Thermoplastic Waterproofing Membranes in Green Roof System Construction 2004

By Peter J. D'Antonio

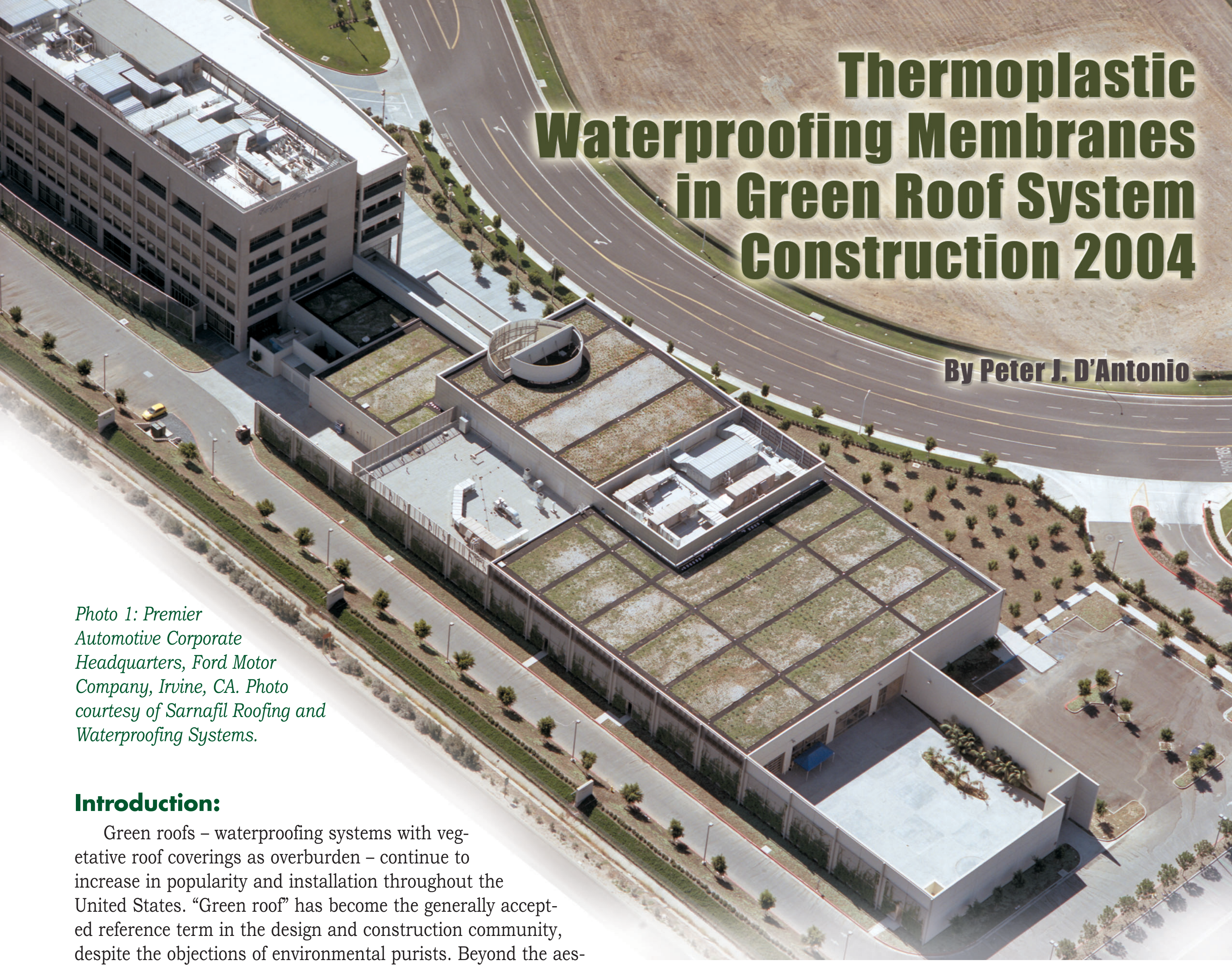

Photo 1: Premier Automotive Corporate Headquarters, Ford Motor Company, Irvine, CA. Photo courtesy of Sarnafil Roofing and Waterproofing Systems.

Introduction:

Green roofs – waterproofing systems with vegetative roof coverings as overburden – continue to increase in popularity and installation throughout the United States. "Green roof" has become the generally accepted reference term in the design and construction community, despite the objections of environmental purists. Beyond the aesthetic appearance, there are a number of significant environmental and owner benefits to installing green roofs. Both the U.S. Department of Energy and the Environmental Protection Agency have promoted the use of green roofs as a method to mitigate the urban heat island effect. Green roofs have been adopted by the U.S. Green Building Council and other organizations promoting sustainable design in the form of recognition points through the various LEED standards. (See article, page 15 this issue.) Many design professionals and building owners are using green roofs to capitalize on the LEED recognition. (See *Photo 1*.)

Health care professionals and facility designers have long recognized the psychological and physical benefits that natural surroundings may provide in a hospital. Patients are able to recover faster. Green roofs provide a natural environment that promotes healing and makes better use of vacant roof space (*Photo 2*).

The city of Chicago has become a strong proponent of green roofs, based on the successful Chicago City Hall project in 2000. (See cover.) The city is encouraging developers to include green roofs in project submittals. Developers are realizing higher rents and property values as a result of installing rooftop patios and green roofs on mixed-use projects. Numerous projects are in the early stages of design (*Photo 3*).

European Experience:

With its roots (pardon the pun) in Europe, green roof technology is spreading from one side of the pond to the other. New product choices, design, and installation techniques are becoming more widely recognized in the U.S. construction industry. At the forefront of this technology transfer, thermoplastic roofing and waterproofing membrane systems have become a preferred choice for green roof system installations. PVC-based thermoplastic membranes have been utilized in green roof systems in Europe for nearly 35 years and in North America for almost 25 years with an excellent track record. New to the roofing market, polyolefin-based thermoplastic membranes continue to evolve in both chemistry and experience.

PVC-based thermoplastic membrane systems offer a number of design and installation advantages. These include:

- Proven membrane performance and track record.
- Design flexibility for both flat and sloped applications.
- Versatility in extensive, semi-intensive, and intensive green roof coverings.
- Ability to be installed in phased applications.

Left: Photo 2. Olson Gardens, St. Louis Children's Hospital. Photo, courtesy Sarnafil Roofing and Waterproofing Systems.

Below: Photo 3: Chicago City Hall. Photo, courtesy City of Chicago.

- Meet critical tests as a root barrier.
- Resist standing or ponding water.
- Reliable for heat welded seams and detailing.
- Less dependent on weather conditions at time of installation.
- Better contractor productivity.
- Long-term durability and waterproofing protection.

Thermoplastic System Design Flexibility and Versatility:

Thermoplastic membrane systems are the most versatile of available green roof waterproofing products. Systems include loose-laid, adhered, and containment grid configurations. The systems can accommodate both intensive and extensive green roof system overburden. The decks can be steeply sloped or flat. The system can be installed not only on concrete decks, but also steel and wood. Increasingly, the vegetative roof cover is being installed not only months, but in some cases years after installation of the membrane system. With planning and foreknowledge, phased construction can easily be accommodated.

Both loose-laid and adhered waterproofing systems are comparable to conventional membrane roof systems. The waterproofing membrane is loose laid over either a geotextile leveling layer or extruded polystyrene insulation. In an adhered system, the waterproofing membrane is bonded to either the concrete substrate or to a layer of insulation (less common). The loose-laid system is the most economical and one of the most commonly specified systems for extensive green roof applications.

For intensive and semi-intensive vegetative coverings, the containment grid system has become a preferred system. This system integrates a series of waterstops below the waterproofing membrane. The grid strips are fully bonded to the concrete deck to compartmentalize the deck area into smaller sections. The grid strips are typically installed around the perimeter of the deck, around projections, at the base of walls, and at the high points of the slope of the drainage fields. The waterproofing membrane is then loose-laid over a geotextile or insulation and welded to the grid strips. Leak detection devices are commonly installed within each grid compartment. The testing devices monitor the performance of the waterproofing system and can be used to determine if repair is necessary. This feature can save significant costs in potential overburden removal and replacement.

The grid system is ideal for new construction projects where the time delay in wet winter months and curing of the concrete deck may be problematic. In renovation projects, the system can save significant time and money in limiting deck preparation costs. In many cases, removal of the existing system can be limited to areas where only the grid strip is installed.

The grid containment system has enjoyed excellent success for more than 25 years. The system provides superior protection and reduces liability for all parties (see *Photo 4*).

Thermoplastic Membranes:

Thermoplastic membranes, both PVC and TPO, by definition can be hot-air welded or permanently fused without dependence on primers, adhesives, or caulking. This welding ability provides permanent seaming of both laps and flashings that will be covered with overburden after construction. The membranes have a strong track record as an impermeable barrier against aggressive root growth and ponding water.

Not all thermoplastic roofing membranes should automatically be considered for green roof application. Proper formulation is the key to long-term performance of any sub-grade waterproofing product. The membrane should have low water absorption characteristics. ASTM D 570, maximum value of 3.0%, is generally acceptable. The membrane should be compounded to properly resist the growth of algae and other organisms. It should have good dimensional stability, a low linear dimensional change (ASTM D 1204, 2%), and have the ability to resist the effects of minor structural settlement and concrete cracks. Membrane durability is obviously important in these applications. Thicker membranes typically have performed better than thinner products. Both 80 mil and 96 mil products have shown greater resistance to construction abuse.

Insulation Location Below the Waterproofing:

Most manufacturers offer products that are designed to be installed directly on a concrete deck with extruded insulation installed above the waterproofing. This installation methodology, however, may not be suitable for all applications. Extensive, semi-intensive, and some intensive systems often purposely integrate ponding water into the design – either for storage or irrigation or as a water feature. In these designs and in severe rain events, the extruded insulation can become buoyant, float, and displace elements above. To resolve this issue, the extruded polystyrene should be positioned below the waterproofing membrane to prevent overburden displacement. In steep slope applications, high wind zones, and phased construction, mechanical securement of the insulation is often necessary to meet code or manufacturer's requirements. In addition, the installation of tapered insulation is often required to influence water flow. Thermoplastic systems provide excellent flexibility to accommodate insulation attachment below the membrane in these project conditions.

Photo 4: Lucas County Public Library, Toledo, Ohio. Photo, courtesy of Midland Engineering, South Bend, Indiana.

FLL Testing for Root Barrier Resistance:

In Germany alone, green roof construction is estimated at more than 20 million square feet per year. Both the Swiss and German governments closely regulate waterproofing products utilized in green roof construction. The Swiss Society of Engineers and Architects SIA 280 Standard evaluates roofing and waterproofing products on the basis of their application in the field. The four application categories include exposed roofing, concealed roofing/waterproofing (green roofs), water vapor barrier, and below-grade protection (foundation). The SIA 280 utilizes 15 test methods, including water absorption (DIN 53475, 53472, and 53495), dimensional stability (DIN 16938 and 53377), and root resistant (DIN 4062) test methodologies.

In Germany, green roof membrane products must be tested by the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau of Essen, or Research Association for Landscape Development and Construction) for resistance to root penetration. The FLL test procedure is considered by many as the most stringent and meaningful green roof membrane test worldwide. To fulfill the test requirements, roofing and waterproofing membranes must "permanently prevent penetration and/or puncturing by roots on flat roofing, in corners and along seams." The FLL test is conducted over a four-year period and is not easily passed.

The test method is conducted using eight square containers made of aluminum sheets. The containers are roughly 31 inches x 31 inches x 14 inches. At the bottom is a transparent pane of glass, darkened with a plastic foil. The glass bottom allows observation and inspection without destroying the planter boxes. The test utilizes four containers for the material being tested and four containers for the control. In each planter box, 2 inches of a wet layer of clay is placed at the bottom and covered with a geotextile fabric.

The control containers are lined with an asphalt-based system consisting of pre-manufactured boards made of bitumen and felt-like material. The boards are about 31 inches x 31 inches and .5 inch thick. Gaps between the boards are sealed with asphalt.

The membrane being tested is installed in the remaining four containers. The membrane is installed with four inside corners, two flat seams, and one T joint running across the middle and up to the edge of the container. See *Illustration 1*.

The material being tested must not contain any applied herbicides or slow growth substances. The area at and around the seams cannot be treated with any substance before, during, or after the installation.

After the waterproofing and control asphalt are in place, the soil mix and plants are installed. The soil mix consists of 70% light decomposed "north German high moor peat and 30% volume billow clay." The soil is spread about 25 cm thick (about 6 inches) directly over the waterproofing. The soil mix is treated with common fertilizers and a pH standard of 5.5 to 6.5 is maintained.

The standard plant species includes two gray alders (*Alnus incana*) two years old, 60 to 100 cm (15 - 25 inches); two trembling poplars (*Populus tremula*) two years old, 50 to 80

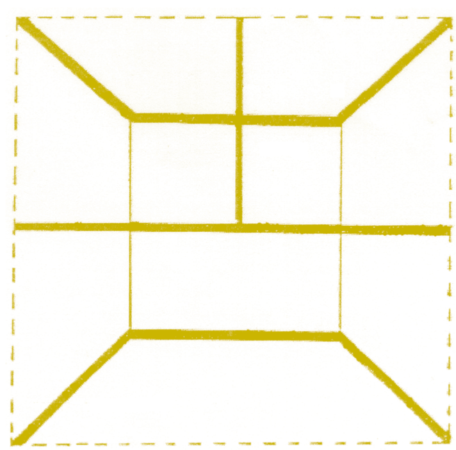

Illustration 1: Arrangement of gaps in isometric container proctoring.

cm (12 - 20 inches); and eight prickly field thistle (*Cirsium arvense*) seeds. These are planted in each container. The plants are regularly watered and fertilized each spring. Dead plants are replaced as necessary each year. During the four-year test period, the trees are regularly measured for height and trunk diameter to ensure that plants develop normally and that root pressures are the same in both the test specimen and the control. The containers are visually inspected twice per year, once in the spring (June) and in the fall (October). After the fourth year, at the end of the test, the containers are emptied and the waterproofing is inspected. Root penetrations are measured for quantity and location. The tested membrane must have no penetrations in order to pass the test.

In a past PVC membrane test, the asphalt control samples had an average of more than 100 root penetrations per container while the PVC had none. In fact, all four asphalt containers had root penetrations after only six months. Roofing manufacturers must test membranes individually. After testing and passing the test procedure, the manufacturer receives a certificate of compliance for the specific membrane. Contractors must submit the manufacturer's FLL certification as specified in the construction documents through project submittals for approval by the architect/designer.

With all the great benefits delivered, what has limited the growth of green roofs?

- Initially, there was a perceived lack of suitable products, competent installers, and technical expertise. In the last few years, the technology base has significantly expanded.

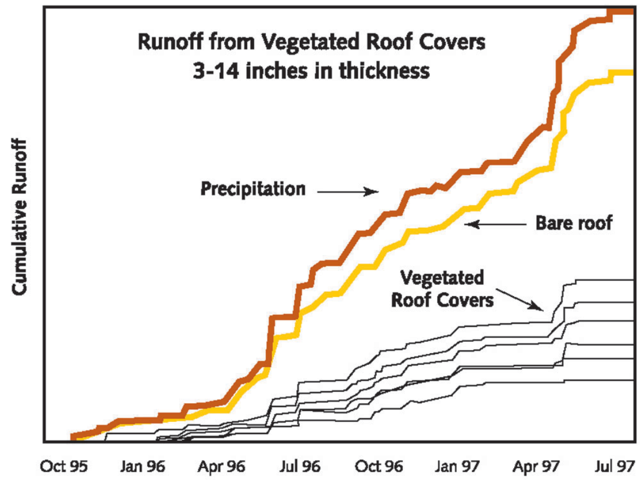

Chart 1: Stormwater Reduction Chart, courtesy of Roofscapes Inc., Philadelphia, PA.

RCI has been at the forefront, offering technical seminars around the country. Manufacturers are offering specialized roofing/waterproofing products. The LEED standard has forced the design issue in some areas on high profile projects, increasing the technical expertise of architects, landscape contractors, and landscape architects.

- The CSI format remains a minor stumbling block, as the green roof landscaping section is recognized in Division 2 rather than Division 7. This is a purely operational, yet still a procedural problem for green roof construction planning, bidding, and construction responsibility.

- There is a lack of recognition of green roofs as an approved method to reduce mandated stormwater infrastructure investment. One of the primary incentives to the growth of green roofs in Europe has been the tax credit offered for stormwater reduction. Countless studies show up to a 50% reduction of stormwater runoff into sewers and wastewater treatment plants from green roofs. With increasing pressures on today's urban centers to construct larger wastewater treatment plants, green roof construction could make a positive impact. In suburban and new growth areas, standard practice requires stormwater reduction plans, including holding ponds that are expensive, occupy valuable land, and breed mosquitoes. Parking lots are now being designed with porous paving. Green roofs would also significantly lessen runoff (see *Chart 1*).
- Unfortunately, there is no accredited U.S. test method comparable to the SIA 280 Standard or FLL for root barrier resistance at this time. Word has it that there is a proposal being prepared for ASTM D 08 this year. Although ASTM E 06.71 – the Sustainability Green Roof Subcommittee – is working toward a Green Roof Standard, the ASTM D 08 committee on roofing would seem to have higher standing in this matter. In either case, an ASTM test method would help the design community better qualify available products.
- Extensive vegetative covers are now being installed over existing roof systems. All parties should use diligence in properly inspecting the roof and notifying the appropriate parties as to construction plans. Make sure that everyone is aware of the ramifications. The installation of overburden, such as a vegetative covering, may void a manufacturer's warranty.
- Despite the expansion of the knowledge base, installed prices have been high and have limited the number of projects constructed. With few notable exceptions, many projects have been small in size. The governor on the growth has been the bottom line cost of the completed system. Regardless of the waterproofing system type, the installed price for an intensive green roof system consistently is running $20 to $40 per square foot. Extensive systems are less, but both far exceed the $5 to $10 per square foot average cost of a quality exposed roof system. There do appear to be some pricing reductions on the horizon in certain markets. Factors such as increased contractor familiarity, progress in material handling, and installation techniques are making an impact and reducing costs in some large market areas. Recently, there has been progress made in reducing the installed system cost on an average-sized roofing project to about $12 per square foot for an extensive system with limited plant selection and thin soil base. With all the positive attributes, the number, size, and frequency of green roofs should increase as the system unit cost declines (*Photo 5*).

Photo 5: Hazelton Chiropractic Center, Hazelton, PA. Architect: Van De Ruyn, San Francisco, CA. Vegetative cover by Roofscapes. Photo, courtesy of Sarnafil.

Summary

There seems to be a lot of momentum in favor of green roof systems today. As an organization, RCI needs to remain at the forefront in studying and understanding the suitability of the most important component in the system – the roof. It is important for all parties to recognize that not all products are suitable for green roof system applications. Roofing and waterproofing products must be designed to accommodate a number of important conditions, including ponding water and aggressive root growth. As this fascinating and exciting form of roof design and construction expands, RCI and its members should work to learn from the European experience, avoid potential problems, and their almost certain resultant litigation. The design and construction community needs a knowledgeable and skilled consultancy and RCI should continue to strive to provide that expertise.

About the Author

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Peter D'Antonio has been with Sarnafil Roofing and Waterproofing Systems for 23 years. He currently serves as the manager of the Waterproofing Division in the U.S. and the national sales manager for educational facilities. He has been an active member of RCI since 1988. D'Antonio has served on the board of the Sealant, Waterproofing, and Restoration Institute and the Boston Chapter of the Construction Specifiers Institute. He is a member of ASTM Sustainability E.06.71 Green Roofing Committee. D'Antonio also acts as the Sarnafil coordinator for the U.S. DOE Rebuild America/Energy $mart Schools Initiative and the U.S. Green Building Council. He has lectured and published widely. D'Antonio holds a BA from the University of Massachusetts. He and his family reside in the woodlands of New Hampshire.

