



EXPLORING

the Sustainably
Built Environment

Fire And Wind Resistance Standards For Vegetative Roofs

MIKE ENNIS, RRC

Single-Ply Roofing Industry (SPRI)

1100 Rosehill Road, Reynoldsburg, OH 43068

Phone: 614-578-7875 • E-mail: m.ennis@mac.com

ABSTRACT

During the 2006/2007 International Building Code (IBC) code change cycle, a proposal was presented and adopted to require vegetative roof systems to be evaluated for their wind and fire resistance. Currently available procedures could not be used to evaluate these types of systems due to the vast array of variables that could be present, such as plant material present, water content of the soil, spacing of the plant material, and many others.

Recognizing this disconnect, SPRI, Inc., the trade association representing the single-ply roofing industry, along with Green Roofs for Healthy Cities and numerous manufacturers and consultants involved in the vegetative roof industry, undertook a project to develop standard design guides for vegetative roof systems for wind uplift and fire-spread resistance. This presentation will summarize the requirements contained in these standards and the data used to support the development of these standards.

SPEAKER

Mike Ennis has been technical director for SPRI, the association representing the single-ply roofing manufacturers and component suppliers, for three years. Prior to this, he worked for the Dow Chemical Company and was the North American application technology leader for commercial products in Dow's Building Solutions business, where he led the development of new products and applications. Mike has 32 years of building and construction experience to his credit.

Ennis is a Registered Roof Consultant (RRC) and is a member of the board of directors of the Roofing Industry Committee on Weather Issues (RICOWI) and the Cool Roof Rating Council (CRRC). He is a member of ASHRAE and ASTM Committees D08, Roofing and Waterproofing; E5, Fire Standards; and E60, Sustainability.

Fire And Wind Resistance Standards For Vegetative Roofs



Figure 1 – Chrysler-Daimler Headquarters, Stuttgart, Germany.

ABSTRACT

Vegetative roof systems have become a popular alternative to conventional systems. They have demonstrated their ability to be sustainable, providing the following positive benefits, to name a few:

- Initial retention and slow release of stormwater
- Reduction of urban heat-island effects
- Improved energy performance

- Improved aesthetics and workplace environment

During the 2006/2007 International Building Code (IBC) change cycle, a proposal was presented and adopted to require vegetative roof systems to be evaluated for their wind and fire resistance. Currently available procedures could not be used to evaluate these types of systems due to the vast array of variables that could be present, including plant material, water content of the soil, spacing of the plant material, and many others.

Recognizing this disconnect, SPRI, Inc. (the trade association representing the single-ply roofing industry), along with Green Roofs for Healthy Cities (GRFHC) and numerous manufacturers, consultants, and contractors involved in the vegetative roof industry, undertook a project to develop standard design guides for vegetative roof systems for wind uplift and fire-spread resistance.

The wind uplift design guide uses data developed in wind tunnel testing, initially used for ballasted single-ply roof systems, and historical industry



Figure 2 – Rockefeller Center, constructed 1933.

practices that have demonstrated acceptable levels of wind-load resistance for over 40 years.

The fire design standard uses the concept of setbacks, firebreaks, roof maintenance, and in some instances, sprinklers to control the fire-spread potential of vegetative roof systems.

This paper details the requirements of the IBC, along with these consensus standard design guides.

INTRODUCTION

Vegetative roofs became popular in Europe about 50 years ago, and while they are not new to the United States (see *Figures 1 and 2*), they have not gained the popularity that they achieved in Europe. This all began to change about five years ago with the increased emphasis on utilizing sustainable building techniques.

The use of vegetative roofs as part

of a sustainable building design is being driven by local codes, energy codes, and green building design guides such as LEED®. Examples include the following.

LEED®

LEED® is a third-party certification program developed by the U.S. Green Building Council (USGBC). This certification program recognizes performance in five areas as follows: site development, water savings, energy efficiency, materials selection, and indoor environmental quality. The use of vegetative roofs can contribute to points in the following categories:

- Site development—protect or restore habitat category
- Site development—maximize open space
- Stormwater design—quantity control

- Heat island mitigation

Green Globes

The Green Globes system is a building environmental design and management tool that provides third-party recognition of buildings' environmental attributes. The use of vegetative roofs can contribute to points in the following categories:

- Heat island mitigation
- Building energy performance

ASHRAE

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) is working on an addendum to Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings; and Standard 189.1, Proposed Standard for the Design of High-Performance

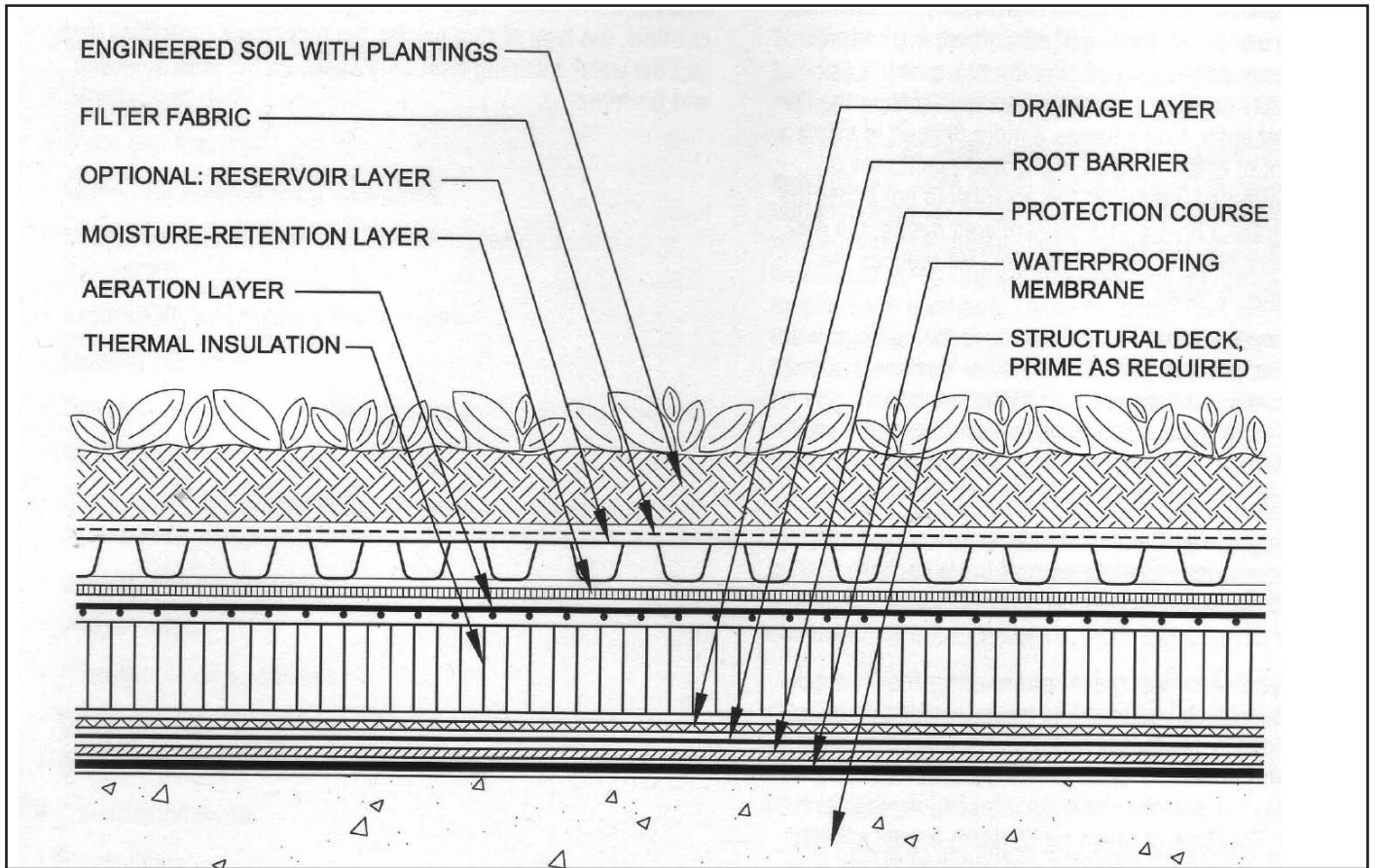


Figure 3 – Typical vegetative roofing system (NRCA, 2008).

Green Buildings Except Low-Rise Residential Buildings. Addendum F to Standard 90.1 provides prescriptive requirements for the use of highly reflective roofs in Climate Zones 1, 2, and 3. The use of a vegetative roof is recognized as an exception to this requirement.

City of Toronto

In May 2009, the city of Toronto, Canada, passed a Green Roof Bylaw. This by-law requires the use of green roofs for all new development above 2,000m² (21,528 sq ft) gross floor area. The requirement became effective on January 31, 2010. The green

roof coverage requirement is graduated based on the gross floor area of the building as shown in *Table 1*.

Currently, the bylaw does not cover industrial buildings. Coverage requirement for industrial buildings, which starts in 2011, equals 10% of the available roof space up to a maximum of 2,000 m² (21, 528 sq ft).

These are just a few examples of regulations that are driving the growth of the vegetative roofing market.

WHAT IS A VEGETATIVE ROOF?

A vegetative roof typically consists of the following components from the top down (see *Figure 3*):

1. Vegetation
2. Growing medium
3. Filter fabric
4. Optional reservoir layer

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000 – 4,999 m ² (21,528 – 53,809 sq ft)	20%
5,000-9,999 m ² (53,820 – 107,628 sq ft)	30%
10,000-14,999 m ² (107,639 – 161,448 sq ft)	40%
15,000-19,999 m ² (161,459 – 215,267 sq ft)	50%
20,000 m ² or greater (215,278 sq ft or greater)	60%

Table 1



Figure 4 – Vegetation being planted as plugs.

5. Moisture-retention layer
6. Aeration layer
7. Thermal insulation
8. Drainage layer
9. Root barrier
10. Protection course
11. Waterproofing membrane
12. Structural deck

In some instances, the insulation can be installed below the waterproofing layer. Whichever design is used, it is most desirable to adhere the waterproofing layer to a very stable substrate, as this helps minimize potential problems with this layer. As one would expect, damage in the waterproofing layer can be difficult to find and repair.

There are many options for the vegetative covering. The vegetative covering can be low-lying plants installed as plugs (see Figure 4), or a vegetative mat (see Figure 5) to provide ground cover, all the way to

plants typically used in natural landscapes, ranging from 1 to 15 ft high. There are also tray systems that are typically interlocking to provide the

sedums or native ground covers. These types of roofs are not generally designed to be walked on;



Figure 5 – Example of vegetative mat (Xero Flor, 2007).

vegetative covering (see Figure 6). The type of vegetative covering used will dictate the depth of growth media required for the vegetative roofing system.

While there are no consensus definitions for types of vegetative roofing systems, there are generally three types of vegetative roofing systems referred to (NRCA 2008):

- **Extensive vegetative roofs** – These systems are designed to be lightweight, with a growing medium of 2 to 6 in. These systems are typically covered with

- **Semi-intensive vegetative roofs**

- These systems are heavier in weight, having 6 to 10 in of growing media. Because of the greater depth of the growing media, a wider variety of plants can be used and the rooftop can be designed to provide walking surfaces;

- **Intensive vegetative roofs**

- These systems have more than 10 in of growing medium and can contain the widest variety of vegetation. This type of system is used when the building owner wishes to have a vegetative space that can be used by building occupants or the general public.



Figure 6 – Example of tray system being installed.

BENEFITS OF A VEGETATIVE ROOF

There are many benefits associated with the use of vegetative roofing systems. According to GRFHC, these benefits include:

Stormwater retention

Vegetative roofs have demonstrated the ability to store stormwater in the substrate and return it to the atmosphere through transpiration and evaporation. This reduces the runoff and delays the time that runoff occurs, resulting in decreased peak loads on the sewer systems. The ability of the vegetative roof system to reduce stormwater runoff is dependent upon the depth of growing medium and type of plants, but in general, they retain 70% to 90% of the precipitation that falls on them in the summer months and 25% to 40% in the

winter months. However, the ability of the vegetated roof to absorb moisture and reduce stormwater runoff is dependent upon the level of saturation of the growth media prior to rainfall. If the growth media is already highly saturated, little stormwater retention benefit is observed (K.Y. Liu *et al.*, 2005).

In addition to retaining stormwater, a vegetative roof moderates the temperature of the water and acts as a filter for any of the water that does run off.

Moderation of the Urban Heat-Island Effect

The urban heat-island effect is primarily due to dark-colored surfaces in cities absorbing and reradiating solar energy, resulting in higher temperatures in the city as compared to the surrounding countryside. Vegetative roofs can moderate this effect through a process known as evapo-transpiration. In this process, plants are able to cool cities in hot summer months by using heat energy from their surroundings to evaporate water. In

recognition of this benefit, the USGBC's LEED® program provides one credit for the use of vegetative roofs as a method to mitigate the urban heat-island effect. In order to obtain this credit, at least 75% of the roof surface must be covered by the vegetative roofing system.

The impact of a vegetated roof on the roof membrane surface temperature was documented in research conducted at the National Research Council of Canada. In this work, the surface temperature of a black roof membrane surface was 158°F, and the membrane surface temperature of the vegetated roof was 77°F. This reduced temperature also lowers the temperature of surfaces and air around the roof surface (Liu K.Y. *et al.*, 2005).

Insulating buildings

Vegetative roofs insulate buildings due to the mass of the growing medium and the vegetation on top of the roof system. As noted under the urban heat-island effect, the vegetation absorbs heat energy and shades

the roof surface. To maximize the shading effect, broadleaf plants are most beneficial. SPRI initiated a study in June 2008 to document the potential energy savings of vegetative roofing systems. One of the objectives of this study was to provide data that can be used to develop a method of modeling the thermal performance of vegetative roofing systems, including the impact of plants and moisture in the soil.

Other Benefits

In addition, vegetative roofs can provide the following additional benefits:

- Sound insulation
- Improved aesthetics
- Food production
- Garden spaces
- Local credits for building owners to help offset the cost of the vegetative roof

These are just a few of the benefits associated with vegetative roofing systems. For more detailed information on vegetative roofing systems, refer to the GRFHC Web site, www.greenroofs.org/index.php/about-green-roofs/green-roof-benefits.

BUILDING CODE REQUIREMENTS

Due to these benefits and the increased emphasis on utilizing sustainable building practices, vegetative roofing systems have gained popularity in the United States. With this increased popularity, a need was perceived to establish building code requirements for these systems. During the 2006/2007 code change cycle for the IBC, the following section was added:

Section 1507.16, Roof gardens and landscaped roofs. Roof gardens and landscaped roofs shall comply with the requirements of this Chapter, Section 1607.11.2.2 and Section 1607.11.2.3.

DISCUSSION

Due to the addition of Section 1507.16 to the IBC, vegetative roofing systems now must be evaluated for wind and fire resistance, but how?

There is a 50-year history of proven performance in Europe and a more limited history in the United States. This history has demonstrated an excellent track record of performance for vegetative roof systems with respect to fire and wind resistance. However, more work needs to be completed to understand the wind performance of these systems when exposed to design wind speeds.

In 1988, a series of fire tests were conducted on vegetative roofing systems in Stuttgart, Germany. In these tests, fires were set on vegetative roofs using dry wood as the fuel source.

The result of all of these experiments and research was a short answer: it is nearly impossible to set an extensive vegetative roof on fire which [*sic*] spreads over the roof or starts a glowing/burning of the growing media. The risk of fueling fires is 15-20 times higher on bare roofs with fully adhered bituminous waterproofing membranes than on extensive vegetative roofs with grasses, perennials, and sedums. Today in Germany, there are at least 2 billion square feet of extensive vegetative roofs built, and there is no fire recorded. (Breuning 2007)

There has been a concern expressed over the years with the potential fire performance of vegetated roof systems using tall grasses and trees. A wide variety of possible scenarios exists when considering this type of system. More work is necessary to quantify their potential hazards.

With respect to wind performance, we can also learn from experience how vegetative systems perform under wind loads.

Through 15 years of experience

and 300 million sq ft of vegetative roof installations, the following has been learned:

1. Wind erosion can happen on a building, regardless of the height of the roof or the height of the parapet.
2. Most erosion on roofs below 60 ft is hardly recognized since it typically starts during the establishment phase of the plants, and the plants usually cover these areas soon.
3. Large organic particles (wood chips, etc.) and very lightweight aggregates are blown away fairly easily and are often found everywhere on the roof where they shouldn't be.
4. Most of the (hard-to-see) wind damage on buildings below 60 ft is also caused by unique aerodynamics of the buildings themselves.
5. All installers agreed that even the smallest wind damage has to be fixed immediately with appropriate solutions to prevent further damage (Breuning 2007).

In 1997, a 560,000-sq-ft extensive vegetative roof was installed on a building over 60-ft tall. It was located in an open field on top of a hill. The roof was exposed to a storm with wind speeds up to 90 mph and wind gusts up to 115 mph. During this storm, some large areas of the famous Black Forest were gone, along with 0.8% of the vegetative roof on this big box (4,000 sq ft). This vegetative roof survived and performed well because it was designed according the existing standard and the FLL Guideline for the Planning, Execution, and Upkeep of Vegetative-Roof Sites to withstand very high wind loads (Breuning 2007).

As mentioned, more information is needed on the performance of vegetated roof systems at design wind speeds. Of particular concern are veg-

etated roof systems that include large plants and trees. An example of this type of system is shown in *Figure 7*. This roof was exposed to Hurricane Ike. Few, if any, tree limbs were blown away during this wind event. Sheltering from nearby buildings may have prevented limb damage. Also, the low-level wind speeds in the downtown area were not sufficiently high to cause substantial loss of limbs. The concern with limbs is their potential to damage glazing, particularly when trees are placed many floors above grade (FEMA MAT P-757 2009).



Figure 7 – Example of vegetative roof with trees.

While there have been no significant issues with fire and wind resistance of vegetative roofing systems, there are also no consensus standards to test their fire and wind resistance.

The standards currently referenced in the code are not appropriate for evaluating vegetative roofing systems. For example, the code currently references the use of FM4450, FM4470, UL580, or UL1897 for evaluating the wind uplift resistance of roofing assemblies. All of these procedures use pressure either above or below the roof deck, or a combination of both, to determine the load at which the roofing assembly will fail. This approach is not appropriate for vegetative roofing assemblies, since the top covering is loose-laid. These systems perform like ballasted roofing assemblies and require techniques such as wind-tunnel testing to under-

stand the performance of these systems.

For evaluating the fire resistance of the top surface of roofing assemblies, the code states, “Roof assemblies shall be divided into the classes defined below. Class A, B and C roof assemblies and roof coverings required to be listed by this section shall be tested in accordance with ASTM E108 or UL790.”

While these test procedures could be used to test a vegetative roof system, the question is what system to test. As noted earlier, there are many variables in a vegetative roofing system: plant types, plant spacing, trays or landscape plantings, and growing media conditions (wet or dry), to name a few. Both UL and FM are evaluating methods to fire-classify vegetative roofing systems. One option being considered is to classify only very specific systems, such as sedum-based or lawn-grass-based vegetative roof systems.

TEST METHOD DEVELOPMENT

Due to a lack of consensus standards and the need for these standards to meet the requirements of the International Building Code, SPRI, and GRFHC teamed up to develop the required standards. For the reasons noted above, it was decided to take a design approach vs. a test approach in their development.

After completion of these consensus standards, the intention is to propose that they be included in the IBC to address the requirements of Section 1507.16.

The wind and fire performance of vegetative roof systems is influenced by the maintenance of these systems. For example, the excellent wind performance of these systems is due to the tenacity of the root system holding everything together. The moisture content of the plants can influence the fire performance of the system. Since maintenance is an important

factor, it will also be necessary to submit code change proposals to the International Property Maintenance Code to describe maintenance requirements for vegetative roof systems.

WIND STANDARD

Since the top covering on the vegetative roof assembly is loose-laid, it behaves like a ballasted roofing assembly. Extensive wind-tunnel testing has been conducted over the years to understand the performance of ballasted roofing assemblies. These test programs lead to understanding the impact of such variables as wind speed, ballast particle size, ballast weight, building height, parapet height, and the location at which the wind impacts the building.

These data were used in the development of ANSI/SPRI RP-4. This standard provides ballast system recommendations for various design wind speeds, building heights, and parapet heights. Since these data and approach already existed, it was viewed as an excellent starting point for the development of a wind standard for vegetative roof assemblies.

One of the differences between an aggregate ballasted roof and a vegetative roof is that the growth media used in vegetative roofs contains small particles. If left exposed, these small particles can be displaced at relatively low wind speeds. For this reason, the NRCA sponsored wind-tunnel testing. One of the objectives of this testing was to determine the maximum area that could be left exposed without resulting in significant amounts of growth media blowing off and providing wind-borne debris. This work determined that additional measures must be taken to prevent wind blow-off of growth media in any exposed areas in excess of 5 sq in.

BSR/SPRI RP-14 Wind Design Standard for Vegetative Roof Systems, is the designation for the wind design standard. Fundamentally, this standard takes the same approach as ANSI/SPRI RP-4, providing design

recommendations based on the design windspeed, exposure category, building height, and parapet height.

This standard provides a method of designing wind-uplift resistance of vegetative roofing systems. It is intended as a design and installation reference and should be used in conjunction with the installation specifications and requirements of the manufacturer of the specific products used in the vegetative roofing system.

SYSTEM OPTIONS FOR VEGETATIVE ROOFING SYSTEMS

There are three basic design options for vegetative roofing systems in the RP-14 standard: Systems 1 through 3. As the number of the system increases, its ability to resist wind loads also increases. There are two ballast options provided in the standard.

Ballast Option #4

Growth media installed at a rate of 1,000 pounds per 100 sq ft plus organic material and protected by vegetation, with maximum bare spots of 5 sq in, or provisions have been made to prevent wind scour. In the NRCA-sponsored wind-tunnel tests, liquid tackifiers were found to be particularly successful in preventing blow-off of growth media. Other allowable forms of ballast:

- Nominal 1.5-in, smooth, river-bottom stone ballast, gradation size #4, (or alternatively, #3, #24, #2, or #1) as specified in ASTM D448, Standard Sizes of Coarse Aggregate, spread at a minimum rate of 1,000 pounds per 100 sq ft.
- Standard concrete pavers (minimum 18 psf).
- Interlocking, beveled, doweled, or contour-fit lightweight concrete pavers (minimum 10 psf dry weight plus organic material).

- Modular preplanted or pre-grown vegetative roof trays that are independently set (minimum size of 2.25 sq ft), interlocking, contoured-fit, or strapped together (minimum 10 psf dry weight plus organic material).

Ballast Option #2

Growth media installed at a rate of 1,300 pounds per 100 sq ft plus organic material and protected by vegetation, with maximum bare spots of 5 sq in, or provisions have been made to prevent wind scour. Other allowable forms of ballast:

- Nominal 2.5-in, smooth, river-bottom stone of ballast gradation size #2 (or alternatively, #1), as specified in ASTM D448, Standard Sizes of Coarse Aggregate, spread at a minimum rate of 1,300 pounds per 100 sq ft.
- 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.
- Modular preplanted or pre-grown individually set vegetative roof, minimum 22 psf dry weight, plus organic material.
- Modular preplanted or pre-grown trays that are interlocking, contoured-fit, or strapped together, minimum 13 psf inorganic material dry weight, plus organic material.

DESIGN OPTIONS

The design options are:

System #1

Install ballast #4 over the entire membrane.

System #2

In the field of the roof, the installed membrane shall be ballasted with ballast #4. Number 2 ballast

shall be the minimum ballast used in wind-borne debris areas. Corner and perimeter areas shall be ballasted with #2 ballast.

System #3

In the field of the roof, the installed membrane shall be ballasted with #2 ballast. In corner and perimeter areas, install an adhered or mechanically attached roof system designed to withstand the uplift loads in accordance with ANSI/ASCE 7 or the local building code. No loose stone, growth media, or modular vegetative roof trays can be placed on the membrane. When a protective covering is required over the membrane, a fully adhered system shall be used. Over the fully adhered membrane, install minimum 22 psf pavers. Mechanically fastened membrane systems shall not be used when a protective covering is required.

DESIGN CONSIDERATIONS

1. Definition of Roof Corners and Perimeter

Corner. The corner is defined as the space between intersecting walls forming an angle greater than 45° but less than 135°, and 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 ft (see Figure 8).

Perimeter. The perimeter area is defined as the rectangular roof section parallel to the roof edge and connecting the corner areas with a width measurement equal to 40% of the building height, but not less than 8.5 ft (see Figure 8).

Note that 40% of the building height is used to determine the corner and perimeter areas, subject to a minimum of 8.5 feet. As a result, the corners and perimeter areas are subject to more restrictive ballast requirements and are greater in size than the corner and perimeter areas in mechanically attached or adhered roof assemblies. This recognizes the potential for displacement and possible blow-off of vegetative roof materi-

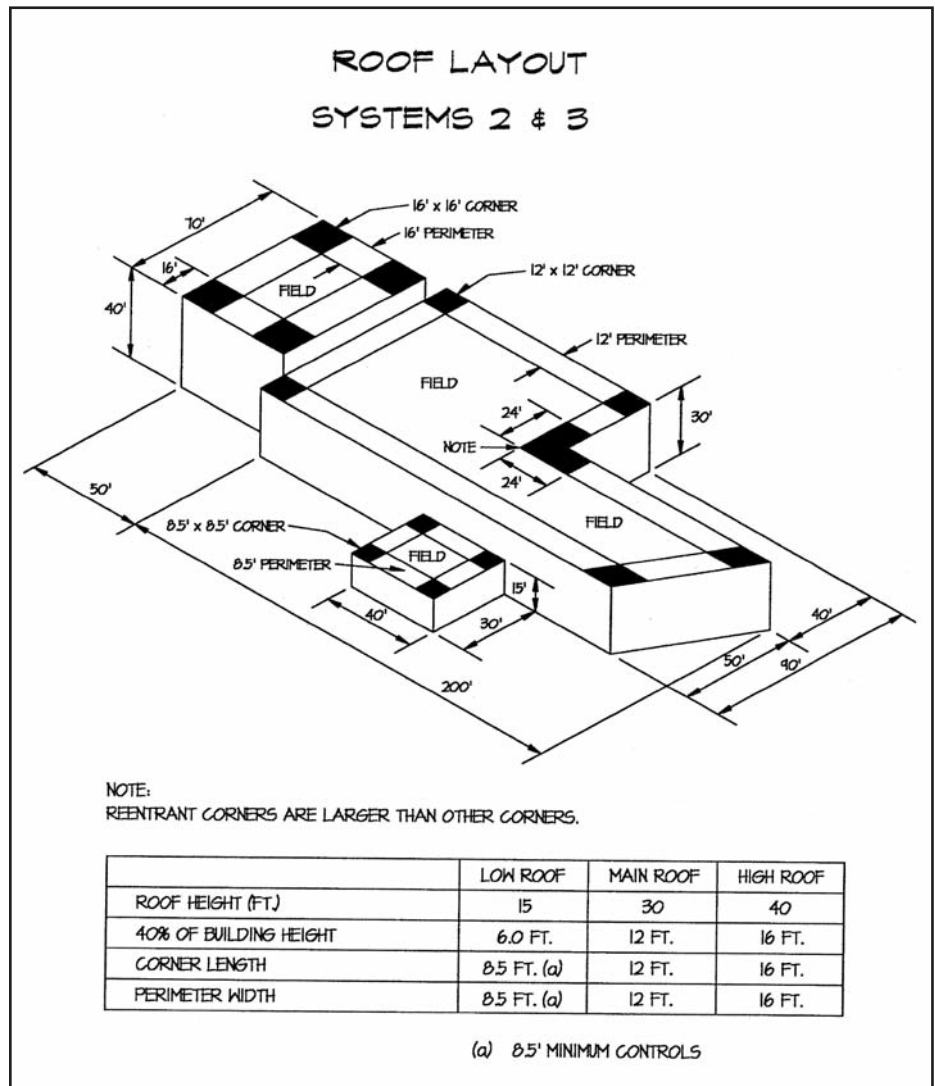


Figure 8 – Corner and perimeter layout (BSR/SPRI RP-14 2008).

als and requires special detailing of these areas.

2. Parapet Height

The parapet height for vegetative roof systems is the distance from the top of the soil media to the top of the parapet.

Limitation: If the gravel stop or parapet is less than 2 in above the soil media, the vegetative roof shall only be installed in the field of the roof. The exposed edge of the vegetative roof shall be protected with stone, pavers, or special design-edge treatment to protect the components of the vegetative roof and soil media from the wind.

3. Large Openings in a Wall

If a fully adhered membrane roof system is not used and the total area of all openings in a single exterior wall is between 10% and 50% of that wall area in the story located immediately below the roof, a rectangular area that has a width that is 1.5 times the width of the opening and a depth that is 2.0 times the width of the opening 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 rectangular area (see Figure 9).

When a fully adhered membrane roof system is not used and the total area of all openings in a single exterior-

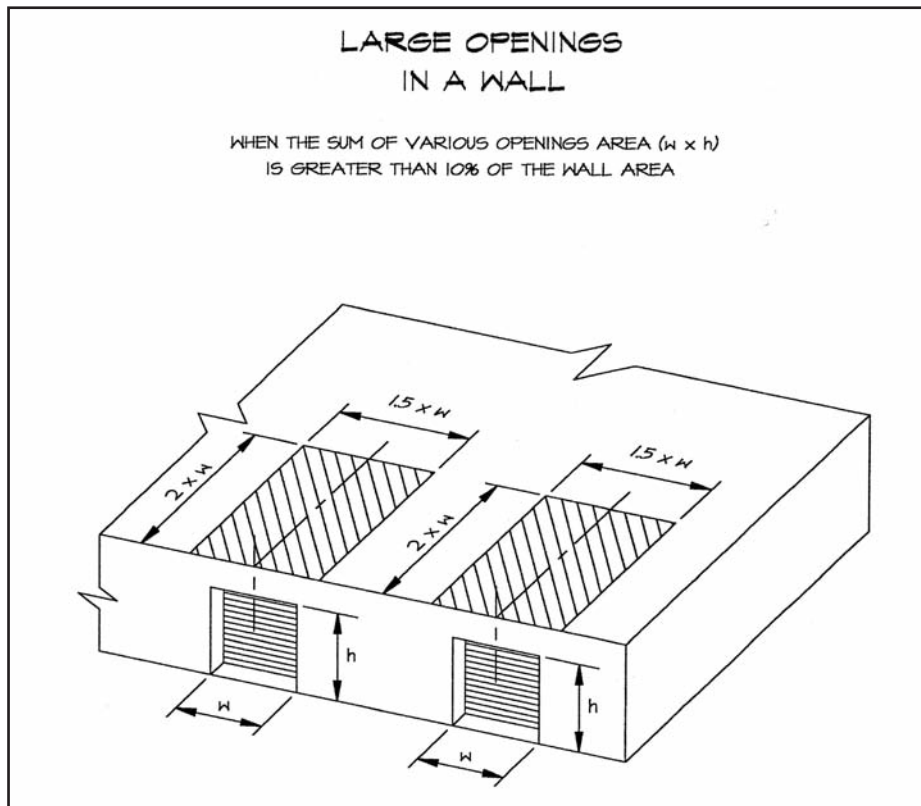


Figure 9

or wall exceeds 50% of that wall area in the story located immediately below the roof, the system design must be upgraded to the next design level. That is, a System 1 design must be upgraded to a System 2 design, a System 2 design must be upgraded to a System 3 design, and a System 3 design must be upgraded to a roof system that is designed to resist the uplift loads in accordance with ASCE 7 or the local building code. The rectangular roof area over the opening must be designed as a corner section.

4. Positive Pressure in Building Interior.

When a fully adhered membrane roof system is not used and positive pressure conditions between 0.5 and 1.0 inch of water are present in a building, the design roof top wind speed must be increased by 20 mph from the basic wind speed from the wind map. The roof must be designed to meet this higher design wind speed. When positive pressures are greater than 1.0 inch of water, the design of the roof must be based on a

licensed design professional method and approved by the authority having jurisdiction.

5. Rooftop Projections

When rooftop projections rise 2 ft or more above the parapet height and have at least one side greater than 4 ft in length, the roof area that extends 4 ft out from the base of such projections and that does not have a minimum 80% vegetative coverage must be covered with a wind erosion mat.

6. Overhangs, Eaves and Canopies

Impervious Decks. Eaves and overhangs must be designed as perimeter areas of the applicable design. Canopies must be designed as corner sections of the applicable design.

7. Pervious Decks

When the deck is pervious and a fully adhered membrane roof system is not used, overhang, eave and/or canopy areas must be upgraded to

the corner design of the next-level system for wind resistance over the applicable design. For this situation, the entire overhang, eave, or canopy of a System 1 design shall be upgraded to a System 2 corner design; the entire overhang, eave, or canopy of a System 2 design shall be upgraded to a System 3 corner design; the entire overhang, eave, or canopy of a System 3 design shall be designed to the System 3 corner design.

When a fully adhered membrane roof system is used, follow the design recommendations for an impervious deck design.

8. Exposure D

For buildings located in Exposure D, the design wind speed is to be increased by 20 mph from the basic wind speed from the wind map. Under these conditions, a building roof located in a 90-mph wind zone would be upgraded to 110 mph. Installation would then follow all of the requirements for the higher design wind speed.

9. Wind-borne Debris Regions

For vegetative roofs used in wind-borne debris regions, consideration shall be taken to minimize woody vegetation that could become wind-borne debris. Trees, palms, and woody bushes could have limbs break off in the wind, leading to building damage.

10. Wind Erosion Protection

If bare spots exceed a maximum of 5 sq in, provisions must be made to prevent wind scour. Wind-tunnel tests have demonstrated that tackifiers are particularly successful in preventing blow-off of growth media.

11. Importance Factor

For buildings fitting category III or IV the design wind speed is to be increased by 20 mph from the basic wind speed from the wind map. Under these conditions a building roof located in a 90 mph wind zone would be upgraded to 110 mph etc. Installation would then follow all of the requirements for the higher design wind.

Determining System Design

To determine the system design (1, 2, or 3) to use for the vegetative roofing system, use the appropriate design table and find the design that matches the wind speed, building height, parapet height, and exposure condition after making adjustments (i.e., importance factor, openings, etc.) for the building under design.

For example, for a 75-ft building with a 10-in parapet height in an Exposure C area and a design wind speed of 90 mph, a System 2 would be required (see outlined number in Table 2).

FIRE STANDARD

The designation for the fire standard is BSR/SPRI VF-1, Fire Design Standard for Vegetative Roofs. The design options provided in this standard were developed to provide a barrier to prevent the spread of fire from the vegetative section of the roof to other parts of the building. These design options were developed from European experience, forest fire prevention, and roofing experience. The use of the IBC-prescribed standard procedures to test vegetative roof designs using ASTM E108 and UL 790 were considered to be practical only on a very limited basis. With all the plant types that could be used in a roof design, the varying weather conditions that occur throughout the year, and the effects of seasons, too many variables exist to classify most roof constructions. For this reason, the barrier design method is used.

This standard provides a method for designing fire resistance for the most common and recognized of the vegetative roof systems. It is intended as a design and installation reference for those individuals who design, specify, and install vegetative roofing systems. The standard should be used in conjunction with the installation specifications and requirements of the manufacturer of the specific products used in the system.

Vegetative Roof Design Options and Generic Fire-Resistive Vegetative Systems

The standard lists two systems that have demonstrated excellent fire-resistive characteristics and requires the use of either of these systems, systems that have documented an equivalent performance, or systems that are approved by the jurisdiction having authority. The generic fire-resistive systems listed are:

1. **Succulent-based systems:** Systems in which the vegetative portion of the roof is planted in growth medium that is greater than 80% inorganic material, and the vegetation consists of plants that are classified as succulents. Nonvegetative portions of the rooftop shall be systems that are classified ASTM E108, Class A.
2. **Lawn grass-based systems:** Systems in which the vegetative portion of the roof is planted in growth medium that is greater than 80% inorganic material, and the vegetation consists of plants that are classified as lawn grass. Nonvegetative portions of the rooftop shall be systems that are classified ASTM E108, Class A.

Vegetative Roof System Requirements

Fire protection for rooftop structures and penetrations. For the purpose of this standard, a penetration is an object that passes through the roof structure and rises above the roof deck/surface. These may consist of but are not limited to HVAC units, penthouses, ducts, pipes, expansion joints, and skylights. For all vegetative roofing systems abutting combustible vertical surfaces, a Class A-rated (per ASTM E108 or UL790) roof system shall be achieved for a minimum 6-ft (1.8-m) wide continuous border placed around rooftop structures and all rooftop equipment.

Spread of fire protection for large roof areas. A firestop as described below shall be used to partition the roof area into sections not exceeding 15,625 ft² (1,450 m²), with each section having no dimension greater than 125 ft (39 m). One or more standpipes from the building sprinkler system shall be provided on large-area roofs.

Fire-stop Options

1. **Walls.** Fire-stop walls shall be of noncombustible construction complying with the applicable building code and extending above the roof surface a minimum of 36 in.
2. **Firebreak roof areas** shall consist of a Class A- (per ASTM E108 or UL790) rated roof system for a minimum 6-ft (1.8-m) wide continuous border.

MAINTENANCE REQUIREMENTS

The standard requires that maintenance be provided as needed to sustain the system, keeping vegetative roof plants healthy and dry foliage to a minimum. Maintenance includes but is not limited to irrigation, fertilization, and weeding. Excess biomass such as overgrown vegetation, leaves, and other dead and decaying material shall be removed at regular intervals not less than two times per year. Provision shall be made to provide access to water for permanent or temporary irrigation. The requirement for maintenance shall be conveyed by the designer to the building owner, and it shall be the building owner's responsibility to maintain the vegetative roof system.

CONCLUSIONS

Fire- and wind-resistance standards have been developed for vegetative roofing assemblies. These standards were developed to help address requirements of the International Building Code (IBC). Code-change proposals have been submitted to include these standards in the IBC.

**A. FOR PARAPET HEIGHTS FROM 2 IN TO LESS THAN 6
MAXIMUM ALLOWABLE WIND SPEED (MPH)**

BLDG. HEIGHT (ft)	SYSTEM 1		SYSTEM 2		SYSTEM 3	
	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B
0-15	100	105	115	115	130	140
> 15-30	100	105	110	115	130	140
> 30-45	90	100	100	115	130	140
> 45-60	NO	NO	95	115	120	140
> 60-75	NO	NO	90	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 IN TO LESS THAN 12 IN
MAXIMUM WIND SPEED (MPH)**

BLDG. HEIGHT (ft)	SYSTEM 1		SYSTEM 2		SYSTEM 3	
	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B
0-15	100	105	115	115	130	140
> 15-30	100	105	110	115	130	140
30-45	90	100	100	115	130	140
> 45-60	NO	NO	95	115	120	140
> 60-75	NO	NO	90	110	120	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 IN TO LESS THAN 18 IN
MAXIMUM WIND SPEED (MPH)**

BLDG. HEIGHT (ft)	SYSTEM 1		SYSTEM 2		SYSTEM 3	
	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B	EXPOSURE C	EXPOSURE B
0-15	100	105	115	115	140	140
> 15-30	100	105	110	115	140	140
> 30-45	90	105	105	115	140	140
> 45-60	NO	90	95	115	130	140
> 60-75	NO	90	90	110	120	130
> 75-90	NO	NO	90	110	110	120
> 90-105	NO	NO	90	100	110	110
> 105-120	NO	NO	85	100	100	110
> 120-135	NO	NO	NO	100	100	110
> 135-150	NO	NO	NO	95	100	110

Table 2

Code-change proposals have also been submitted to the International Property Maintenance Code to require maintenance of these systems.

In both cases, the standards are design standards versus test standards. This approach was taken due to the extensive number of variables that are present in vegetative roof system design, including the thickness of growth media, plant types, and moisture content of the assembly at any point in time.

REFERENCES

J. Breuning, "Do We Need a Belt, Suspenders, and a Nail in Our Belly Button to Hold Our Pants?" *The Vegetative Roof Infrastructure Monitor*, Spring 2007, pp. 12-13.

National Roofing Contractors Association, *The NRCA Vegetative Roof Systems Manual*, Second Edition, 2008, pp. 30-32.

Single Ply Roofing Industry, BSR/SPRI Standard RP-14, Wind Design Standard for Vegetative Roof Systems, 2008.

Single-Ply Roofing Industry, BSR/SPRI Standard VF-1, Fire Design Standard for Vegetative Roof Systems, 2008.

K.Y. Liu and A. Baskaran, "Using Garden Roof Systems to Achieve Sustainable Building Envelopes," National Research Council of Canada, Technology Update No. 65, September 2005.

FEMA Mitigation Assessment Team Report, Hurricane Ike in Texas and Louisiana, FEMA P-757, April 2009).