 2.8.2 for definition of corner area): The installed membrane in the corner area shall be ballasted with #2 ballast (See Section 3.3.2 and Figure 1).

4.1.2.2 Perimeter (See Section 2.8.3 for definition of perimeter area): The installed membrane in the perimeter area shall be ballasted with #2 ballast (See Section 3.3.2 and Figure 1).

4.1.2.3 Field (See Section 2.8.4 for definition of field): In the field of the roof, the installed membrane shall be ballasted with #4 ballast (See Section 3.3.1).

4.1.3 System 3
The installed membrane shall be ballasted as follows:

4.1.3.1 Corner Area (See Section 2.8.2 for definition of corner area): In each corner area, an adhered or mechanically attached roof system designed to withstand the uplift force in accordance with ANSI/ASCE 7-95 or the local building code, whichever is more conservative, shall be installed in accordance with the provisions for the corner location with no loose aggregate placed on the membrane (See Figure 1 and Commentary Section 4.1.3).

When a protective covering is required, a fully adhered membrane system shall be used. Over the fully adhered membrane, install minimum 22 psf pavers or other material approved by the authority having jurisdiction. Mechanically fastened membrane systems shall not be used when a protective covering is required.

4.1.3.2 Perimeter: (See Section 2.8.3 for definition of perimeter area): In the perimeter area, an adhered or mechanically attached roof system designed to withstand the uplift force in accordance with ANSI/ASCE 7-95 or the local building code, whichever is more conservative, shall be installed, in accordance with the provisions for the perimeter location with no loose aggregate placed on the membrane.

When a protective covering is required, a fully adhered membrane system shall be used. Over the fully adhered membrane, install minimum 22 psf pavers or other material approved by the authority having jurisdiction. Mechanically fastened membrane systems shall not be used when a protective covering is required.

4.1.3.3 Field: (See Section 2.8.4 for definition of field) In the field of the roof, install #2 ballast (See Section 3.3.2).

4.1.3.4 Transition: At the junction of the loosely laid roof membrane with the adhered or mechanically attached membrane areas, a mechanical termination shall be provided. The termination shall be designed for 100 pounds per linear foot holding power, as tested in accordance with the procedure outlined in Attachment I. The termination shall also be of sufficient height to serve as a gravel stop (See Section 2.9.1).

4.2 Protected Membrane Roofing Assemblies: (For definition of Protected Membrane Roofing Assemblies, See Section 2.2).

The protected membrane roof wind designs include, but are not limited to, the generic systems shown below. Other systems which comply with the provision of this specification shall be used when approved by the authority having jurisdiction.

4.2.1 Protected Membrane Roofing Systems Using Stone and/or Pavers for Ballast.

4.2.1.1 System 1 and System 2
When the design criteria based on wind speed, building height, and parapet height and exposure, require a System 1 or System 2 design, the ballasting procedures for that respective system shall be followed. See Sections 4.1.1 and 4.1.2, respectively.

4.2.1.2 System 3
When the design criteria, based on wind speed and building height, parapet height and exposure require a System 3 design, a minimum 24" parapet height (See Section 2.9.2 for determining parapet height) is required and the ballasting procedures for System 3 as defined in Section 4.1.3 above shall be followed. In addition, the insulation that is installed over the fully adhered perimeter and corner areas (mechanically attached systems shall not be used) shall be ballasted with 22 psf pavers (minimum) or other material approved by the authority having jurisdiction.

4.2.2 Protected Membrane Ballasted Roof Assemblies Using a Cementitious Coating Which Has Been Attached to the Insulation as Ballast

For definition of Protected Membrane Ballasted Roof Assemblies using a cementitious coating, see Section 2.3. For systems utilizing a loose-laid design or non-reinforced membrane in a mechanically fastened design, the roof system shall be installed over an impervious deck or incorporate an air retarder that is designed to resist the uplift load in accordance with ANSI/ASCE 7-95 or the local building code.

4.2.2.1 System 1: When the design criteria based on wind speed, building height, and parapet require a System 1 design, the insulation panels with cementitious coating shall be installed over the membrane. For the area within two feet of the perimeter, minimum 22 psf pavers or other material approved by the authority having jurisdiction shall be installed over the panels.

4.2.2.2 System 2: When the design criteria based on wind speed, building height, and parapet require a System 2 design, the insulation panels with cementitious coating shall be installed over the membrane. In addition, for the roof surface within the perimeter and corner areas (See Section 2.8.2 and 2.8.3), 22 psf pavers (minimum) or other material approved by the authority having jurisdiction shall be installed.

4.2.2.3 System 3: When the design criteria based on wind speed and building height require a System 3 design, the roof design shall be based on an experts design method and approved by the authority having jurisdiction.

5.0 DESIGN PROVISIONS

5.1 Large Openings in a Wall
(See Section 2.11 for description):

When the total area of all openings in a single exterior wall is between 10 and 50 percent of that wall area in the story located immediately below the roof, the following roof location shall be designed as a corner area of the respective System 2 or System 3 designs. For System 1 designs, they shall use the corner area specifications of a System 2 design for the rectanuglar area.

A rectangle, located directly above the opening, which has as its width 1.5 times the width of the opening and as its depth 2.0 times the width of the opening (See Figure 2).

When the total area of all openings in a single exterior wall exceeds 50 percent of that wall area in the story located immediately below the roof, the roof shall be designed as part of an open structure. Under these conditions, the roof system design as identified in the Design Tables (See Table 1) shall be upgraded to the next level of resistance to the wind. That is, a System 1 design shall be upgraded to a System 2 design, a System 2 design shall be upgraded to a System 3 design, and a System 3 design shall be upgraded to a roof system that is designed to resist the uplift loads in accordance with ANSI/ASCE 7-95 or the local building code, whichever is more conservative. The rectangular roof area over the opening shall be designed as a corner section.

5.2 Positive Pressure in Building Interior

(See Section 2.12 for description):

When positive pressure conditions between 0.5 and 1.0 inch of water are present in a building, the applicable roof system design as identified in the Design Tables (See Table 1) shall be upgraded to the next level of resistance to wind. Under these conditions, a System 1 design shall be upgraded to a System 2 design; a System 2 design shall be upgraded to a System 3 design; a System 3 design shall be upgraded to a roof system which is designed to resist the uplift loads in accordance with ANSI/ASCE 7-95 or the local building code, whichever is more conservative. When positive pressures are greater than 1.0 inch of water, the design of the roof shall be based on an experts design method and approved by the authority having jurisdiction.

5.3 Rooftop Projections
(See Section 2.13 for description):

When rooftop projections rise two feet or more above the parapet height and have at least one side greater than four feet in length, the roof area which extends four feet out from the base of such projections shall have the same design as the corner area of the roof.

5.4 Overhanging Eaves and Canopies:
(See Section 2.14 for description):

5.4.1 Impervious Decks (See Section 2.15 for description):

When a deck is impervious, overhanging eaves and canopy shall be defined as the following:

Eaves: The overhanging eave shall be considered the perimeter of the applicable design (See Figure 3).

Canopies: The entire canopy area shall be designed as a corner section of the applicable design.

5.4.2 Pervious Decks (See Section 2.16 for description)

When the deck is pervious, the design of the entire overhanging eave or canopy area shall be upgraded to the corner design of the next level system for wind resistance over the applicable design (See Figure 4). For this situation, the entire overhanging eave or canopy of a System 1 Design shall be upgraded to a System 2 Corner Design; the entire overhanging eave or canopy of a system 2 Design shall be upgraded to a System 3 Corner Design; the entire overhanging eave or canopy of a System 3 Design shall be designed to the System 3 Corner Design.

In addition, the main roof area extending in from the overhanging eave shall be ballasted to the applicable system design as though the overhang did not exist. This means the appropriate corner and perimeter areas are to be ballasted in accordance with Section 4.0 in addition to the overhanging eave area treatment as described above (See Figure 4).

5.5 Exposure D:
(See Section 2.10 for description.)

For buildings located in Exposure D, the roof design as identified in the Design Tables (See Table 1) under Exposure A & C shall be upgraded to the next level of resistance to wind. Under these conditions, a System 1 design shall be upgraded to a System 2, and a System 2 design shall be upgraded to a System 3 design. System 3 shall use System 3 corner design across the entire roof surface.

5.6 Importance Factor:
(See Section 2.17 for description)

For buildings fitting category III or IV as per Section 2.17, the applicable roof system design as identified in the Design Tables (See Table 1) shall be upgraded to the next level of resistance to wind. For this situation, a System 1 design shall be upgraded to a System 2 design; a System 2 design shall be upgraded to a System 3 design; a System 3 design shall use its corner design across the entire roof surface.

6.0 DETERMINATION OF BALLASTED SYSTEM ROOF DESIGN:

To determine the ballast design for a given building, the following process shall be followed (See Commentary):

6.1 Based on the building location, the basic wind speed shall be determined following Section 2.6 and exposure from Section 2.10.

6.2 The building height shall be determined by following Section 2.7 and the parapet height from Section 2.9.

6.3 Knowing the wind speed, building height, parapet height, and exposure, locate the System I, II or III in the Design Tables of Table 1 that meets the criteria.

6.4 Having determined the System from the Design Tables (Table 1), Section 4.0, Design Options, shall be used to determine the ballasting requirements based on the type of roof system; Conventional or Protected Membrane.

6.5 Then Section 5.0, Design Provisions shall be reviewed to determine the necessary enhancements to the systems' ballasting requirements. These provisions are the accumulative addition to the base design from the Design Tables.

7.0 MAINTENANCE

When wind scour occurs to an existing ballasted roof system and the scour is less than 50 square feet, the ballast shall be replaced. For scour areas greater than 50 square feet, the ballast shall be upgraded to the next system design level per Section 4.0.

Design Tables[3]

Table 1

A. FROM 2 INCH HIGH GRAVEL STOP TO LESS THAN 6.0 INCH HIGH PARAPET
MAXIMUM ALLOWABLE WIND SPEED (MPH)

BLDG.	SYSTEM 1		SYSTEM 2		SYSTEM 3	
HT. FT.	EXPOSURE A+C*	EXPOSURE B*	EXPOSURE A+C	EXPOSURE B	EXPOSURE A+C	EXPOSURE B
0-15	90	105	120	120	130	140
> 15-30	90	105	120	120	130	140
> 30-45	85	90	110	120	130	140
> 45-60	NO	NO	110	120	130	140
> 60-75	NO	NO	110	110	120	120
> 75-90	NO	NO	NO	NO	NO	NO
> 90-105	NO	NO	NO	NO	NO	NO
> 105-120	NO	NO	NO	NO	NO	NO
> 120-135	NO	NO	NO	NO	NO	NO
> 135-150	NO	NO	NO	NO	NO	NO

B. FOR PARAPET HEIGHTS FROM 6.0 TO LESS THAN 12.0 INCHES
MAXIMUM WIND SPEED (MPH)

BLDG.	SYSTEM 1		SYSTEM 2		SYSTEM 3	
HT. FT.	EXPOSURE A+C	EXPOSURE B	EXPOSURE A+C	EXPOSURE B	EXPOSURE A+C	EXPOSURE B
0-15	90	105	120	120	140	140
> 15-30	90	105	120	120	140	140
> 30-45	85	90	120	120	140	140
> 45-60	NO	NO	110	120	130	140
> 60-75	NO	NO	110	110	130	130
> 75-90	NO	NO	NO	NO	NO	NO
> 90-105	NO	NO	NO	NO	NO	NO
> 105-120	NO	NO	NO	NO	NO	NO
> 120-135	NO	NO	NO	NO	NO	NO
> 135-150	NO	NO	NO	NO	NO	NO

C. FOR PARAPET HEIGHTS FROM 12.0 TO LESS THAN 18.0 INCHES
MAXIMUM WIND SPEED (MPH)

BLDG.	SYSTEM 1		SYSTEM 2		SYSTEM 3	
HT. FT.	EXPOSURE A+C	EXPOSURE B	EXPOSURE A+C	EXPOSURE B	EXPOSURE A+C	EXPOSURE B
0-15	105	110	120	120	140	140
> 15-30	90	105	120	120	140	140
> 30-45	85	105	120	120	140	140
> 45-60	85	90	110	120	130	140
> 60-75	85	85	110	110	130	130
> 75-90	85	85	110	110	120	120
> 90-105	NO	NO	95	95	110	110
> 105-120	NO	NO	95	95	110	110
> 120-135	NO	NO	95	95	110	110
> 135-150	NO	NO	95	95	110	110

Design Tables[3]

Table 1

D. PARAPET HEIGHTS FROM 18.0 TO LESS THAN 24.0 INCHES
MAXIMUM WIND SPEED (MPH)

	BLDG. HT. FT.	SYSTEM 1 XPOSURE A+C*	SYSTEM 1 EXPOSURE B*	SYSTEM 2 EXPOSURE A+C	SYSTEM 2 EXPOSURE B	SYSTEM 3 EXPOSURE A+C	SYSTEM 3 EXPOSURE B
	0-15	110	110	120	120	140	140
>	15-30	110	110	120	120	140	140
>	30-45	95	110	120	120	140	140
>	45-60	85	95	120	120	140	140
>	60-75	85	85	110	110	140	140
>	75-90	85	85	110	110	120	130
>	90-105	NO	NO	95	95	110	120
>	105-120	NO	NO	95	95	110	110
>	120-135	NO	NO	95	95	110	110
>	135-150	NO	NO	95	95	110	110

E. FOR PARAPET HEIGHTS FROM 24.0 TO LESS THAN 36.0 INCHES
MAXIMUM WIND SPEED (MPH)

	BLDG. HT. FT.	SYSTEM 1 EXPOSURE A+C	SYSTEM 1 EXPOSURE B	SYSTEM 2 EXPOSURE A+C	SYSTEM 2 EXPOSURE B	SYSTEM 3 EXPOSURE A+C	SYSTEM 3 EXPOSURE B
	0-15	110	110	120	120	140	140
>	15-30	110	110	120	120	140	140
>	30-45	95	110	120	120	140	140
>	45-60	85	110	120	120	140	140
>	60-75	85	85	120	120	140	140
>	75-90	85	85	110	110	140	140
>	90-105	NO	NO	110	110	140	140
>	105-120	NO	NO	110	110	140	140
>	120-135	NO	NO	110	110	140	140
>	135-150	NO	NO	95	95	140	140

F. FOR PARAPET HEIGHTS FROM 36.0 TO LESS THAN 72 INCHES
MAXIMUM WIND SPEED (MPH)

	BLDG. HT. FT.	SYSTEM 1 EXPOSURE A+C	SYSTEM 1 EXPOSURE B	SYSTEM 2 EXPOSURE A+C	SYSTEM 2 EXPOSURE B	SYSTEM 3 EXPOSURE A+C	SYSTEM 3 EXPOSURE B
	0-15	110	110	120	120	140	140
>	15-30	110	110	120	120	140	140
>	30-45	95	110	120	120	140	140
>	45-60	95	110	120	120	140	140
>	60-75	85	85	120	120	140	140
>	75-90	85	85	120	120	140	140
>	90-105	85	85	110	110		140140
>	105-120	85	85	110	110		140140
>	120-135	85	85	110	110		140140
>	135-150	NO	85	110	110		140140

Design Tables[3]

Table 1

G. FOR PARAPET HEIGHTS FROM 72 INCHES AND ABOVE
MAXIMUM WIND SPEED (MPH)

	BLDG. HT. FT.	SYSTEM 1 EXPOSURE A+C*	SYSTEM 1 EXPOSURE B*	SYSTEM 2 XPOSURE A+C	SYSTEM 2 EXPOSURE B	SYSTEM 3 EXPOSURE A+C	SYSTEM 3 EXPOSURE B
	0-15	110	110	120	120	140	140
>	15-30	110	110	120	120	140	140
>	30-45	95	110	120	120	140	140
>	45-60	95	110	120	120	140	140
>	60-75	95	95	120	120	140	140
>	75-90	95	95	120	120	140	140
>	90-105	95	95	120	120	140	140
>	105-120	85	85	120	120	140	140
>	120-135	85	85	120	120	140	140
>	135-150	85	85	110	110	140	140

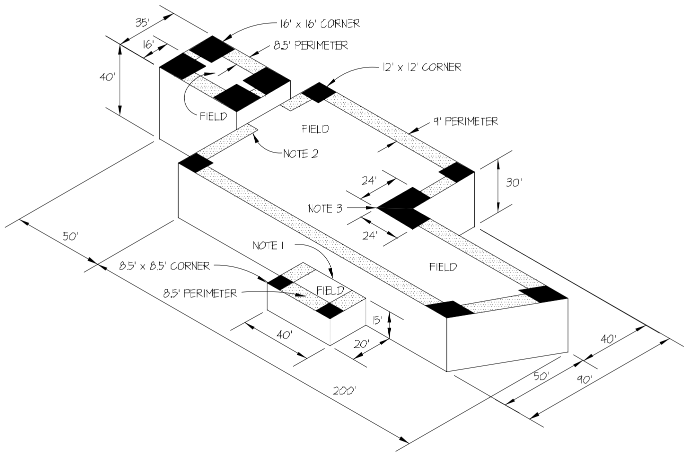
* EXPOSURE A = LARGE CITIES
EXPOSURE B = SUBURBS AND SMALL CITIES
EXPOSURE C = OPEN TERRAIN

[3] Wind speed reference see Section 2.6
Wind speeds in above tables are “3 second gust” measured at 10 meters (33 feet).

N0TE: Any building not fitting the above Design Tables shall be treated as a Special Design Consideration requiring a competent roof design specialist and reviewed by the authority having jurisdiction.

ROOF LAYOUT

SYSTEMS 2 & 3



NOTES:

1. NO CORNERS OR PERIMETER ALONG ROOF EDGE WHERE THE HIGHER WALL ABUTS THE LOWER ROOF.
2. NO CORNERS OR CONTINUOUS PERIMETER AT THIS POINT. PERIMETER EXTENDS INWARD A DISTANCE EQUAL TO ITS WIDTH TO PROVIDE EXTRA PROTECTION AT THIS JUNCTION.
3. REENTRANT CORNERS ARE LARGER THAN OTHER CORNERS.

	LOW ROOF	MAIN ROOF	HIGH ROOF
ROOF HEIGHT (FT.)	15	30	40
ROOF PLAN LESSER DIMENSION (FT.)	20	90	35
CORNER LENGTH (FT.)	8.5 (a)	12 (b)	16 (b)
PERIMETER WIDTH (FT.)	8.5 (a)	9 (c)	8 (a)

(a) 8.5' MINIMUM CONTROLS
(b) 0.4 x ROOF HEIGHT CONTROLS
(c) 0.1 x ROOF PLAN LESSER DIMENSION CONTROLS

Figure 1

LARGE OPENINGS
IN A WALL

WHEN THE SUM OF VARIOUS OPENINGS AREA (w x h)
IS GREATER THAN 10% OF THE WALL AREA

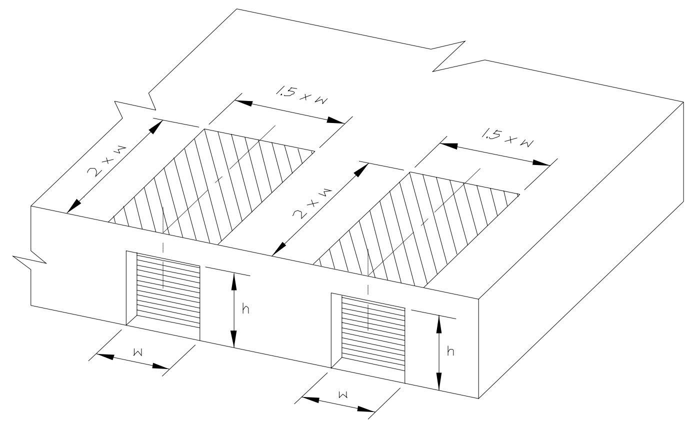


Figure 2

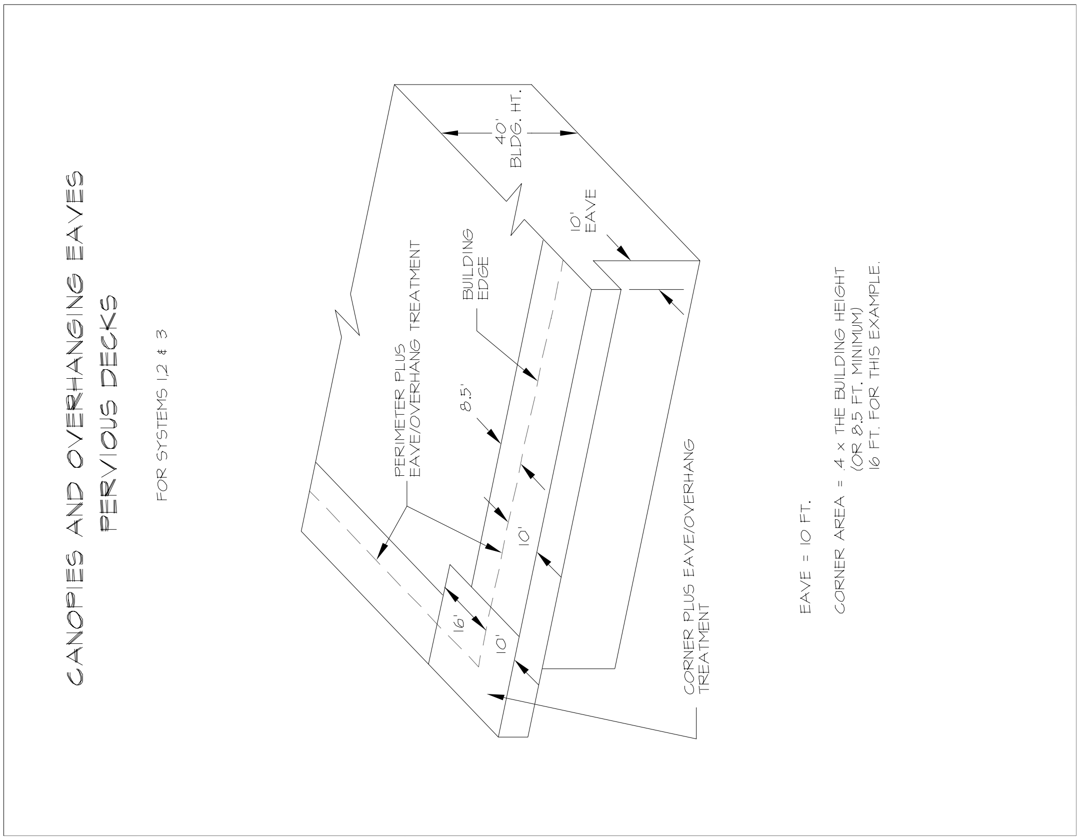


Figure 4

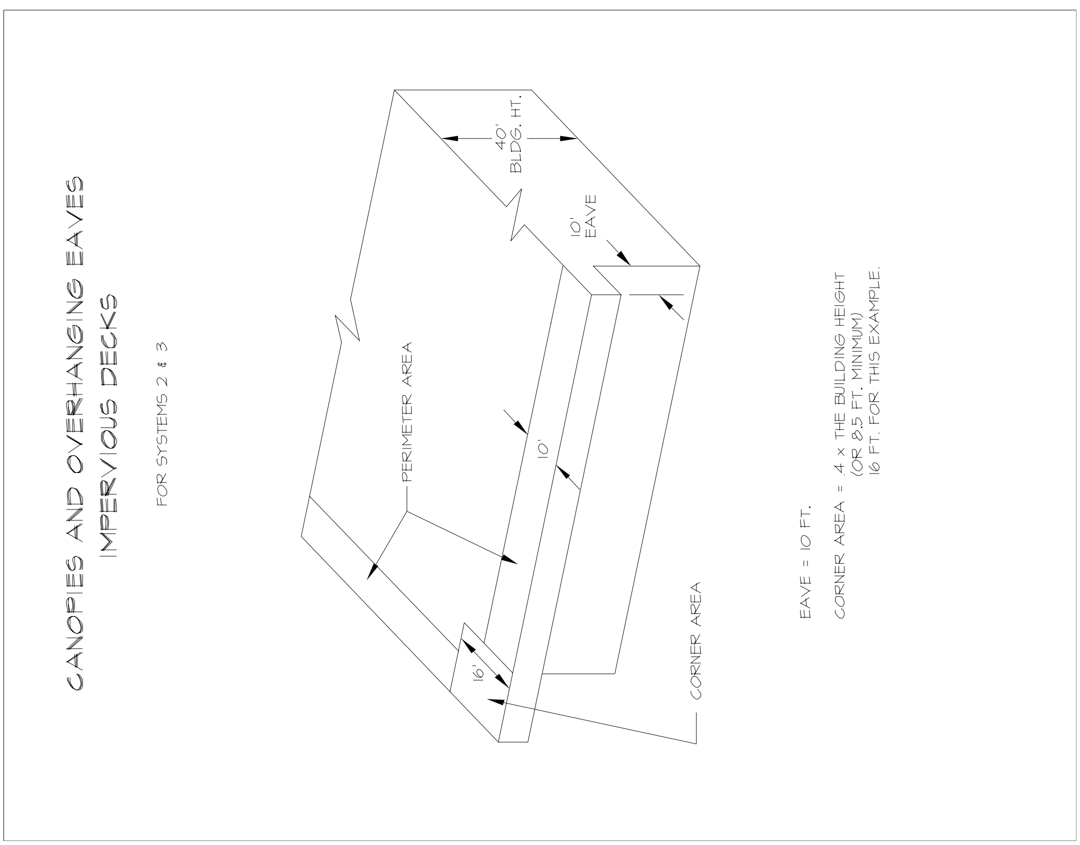
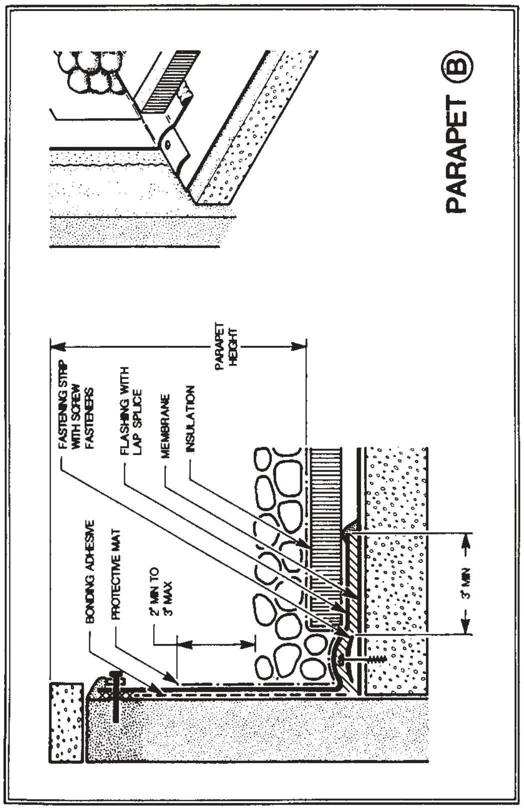
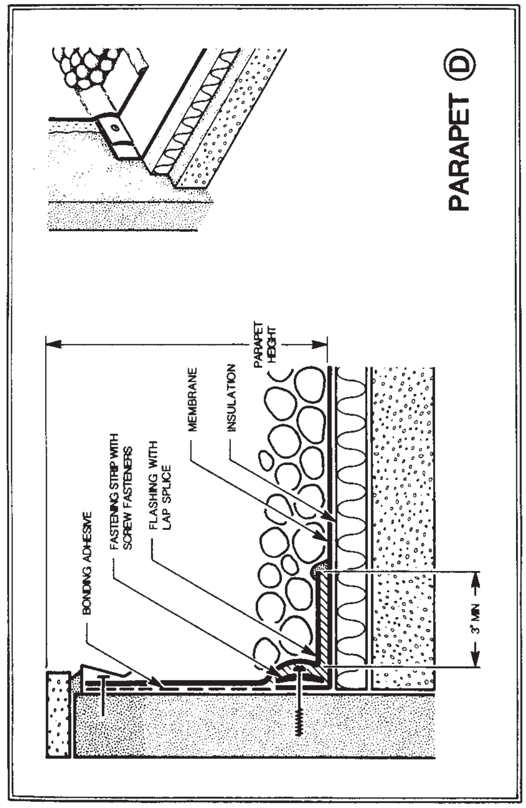
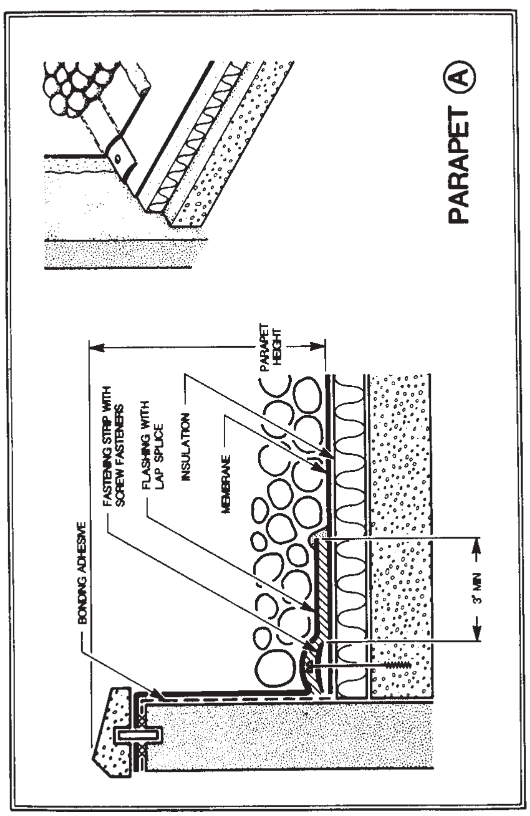


Figure 3

Figure 5


FASTENING STRIP WITH SCREW FASTENERS
FLASHING WITH LAP SPLICE
MEMBRANE
INSULATION
PARAPET HEIGHT
BONDING ADHESIVE
PROTECTIVE MAT
2" MIN TO 3" MAX
3" MIN
PARAPET B


BONDING ADHESIVE
FASTENING STRIP WITH SCREW FASTENERS
FLASHING WITH LAP SPLICE
MEMBRANE
INSULATION
PARAPET HEIGHT
3" MIN
PARAPET D


BONDING ADHESIVE
FASTENING STRIP WITH SCREW FASTENERS
FLASHING WITH LAP SPLICE
INSULATION
MEMBRANE
PARAPET HEIGHT
3" MIN
PARAPET A

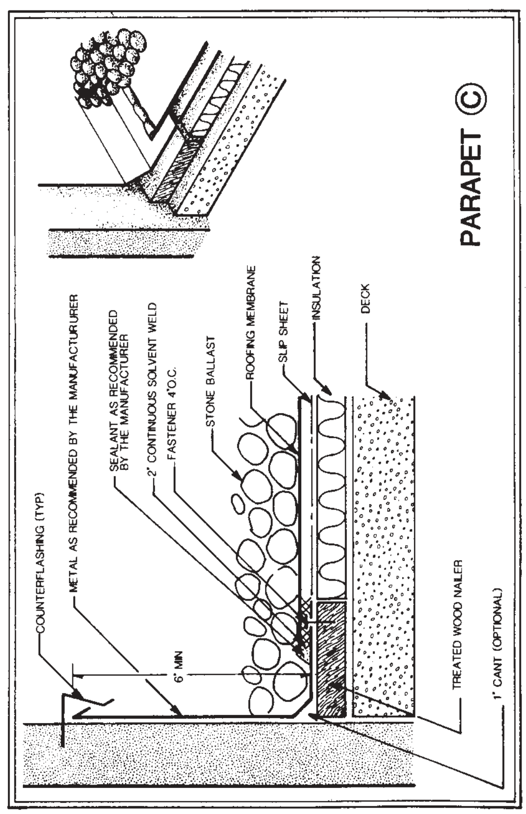
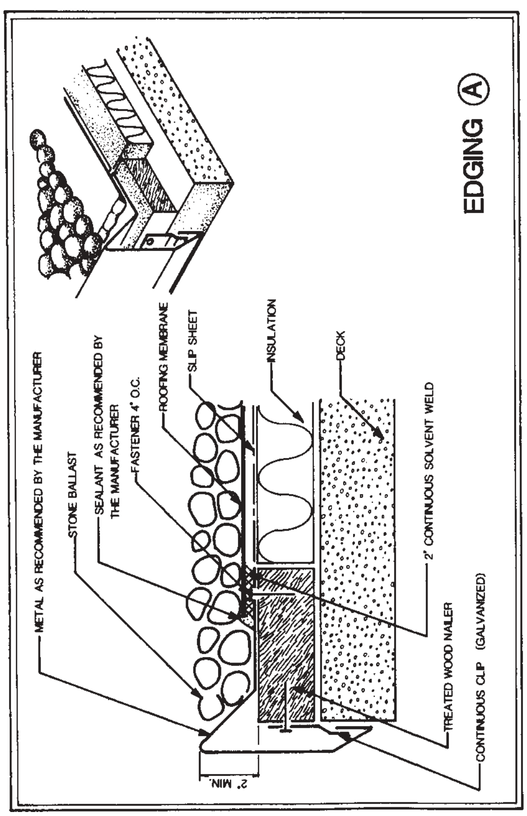
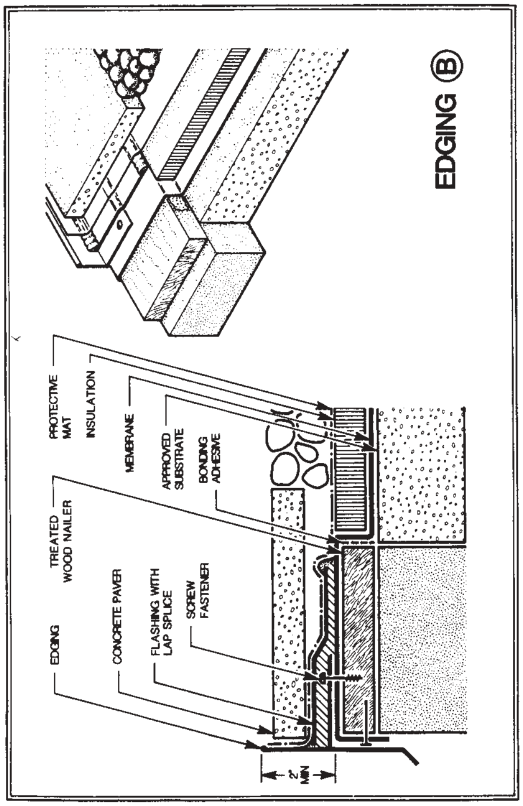

COUNTERFLASHING (TYP)
METAL AS RECOMMENDED BY THE MANUFACTURER
SEALANT AS RECOMMENDED BY THE MANUFACTURER
2" CONTINUOUS SOLVENT WELD
FASTENER 4'O.C.
STONE BALLAST
ROOFING MEMBRANE
SLIP SHEET
INSULATION
DECK
6" MIN
TREATED WOOD NAILER
1" CANT (OPTIONAL)
PARAPET C

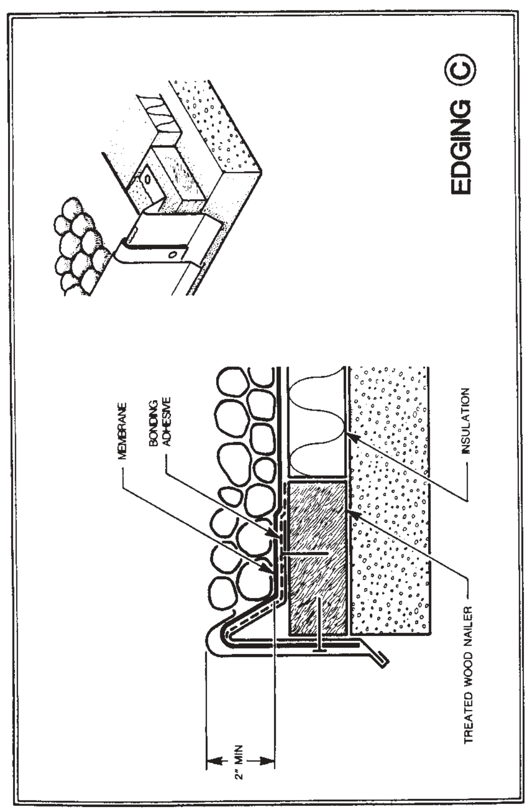
Figure 6



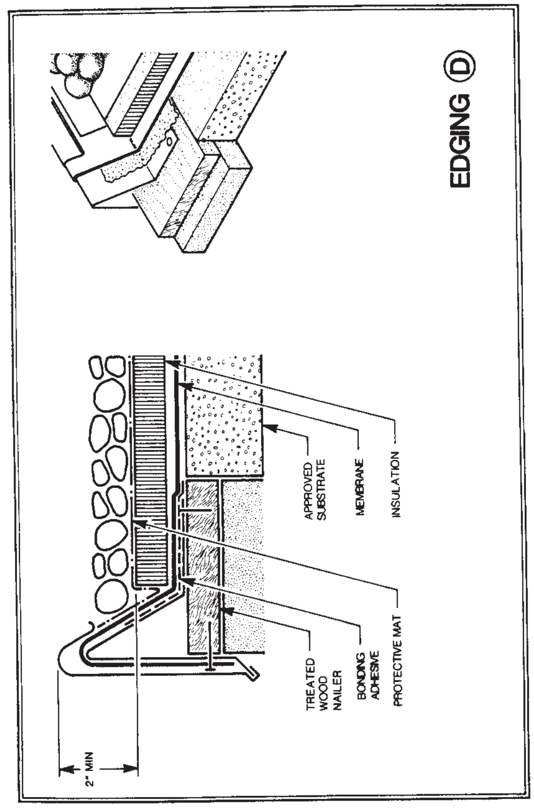
EDGING Ⓐ



EDGING Ⓑ

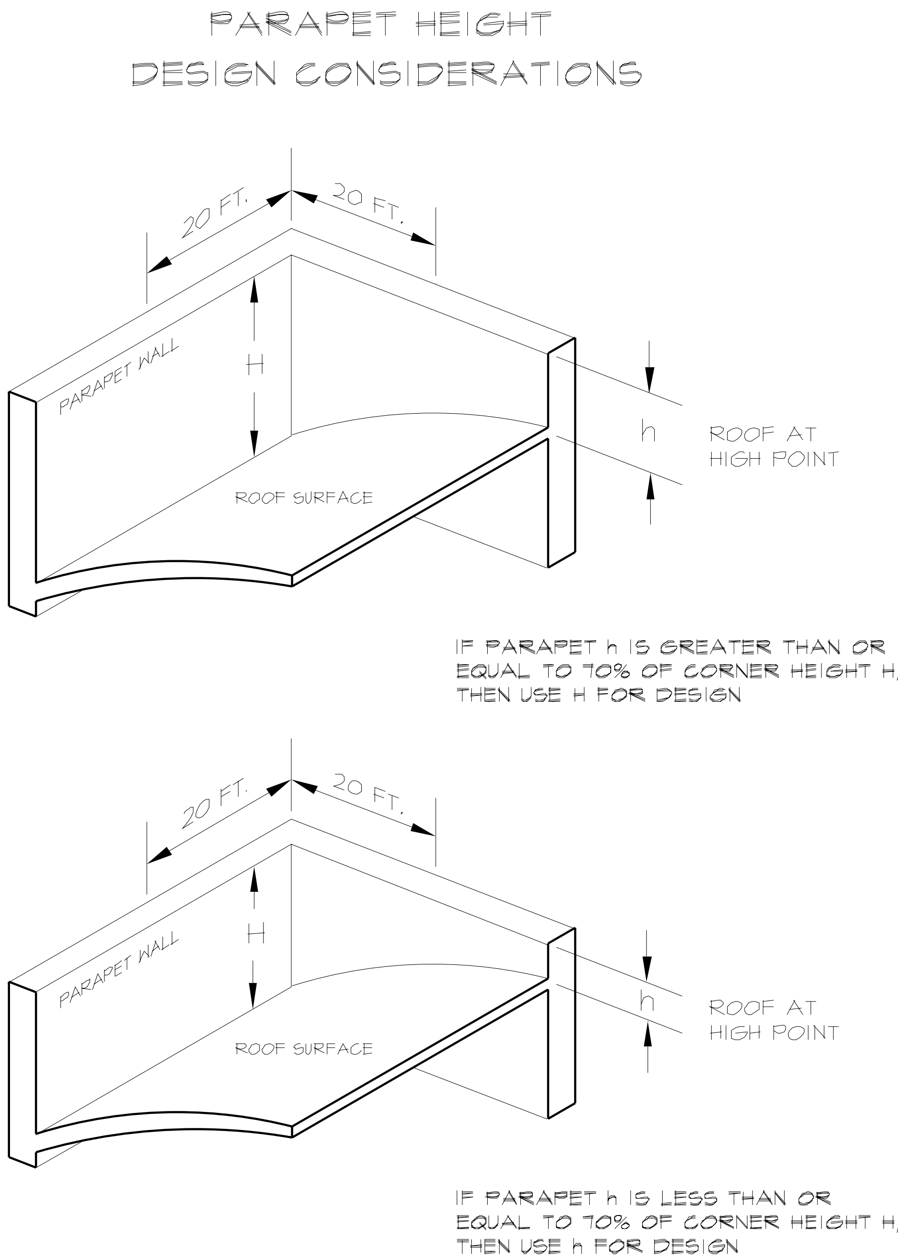


EDGING Ⓒ



EDGING Ⓓ

Figure 7


PARAPET HEIGHT
DESIGN CONSIDERATIONS
20 FT.
20 FT.
PARAPET WALL
H
h
ROOF AT
HIGH POINT
ROOF SURFACE
IF PARAPET h IS GREATER THAN OR
EQUAL TO 70% OF CORNER HEIGHT H,
THEN USE H FOR DESIGN
20 FT.
20 FT.
PARAPET WALL
H
h
ROOF AT
HIGH POINT
ROOF SURFACE
IF PARAPET h IS LESS THAN OR
EQUAL TO 70% OF CORNER HEIGHT H,
THEN USE h FOR DESIGN

SPRI Test Method RE-1

Test for Roof Edge Termination of Single-Ply and Modified Bitumen Roofing Membranes

The method with which the edge of the roofing membrane is terminated (gravel stop, nailer, or other) is the last anchor point to hold the membrane in place should the membrane happen to separate from the roof deck during a high wind. When this happens, the roof system will put a load on the termination. For this reason, the termination must withstand a minimum force of 100 lbs/ft (134 kg/m) when tested using the following method.

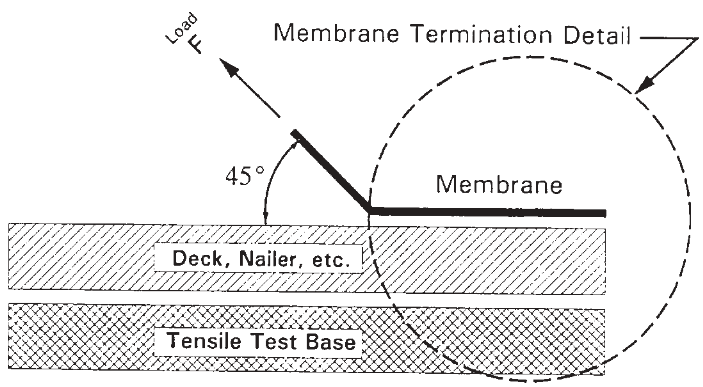


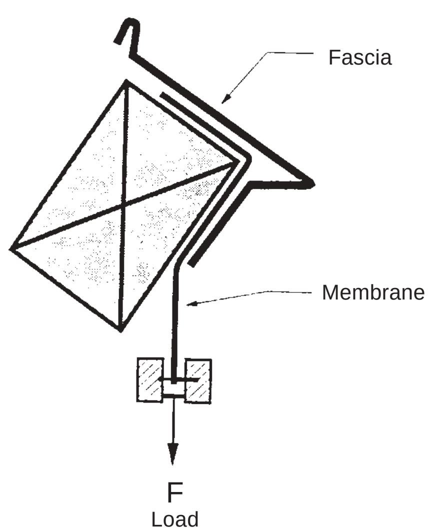
Figure 1. General Test Layout

A 12-inch (30 cm) wide mock-up of the termination system shall be constructed and mounted on the base of a tensile testing device so the membrane is pulled at a 45° angle to the roof deck to simulate a billowing membrane.

The jaws of the tensile tester are connected to two bars which clamp the membrane securely between them so that the load is distributed uniformly along the width of the membrane. The tensile tester is loaded until failure occurs. Failure is defined as any event which allows the membrane to come free of the edge termination or the termination to come free of its mount.

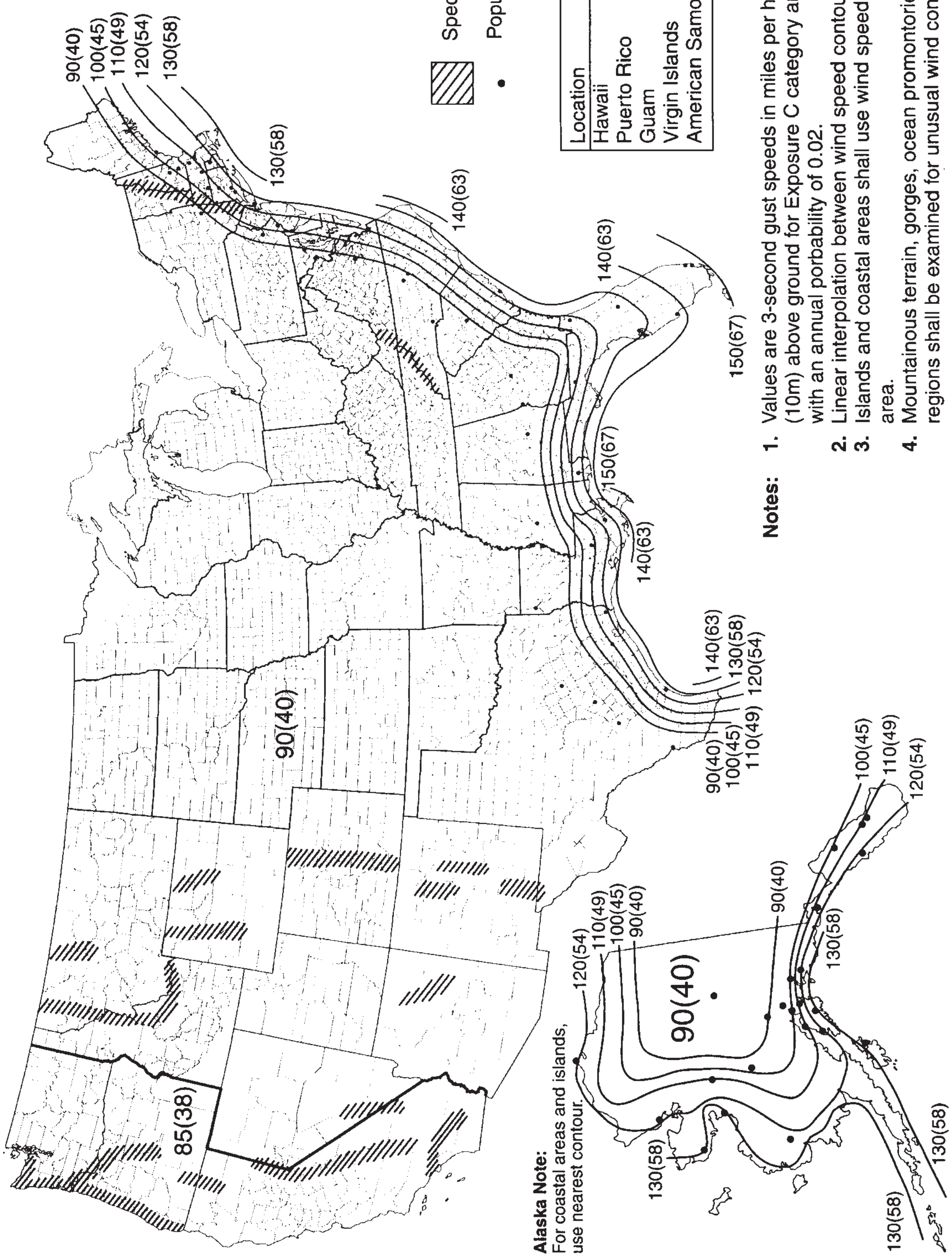
The roof edge termination strength is satisfactory if the test force at failure on a 12" wide sample exceeds 100 pounds (43 kg).

Figure 2. Fascia Membrane Termination Test Set Schematic (Force = F = 100 lbs/ft or 150 kg/m)



ATTACHMENT II

BASIC WIND SPEED MAP



Special Wind Region

• Population Center

Location	V mph	(m/s)
Hawaii	105	(47)
Puerto Rico	125	(56)
Guam	170	(76)
Virgin Islands	125	(56)
American Samoa	125	(56)

Notes:

1. Values are 3-second gust speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category and are associated with an annual porbability of 0.02.
2. Linear interpolation between wind speed contours is permitted.
3. Islands and coastal areas shall use wind speed contour of coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special regions shall be examined for unusual wind conditions.

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COMMENTARY TO ANSI/SPRI

This Commentary consists of explanatory and supplementary material designed to assist designers and local building code committees and regulatory authorities in applying the requirements of the preceding standard.

The Commentary is intended to create an understanding of the requirements through brief explanations of the reasoning employed in arriving at them.

The sections of this Commentary are numbered to correspond to the sections of the RP-4 standard to which they refer. Since it is not necessary to have supplementary material for every section in the standard, there are gaps in the numbering of the Commentary.

1.0 INTRODUCTION

While the standard is intended as a reference for designers and roofing contractors, the design responsibility rests with the "designer of record."

2.0 GENERAL DESIGN CONSIDERATIONS:

2.6 Wind Speed:

- Special Wind Regions (mountains or valleys): Refer to Section 6.5.2.1 of the ANSI/ASCE 7-95 Commentary.

- The intensifying effects of topography (hills or escarpments) are to be accounted for. Information on speed-up over hills and escarpments can be found in the Supplement to the National Building Code of Canada 1990 and in the ASCE-7-95, "Minimum Design Loads for Buildings and Other Structures". See Section 6.5.5. of the ASCE-7-95 document.

  Alternatively, in lieu of increasing the basic wind speed to account for speed-up, a special building height may be utilized. The special building height would be measured from the floor of the valley (or top of the escarpment) to the roof. In some cases, this approach may be overly conservative.

- The "authority having jurisdiction" is the only source for approval of designs not covered in this document. ASCE 7-95 gives guidance on how non-standard conditions should be evaluated.

2.8.1 Corners are not always square. They are formed by the intersection of two walls. This document is using the definition of the angle formed by the two walls as being between 45 and 135 degrees to signify a corner. The designer may choose to include angles outside this range as a corner.

2.9.2 Parapets:

The use of parapets will improve the wind performance of the roofing system. The designer, whenever possible, should use a parapet design that will improve the roof system's ability to resist the wind.

2.10.2 Unprotected Exposures, Exposure A:

The roof being designed in a city center is maybe either too tall to benefit from the protection of adjacent buildings, or is low enough to be affected by wind channeling between them. Because of the effects on ballasted roof systems performance if stone scour were to occur, Exposure A is classified at the same level of severity as Exposure C.

2.11 Large Openings In A Wall:

As an example, because of the great amount of air leakage that often occurs at large hanger doors and roll-up doors (e.g., a warehouse with multiple truck docks), The designer should utilize the provisions of Section 5.1 for design enhancements.

Glazed openings that are sited in hurricane-prone regions with a basic wind speed of 110 mph or greater or in Hawaii, are either required to be designed for missile impact or the building should be designed for higher internal pressure. Glazing below 60 ft is very vulnerable to breakage from missiles unless the glazing can withstand reasonable missile loads and subsequent wind loading, or the glazing is protected by suitable shutters. Glazing above 60 ft is also somewhat vulnerable to missile damage. The designer should take this into consideration and follow the design provision of Section 5.1. See ASCE-7-95 for further details.

2.15 Impervious Deck

The first thing that comes to mind when thinking about materials such as poured concrete and gypsum is that they are impervious to the flow of air. However, in deck constructions there are from time to time penetrations that are cut through these decks that air can pass through. There are also constructions where the expansion joint is located at the deck-wall junction or the wall construction itself (stud or cavity wall construction) can let air in under the roof system. The designer should investigate to assure the "impervious construction" is truly that.

2.16 Pervious decks can result in significant uplift loads on ballasted systems. This can be particularly so if the building is pressurized, or the building is designed as a partially enclosed structure. Partially enclosed areas directly beneath roof area, which allow wind pressure to develop through open soffits, windows or pervious structure should be considered for enhanced design as described in paragraph 5.4.2 or the addition of an air retarding system as described in reference 7.

3.0 Ballast is any object having weight that is used to hold or steady an object. In ballasted roofing systems, the most common ballast used is stone. However, materials such as concrete pavers, lightweight concrete pavers, rubber pavers, and weighted insulation panels are often used to ballast loose laid roofing systems. These ballast systems have been organized into catagories based on their ability to resist the forces of the wind.

3.2 This standard addresses the basic requirements for membrane terminating. For more details on the design of edging and attachment of nailer, see SPRI's document "Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems".

Perimeter Attachment: Some wall constructions allow pressure from the interior of the building to flow up wall cavities, bypassing the deck and entering the space between the roof covering and roof deck. This can be mitigated by following reference #7 or consulting the manufacturer for expert design.

Exterior through wall scuppers if not sealed on the exterior, can allow air on the windward side of the parapet wall to pressurize the space under the roof covering.

3.3 All stone ballast comes with some fines mixed in. ASTM standard D 448 can allow up to 5 percent fines. This may lead to problems at drains, scuppers, etc. due to build-up of these fines. If the source of stone is including too many fines, it may be advisable to have it "double washed" to get the fines below 2 percent.

4.0 DESIGN OPTIONS

The Design Options of Section 4, which also references the Design Tables in Table 1, are built on the wind tunnel work done by Kind and Wardlaw and supported by extensive field investigations (see references). The base used as the design criteria from the wind tunnel work was Critical Wind Speed V_{C2}, the gust wind speed above which scouring of stones would continue more or less indefinitely but not blow off the roof if the wind speed were maintained.

The corners and perimeter areas are where the greatest effects of the disrupted air flow over the building will occur. The worse case scenario is the wind coming onto a corner at a 45% angle. These situations generate wind vortices along the roof edges causing low pressure areas over the roof system as well as wind turbulence that can scour ballast and balloon the membrane. Typically, scour occurs first. To prevent ballast movement, enhanced design provisions are required in some cases for these areas.

The terminology "documented as demonstrated as equivalent with the provisions of the standard" means that a proprietary system has been evaluated through one or all of the following methods:

- Wind Tunnel Testing
- In a Full Scale Test
- Field Documented Studies

The results would show performance levels that meet the locations design requirements.

4.1.3 Test methods typically used to evaluate roof systems for their ability to resist uplift forces are Factory Mutual 4470 and Underwriters Laboratories UL1897. Both testing facilities publish the results for the specific roof assemblies tested. Contact them for additional information.

4.2.2 Protected Membrane Roofing System:

The water-and-air pervious fabric is used for two purposes: one, to prevent gravel fines from working down between the insulation and membrane, which can lead to membrane damage; and two, to control insulation board rafting. Rafting is when an insulation board that may be floating due to a heavy rainfall or a slow draining roof moves out of place when an uneven load, such as foot traffic on the roof, is applied to the insulation board. For information on air retarders, see references 7 and 10. Although all systems may benefit from well installed air retarders, this standard is based on having no deliberately installed air retarders for all systems with 10 lbs/sq ft or more of ballast weight. For lighter weight systems, air retarders are required, but this standard assumes the air retarder is imperfect.

5.0 DESIGN PROVISIONS

5.1 Large Openings In A Wall

The design provision for large openings considers glass as a solid wall. However, if the wall just under the roof system is largely glass, the designer working on a project in an area where there is the potential for severe weather may want to consider the glass as an opening because of the potential for glass breakage due to flying debris. See ASCE-7-95 for further details.

6.0 DETERMINATION OF BALLASTED SYSTEM ROOF DESIGN

If a building does not fit the criteria of this document, the designer should refer to reference 1 and ASCE-7.

References:

1. Kind, R.J. and Wardlaw, R.L., Design of Rooftops Against Gravel Blow-Off, National Research Council of Canada, Report No. 15544, September 1976.
2. Kind, R.J. and Wardlaw, R.L., "The Development of a Procedure for the Design of Rooftops Against Gravel Blow-off and Scour in High Winds," Proceedings of the Symposium on Roofing Technology, 1977, pp. 112.
3. Gillenwater, R.J., "Wind Design Guide For Ballasted Roofing Systems", Proceedings of the Second International Symposium on Roofing Technology, 1985, pp. 219.
4. Kind, R.J. and Wardlaw, R.L., "Wind Tunnel Tests on Loose-Laid Roofing Systems for Flat Roofs," Proceedings of the Second International Symposium on Roofing Technology, 1985, pp. 230.
5. Schneider, K.G. Jr., "A Study of the Behavior of Loose-Laid, Ballasted Single-Ply Roofing Systems Subjected to Violent Winds," Proceedings of the Second Inter- national Symposium on Roofing Technology, 1985, pp. 243.
6. Kind, R.J., Savage, M.G., and Wardlaw, R.L., "Further Model Studies of the Wind Resistance of Two Loose-Laid Roof Systems (High-Rise Buildings), National Research Council of Canada, Report LTR-LA-269, April 1984.
7. "A Guide To Achieve the Secure Single-Ply", Technical Note No. 20, The Dow Chemical Company, 1986.
8. Kind, R.J., Savage, M.G., and Wardlaw, R.L., "Further Wind Tunnel Tests of Loose-Laid Roofing Systems", National Research Council of Canada, Report LTR-LA-294, April 1987.
9. Kind, R.J., Savage, M.G., and Wardlaw, R.L., "Pressure Distribution Data Measured During the September 1986 Wind Tunnel Tests on Loose-Laid Roofing Systems", September 1987.
10. Dregger, P.D., "Role of Air Retarders Deserve Closer Scrutiny," Professional Roofing, October 1991, pp. 46.
11. Smith, T.L., Kind, R.J., McDonald, J.R., "Hurricane Hugo: Evaluation of Wind Performance and Wind Design Guidelines for Aggregate Ballasted Single-Ply Membrane Roof Systems," Proceedings of the VIII International Roofing and Waterproofing Congress, 1992, pp. 598.
12. Proceedings of the Ballasted Single-Ply System Wind Design Conference, held in Carlisle, PA, 1984.
13. American Society of Civil Engineers Standard ASCE 7-95, "Minimum Design Loads For Buildings And Other Structures".