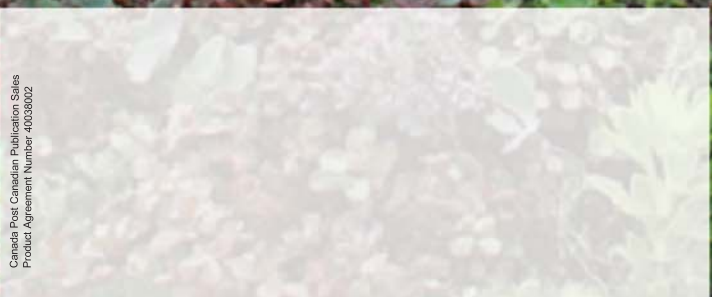


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**What Can We Do About
The New Fire and Wind
Code Requirements?**



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By DAVID L. ROODVOETS

Rooftop Gardens

What Can We Do About the New Fire and Wind Code Requirements?

The following article was originally published in the Proceedings of RCI's Symposium on Building Envelope Technology, Oct. 27 and 28, 2008 in Atlantic, GA. It is reprinted from the January 2010 issue of RCI's Interface magazine. RCI is a professional association of over 2500 building envelope consultants who specialize in the design, repair and management of roofing, exterior wall and waterproofing systems. RCI Professional Members are governed by an established code of ethics and operate without connection to manufacturer or product. For more information, visit www.RCI-Online.org.

THE GREEN REVOLUTION

The green revolution is over. A new paradigm exists. We are very much beyond the revolutionary phase of dramatic change

in roofing practice. One revolution began in 1980. The "army" had been building for several years, but in 1980 the use of non-asphaltic systems exceeded two per cent of the market for the first time. This revolution brought roofing systems with less material content, less weight and less labour. It has been followed by the rapid growth of reflective and (green?) garden roofs since the mid-1990s. Today, although first costs are still a major driving force in the roofing industry, there are more and more owners who want the whole story. Today the issues of carbon footprint, life-cycle costs and values beyond first cost are more likely to be considered.

The building consultant has a major role in providing useful answers to the ar-

chitect and owners designing the building. Questions about life-cycle cost are most important; however, the prospect of other benefits now must be considered. Reflective roofs are considered both to save energy use and to lessen the heat island effect. Garden roofs provide similar benefits in reduction of energy use and in helping to reduce the heat island effect. Garden roofs have additional benefits in aesthetics and the potential to reduce stormwater flow to drainage systems. This type of roof sometimes helps to achieve a larger effective building footprint, using less land to achieve more salable space.

Garden roofs have become a popular system in many major cities, with Chicago leading the way. This has spread to many of the areas around Chicago, as well. Another area with a significant number of in-



Photo One. (Left) Summer garden roof. (Photo Courtesy of Live Roof Inc.).

Photo Two. (Below) Close-up of typical Sedum. (Photo Courtesy of Live Roof Inc.).





Photo Three. (Left) Interior garden. (Photo Courtesy of Live Roof Inc.)

place systems is the Washington, DC/Alexandria, VA, area. Ford Motor Company in Detroit has one of the largest garden roofs in the world at its River Rouge production plant. Western Michigan has one of the highest concentrations of Leadership in Energy and Environmental Design® (LEED) buildings and buildings with garden roofs in the United States.

Designers are well aware of the significant costs of garden roofs and the additional weight they add to roofing systems, but those significant costs are usually little more than carpet for one floor of the building. The energy saving benefits are expected to offset most of the first costs, and the aesthetics add value to the space (See Photos One and Two).

So the industry has a good thing. Those designing LEED®-certified buildings love it. Garden roofs look great and have had a long performance history. No doubt there have been issues with getting the waterproofing right and the right plants on the

roof, using the right soil, but the knowledge base now exists to answer those questions for most installations. So what could go wrong?

THE BUILDING CODE

Most designers have had little concern for the fire and wind performance of garden roof systems, primarily because there have not been significant problems reported. However, a code change was accepted in the 2006/2007 cycle that has focused attention on the issue of fire and wind and garden roofs. This rather simply worded change, which is part of the 2009 International Building Code, is as follows:

FS210-06/07

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 1607.11.2.3.¹*

Although these requirements were generally understood before the change, they are now explicit. When this code is adopted in many jurisdictions, in 2010 and beyond, it will be the law and remain as the enforced law for many years.

The meaning of the code change: The first phrase covers most every type of garden roof that may be used in commercial construction. If there are plants on the roof, then the system must comply with the requirements of Chapter 15 of the International Building Code where adopted. (It is assumed for the purposes of this article that the code will be adopted by jurisdictions without modification; however, codes can be adopted with modification that could eliminate this requirement).

The language also requires that the systems comply with Sections 1607.11.2.2 and Section 1607.11.2.3. This is not a new requirement. It is in the 2006 International Building Code. Since this is the easy part, it will be discussed first.²

SECTION 1607 ROOF LOADS

Section 1607.11.2.2, Special Purpose Roofs. *Roofs used for promenade purposes, roof gardens, assembly purposes or other special purposes shall be designed for a minimum live load as required in Table 1607.1. Such roof live loads are permitted to be reduced in accordance with 1607.9.*

This is rather straightforward. The structure of the building should be able to support the roof loads. It is not difficult to follow, and there are adequate engineering tables and calculation of the structural elements to design a building that will support the live load.

The code provides a table to determine the design live loads required in Table 1607.1.

Table 1607.1, Section 30. *Roofs used for promenade purposes (Uniform 60 psf). Roofs used for roof gardens or assembly purposes (Uniform 100 psf). Roofs used for other special purposes (consult the code official).*

Reasons To Install A Garden (Green) Roof

- Enhances a building's appearance.
- Adds space for tenant use and recreation.
- One answer to the urban heat island problem.
- Stormwater management: Retain 50 to 90 per cent of a typical rainfall on the roof.
- Improves a building's energy efficiency.
- Processes airborne toxins and reoxygenates the air.
- Creates a therapeutic and peaceful environment.

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The required roof loads are equivalent to corridors, fire escapes and gymnasiums; interestingly, there are no provisions for the difference between intensive and extensive systems (*Photo Three*).

The code may be somewhat confusing when it requires the live loads for landscaped roofs at 20 psf, as shown below. (Are they segregating out the difference between intensive or extensive systems?)

Section 1607.11.2.3, Landscaped Roofs. *Where roofs are to be landscaped, the uniform design load in the landscaped area shall be 20 psf. The weight of the landscaping materials shall be considered dead load and shall be computed on the basis of saturation of the soil.*

The requirement for wet soil weight for the dead-load design makes sense. The load of saturated soil could be on the structure for the most of the year. Snow loads should also be carefully considered, as the snow could pile up from nearby building sections, and the insulation is likely to make the roof act very much as the surrounding open ground.

The structural loads are straightforward. No special test methods are required. Measuring the weight of the soil is simple, and there is no need to develop a test method to determine weight. It is much different when we look at fire and wind.

The clarified or new requirement of this code change is for all roofs to comply with “this chapter” – that is, Chapter 15 of the International Building Code. There are many important requirements in Chapter 15. The first is noted in section 1503.1.

SECTION 1503, WEATHER PROTECTION

Section 1503.1, General. *Roof decks shall be covered with approved roof coverings secured to the building in accordance with the provisions of this chapter. Roof coverings shall be designed, installed, and maintained in accordance with this code and the approved manufacturers’ instructions such that the roof covering shall serve to protect the building or structure.*

Another key requirement is found in



Photo Four. (Above) Sedum planting in a 110-mph wind. (Photo Courtesy of DLR Consultants).

Photo Five. (Below) Checking the wind speed. (Photo Courtesy of DLR Consultants).



Section 1507, where specific ASTM standards are referenced. Basically, products installed on roofs need to comply with the appropriate standards for that product. This also is not new and is common practice. The changes creating concern are complying with sections 1504 and 1505.

SECTION 1504 PERFORMANCE REQUIREMENTS

1504.1, Wind Resistance of Roofs. *Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 16 and sections 1504.2, 1504.3 and 1504.4.*

1504.2, Clay and Concrete Tile.
1504.3, Wind Resistance of Non-Ballasted Low-Slope Roofing Systems. *Ballasted, low-slope (roof slope <2:12) single-ply roofing system coverings installed in accordance with Section 1507 shall be designed in accordance with 1504.8 and ANSI/SPRI RP-4.*

It’s obvious that Sections 1504.2 and

1504.3 don’t apply, but Section 1504.4 may be useful. The systems are expected to perform like ballasted roofs, in that their weight will be part of their wind resistance. But when we look at Section 1504.4 and Chapter 16, Chapter 1609, other problems arise.

SECTION 1609, WIND LOADS

Section 1609.1, Application.

Buildings, structures, and parts thereof shall be designed to withstand the minimum wind loads prescribed herein. Decreases in wind loads shall not be made for the effect of shading by other structures.

SECTION 1609.5, ROOF SYSTEMS

1609.5, Roof Deck. *The roof deck shall be designed to withstand the wind pressures determined in accordance with ASCE 7.*

1609.5.2 *Roof coverings shall comply with section 1609.5.1.*

Roofing Cover. *The covering applied to the roof deck for weather resistance, fire classification or appearance (Chapter 15 definitions).*

Working from the last sentence of the previous section, “Roof coverings shall comply with section 1609.5.1,” it states that the roof coverings shall be designed to withstand the wind pressures determined in accordance with ASCE 7. How do these systems withstand the wind pressures? Since the typical extensive system weighs about 20 psf, the weight of the system might be considered a force that resists wind pressures. Even if this can be demonstrated as a uniform load, this would provide satisfactory code compliance for the field of roofs on urban buildings that were less than 60-ft.-high and in 90 mph wind zones. This does not provide a matching uplift resistance for the pressures as calculated for the perimeters or corners of these roofs.

OPTIONAL WIND-RESISTANCE TESTING CONSIDERATIONS

Using just the weight of the system to resist the uplift does not provide a realistic answer to the performance of these sys-

Photo Six. (Right) Sedum planting after two hours of exposure to 110-mph wind. (Photo Courtesy of DLR Consultants).



tems. Garden roofs have been installed on a wide variety of buildings and, in many cases, roofs were over 100 ft. above the base terrain. Major suppliers of systems report excellent performance of these systems over many years in both Europe and North America. The author, however, was unable to uncover any systematic study of wind exposure for garden roof systems. Also, little is known of the mechanisms of wind resistance for the various systems.

From experience, the Factory Mutual Research Testing approach of pressurizing the system beneath the membrane would only give the resistance of the membrane to uplift. If the membrane were loose-laid, then the uplift resistance would be the same as the weight of the system. If the membrane were adhered, the test would determine the resistance of the adhesion bonds plus the weight of the system. This may have no relationship to the actual wind resistance of the system. Using a reduced pressure (vacuum) above, as in the National Research Council of Canada or Underwriters Laboratories (UL) tests,

Photo Seven. (Below) Completion of the two-hour test at 110-mph wind. (Photo Courtesy of DLR Consultants).



will only measure the resistance of the underlying membrane system.

ASTM D3161, Test Method for the Wind Resistance of Asphalt Shingles (Fan-Induced Method), might be modified to determine if the plants will blow out of the soil. This could determine if the soil particles will become dislodged or if the plants or mats will be uprooted. The major limitation of this test is that it provides no information on the actual resistance to uplift pressure as required by 1609.5.1. However, combining the knowledge of the resistance of the plants to withstand wind and the historic acceptance of ANSI/SPRI RP4, Wind Design Standard

for Ballasted Single-Ply Roofing Systems, may provide one potential direction for the future (See Photos Four to Seven).

ANSI/SPRI RP-4 may be the foundation for an installation standard for garden roofs and is, in fact, the basis for ANSI/SPRI RP-14. ANSI/SPRI RP-4, a standard with over 20 years of proven performance, opens up the building height to 150 ft and wind speeds up to 140 mph when adequate parapets are present and roof perimeters are protected. RP-4 is further restricted by Table 1504.8 when aggregate is used. The roof-height limit in urban areas in the 90-mph wind zone is 110 ft.

First, though, there is a need to show equivalence of a garden roof to ANSI/SPRI RP-4 or to find a test method that would provide wind-resistance data for all systems. At this time, no such test exists. This creates the dual problems of enforcement and compliance. Since the official having jurisdiction can decide if a system complies with the code, any arbitrary decision can be made.

ANSI/SPRI RP-4 is based on model-scale wind-tunnel testing and field verification of the testing results, as well as more than 30 years of field experience. The wind-tunnel and field data confirm the wind-uplift resistance of the system is greater than would be expected of the resistance of just the weight of the ballast.

Testing garden roofs in wind tunnels would be difficult. The original studies of aggregate-ballasted roofs used one-tenth

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scale models of the buildings and ballast. It was not difficult to model stones down to about three-quarters of an inch, but how would one model vegetation and soil that might have as their largest particles lightweight aggregate of three-eighths of an inch? Erosion mats provide some wind resistance. It would be a real challenge to build a scale model using erosion mats or plants. Then there is always the question of scaling all elements coherently so that supportable data are developed.

Although simple modeling is not likely, there may be ways to actually model entire systems if adequate funding existed. There are, however, many questions as to the value of modeling. The best models closely stimulate actual conditions, but there are many variations of roof covers, etc., which would need to be tested in large wind tunnels to get a reasonable look at industry options.

Another possibility is a wall of wind. The wall-of-wind concept is to build an outdoor facility with several engine-driven props to stimulate real wind. This would require not only the assorted engines for power, but also diverters and roughness elements to more closely simulate the wind.

The wall of wind has been discussed

Photo Nine. (Below) Results of 10-minute ASTM E108, Spread-of-Flame Test. Fire only damaged the area of direct impingement. (Photo Courtesy of DLR Consultants).



Photo Eight. (Above) ASTM E108, Class A Spread-of-Flame fire. (Photo Courtesy of DLR Consultants).

since the mid-1980s. One concept proposed by Idaho National Lab would have cost over \$2 billion to install and huge sums to operate.³ More recently, Florida International University has started a less ambitious project, but they are also finding it difficult to get support. Horsepower requirements for high winds are enormous. Should the wall get built, garden roofs could be tested.⁴

Can natural wind be used? That has probably already been answered. Garden roofs are installed all over the world. They have a wide variety of vegetation and soils, yet there are no complaints of the system blowing off. This exposure is far more than is likely possible at any test facility. Most locations rarely see winds of 70 mph or greater. To get any meaningful test data,

the wind needs to exceed 90 mph for some time and should occur more than once. The best understanding of the wind stability of the system is gained from historic data.

What we have today is a history of success with little to worry about if the system is exposed to high winds. The worst case is dust and debris, the aggregate used is small and fragile, and the plants pose little or no danger if uprooted. After a short time, there is a root mass that interlocks the system. The rest of the world has no wind-design standards that must be met. There is little reason to think that a failure that threatens life or property would occur.

The next question that arises is, "What is the fire performance of these systems?" Since garden roofs must comply with the requirements of Chapter 15, they must comply with the requirements of Section 1505.

TESTING FOR FIRE, SECTION 1505, FIRE CLASSIFICATION

1505.1, General. Roof assemblies shall be divided into the classes defined below. Class A, B and C roof assemblies and roof coverings that are required to be listed in this section shall be tested in accordance with ASTM E108 or UL 790. In addition, fire-retardant-treated wood roof coverings shall be tested in accordance with ASTM D2898. The minimum roof coverings installed on buildings shall comply with Table 1505.1 based on the type of construction of the building.

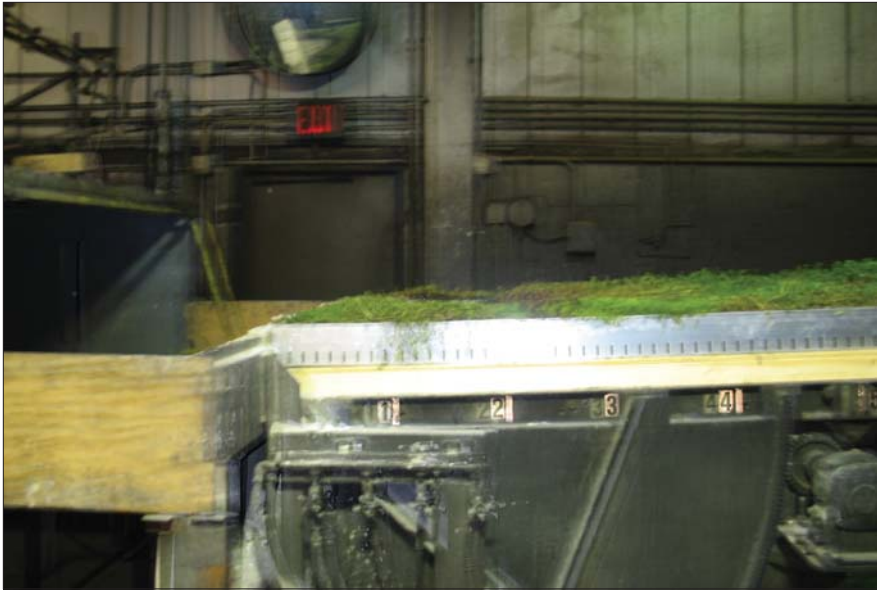


Photo 10. (Above) Fire damage was about two feet, which is the area of direct impingement.. (Photo Courtesy of DLR Consultants).

Commercial buildings require a Class B or A roof, depending on jurisdiction.

The requirements of ASTM E108 are rather straightforward. First, a burning brand placed on top of the roof covering shall not result in flaming that uncovers the roof deck or creates burning brands on the floor. However, if the application is for non-combustible decks, the test is generally waived. Basically, the brand will not burn through three inches of soil, as most of the soils used are largely inorganic and frequently used expanded shale and other lightweight rock that is not combustible.

The second major test is the spread-of-flame test. In this test, the fire should not progress significantly up the test deck or to the sides of the deck. Moist succulents will pass this test easily. There is concern, however, as to the performance of dry materials, particularly grasses. The big question is how would a test agency run these tests? Should the test be run on vegetation that is in a good, moist, growing condition, or should the test be run on dormant or dry plants? What happens if the planting is neglected? Since there is no way to predict stability, there is little hope of a test agency classifying a garden roof for fire resistance. (See Photos Eight to 11).

Is the fire performance a real concern? Again, we need to look at the history. A Google search revealed no matches for “green roof fire” or “garden roof fire” or “garden roof fire” in over 2,000,000 cita-

tions, but in reading down several pages, this article was found:

FIRE IN A ROOF GARDEN

The stage, scenery, tables and chairs, and all other paraphernalia of the Koster & Bial's roof garden were destroyed by fire yesterday morning. The fire started at 8:30... and for three hours the firemen worked to extinguish it. When the last ember was put out, Manager Aarons set at work a large force of men. The debris was cleared away, a temporary stage was erected, new seats were secured and the sacred concert announced for last night was given without interruption. Meantime, the firemen dragged lines of hose to the roof through the foyer and up the stairs leading to the garden. Four

streams were turned on the stage and scenery, but they had been burned beyond repair before the water reached them. The tables and chairs were blazing merrily when the streams were turned on, but the flames were soon extinguished. The fire did not penetrate below the roof, and the interior of the building was not damaged.” [Emphasis by author].

Excerpt from Jun. 19, 1899, New York Times.

So we have one fire on a roof garden reported in Google in the last 109 years. The search of the NFA web site revealed no citations of garden or green-roof fires. The big fire in New York took three hours to put out, primarily because of an outdoor theatre set. The fire did not burn through the roof. There was no interior damage. It does not look like much of a concern.

However, roof gardens were very popular in New York City and elsewhere in the 1890s. One factor in their demise was the firefighters:

WERE THERE EVER ROOF GARDENS IN BOERUM HILL?

By Erik Fortmeyer,
Boerum Hill historian (2005)

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Photo 11. (Below) No damage to anything other than the top cover exposed to direct flame. (Photo Courtesy of DLR Consultants).



Q: Were there ever roof gardens in Boerum Hill?

A. Yes, there were. The idea and use of roof gardens in Brooklyn and Manhattan saw its heyday from the late 1880s up through the beginning of World War I. Boerum Hill was no exception.

Q. Why did roof gardens fade away?

A. Fire inspectors in the late 1890s began to become more and more concerned with commercial roof gardens. If a fire broke out below, and the stairwells and elevators were blocked with smoke and fire, how would the fire department be able to get possibly hundreds of patrons to safety? The question was never satisfactorily answered. Meanwhile, functional air conditioning became available on a limited scale in New York City starting around World War I.⁶

So, 120 years later, the question of fire safety of garden roofs still has no answer, other than 120 years of intervening history that has resulted in no megadisasters and no searchable reports. How do we overcome the firefighters' fears? One thing firefighters like is a sprinkler system. Horticultural experts who are involved with garden roofing always suggest that there be a method of watering the plants to sustain them in the dry periods and to maximize the cooling effects from plant respiration. Are the firefighters and the horticulturalists on the same page?

So, two important entities are concerned about garden roof systems. Both the horticulturalists and the firefighters like a source of water on the roof, but like any good thing, some individuals think they have a better idea. The "better idea" comes from developers of LEED®, who have focused appropriately on reduction of the water usage by buildings. The LEED perspective has influenced the ASHRAE standards committee that is developing a Building Standard 189p, designed to save 30 per cent more energy than the current 90.1 Building Energy standard.⁷ The aim is to have this standard adopted by municipalities that want to have a code they can enforce for buildings that are to meet some higher standard. Interestingly, they have added a section that sets requirements for water use that looks similar to the LEED sustainable sites. They have proposed the following requirement:

**ASHRAE 189P,
POTABLE WATER**

6.3.2.4, Roofs. *The use of potable water to spray roofs for thermal conditioning purposes or irrigation of vegetated roofs is prohibited.*

Using non-potable water sounds like a reasonable idea. Why use fresh water just to water the grass? Saving water is one of the ways to get LEED® points, and it is on many environmentalists' lists of very important things that need to be done to protect the environment.

The use of non-potable water creates problems. First, there is a large cost in setting up the collection system to get an adequate supply of non-potable water to the roof. Because of the cost and in order to meet the code requirements, systems might not be installed to water the roof. Fundamentally, roofs with thin soils and significant exposure to wind and sunlight create near-desert conditions. Sedums and other drought-resistant plants are typically chosen for the roofs, but they may not get enough moisture from rainfall. A well-ir-



Photo 12. (Above) Garden roof in London. (Photo Courtesy of Live Roof Inc.)

rigated garden roof can have a surface temperature as much as 20 degrees Fahrenheit cooler than a roof with similar plantings that has been allowed to dry out. In one study, the roof that had adequate moisture saved 30 per cent more energy than a dry roof.⁸

Sprinkler systems could provide the rapid extinguishing of almost any fire that would occur on the roof garden. Horticulturalists support the idea of watering the roof; it's possible that a dual-purpose system could be developed.

Basically, it is a good idea to have buildings designed to have a non-potable water-collection system. However, its use as roof irrigation appears to be one of the least desirable and least cost-effective uses for non-potable water. The use of potable vs. non-potable water for roof gardens has many ramifications that go far beyond this paper and could be the subject of a future paper. Some questions that may be considered are:

- What are the costs of non-potable

watering systems?

- Are there dangers with non-potable water?
- Is there an adequate source of stored water for the potential drought?

For many areas where fresh water is abundantly available, the benefits of using potable water provide value that should not be restricted by building codes.

THE REST OF THE WORLD

Germany is a leader in the use of garden roofs. It evaluates products and systems carefully before approving them for use. *Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau* (FLL) issued its green roof standards, "Guideline for the Planning, Execution and Upkeep of Green Roof Sites," in English in 2002. It had been available in German for many years previously. The standard covers most aspects of the green (garden) roof, from soil to plants suitable for their climate, as well as fire and wind design.⁹

With reference to wind, the Germans have kept it simple: The standard simply takes the area of the roof of concern, its field, corners and perimeter, and requires that the weight equals the wind-uplift force as required by the building code. This results in some very heavy systems. They do not take advantage of interlocking or potential pressurization effects, nor are they concerned with the potential of small aggregate blowing off the roof. They also don't appear to acknowledge that fully-adhered membranes have significant wind resistance and are likely to provide water penetration protection of the building, even if the soil is blown away. There are no reported wind studies of garden roof systems to back up their position.

Similarly, the Germans do not require special fire tests, but they do have standards as to the separation of plants from walls and fire breaks in large roofs. If a roof is specified for German use, though, there always should be a detailed review of the standard.

The following are some of the general requirements:

- Vegetation should not be adjacent to any large penetration or wall.
- Pavers or gravel are required for the area within 0.5 m (1.6 ft) from the wall or penetration.
- For large roofs, the vegetation must have a firebreak at every 40 m (131 ft). This can be an area of gravel or pavers 1.0 m

(3.3 ft) wide across the entire roof, or a 0.3-m (one-foot) high fire-resistant separation wall. The fire requirements have been carefully considered and do provide a good measure of fire safety.

Similar requirements are found throughout the rest of Europe. The use of garden roofs is encouraged. EN 13956 is a European consensus standard that provides the requirements for low-slope roofing. The fire requirements of this standard for garden roofs are the same as for ballasted roofs. (See Photo 12).

RECOMMENDATIONS

Consultants need to specify systems that are safe, but without test standards, it is difficult to know what is safe. SPRI is attempting to develop installation standards that address these issues, and since SPRI uses the ANSI process, everyone has the right to comment and suggest the language and requirements of standards. This, then, will result in a consensus standard of how systems should be installed.

The wind performance of newly planted systems can be enhanced with the use of erosion mats, and for roofs that are significantly above grade, erosion mats give added wind protection. Systems that are well covered are not likely to blow off, so getting the coverage for the roof as quickly as possible makes sense. Getting the products to grow quickly takes plenty of water, and having a provision to irrigate will allow enhancement of plant growth. The water that is available on the roof should help stabilize the plants in the case of a drought and give the system improved fire resistance.

Systems that are pre-grown offer the advantage of having a finished appearance right away and are likely to be wind- and fire-resistant, starting at the date of installation or very soon thereafter.

The entire fire resistance of the roof is enhanced when succulents are planted. It is key that a horticulturalist who is familiar

with the plants that grow well on roofs in the climate where the roof is installed be consulted and that his or her advice be followed. Following the separation requirements of the German system can keep an incidental fire from becoming destructive.

Code officials may still reject specifiers' proposals, but following the above approaches is likely to produce a system that will perform for the useful life of the building and be defensible as utilizing best practices.

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