Beyond 20-Year Low-Slope Roof Performance

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Abstract

Low-slope roof systems have been designed, built and maintained to perform well beyond the 20-year paradigm. This paper will present information about those roof systems and the resulting benefits.

The key for maximum roof system service life, however, is developing standards to meet or exceed expected performance goals for the fundamentals of design construction and roof management. Low-slope roof systems that deliver long-term or maximum performance can better match a building's service life and minimize building disruption, can be economical, can have a positive environmental impact, and can beneficially affect the contractor and manufacturer.

Based upon more than 29 years of low-slope roof engineering experience the author shares their data, process and outcomes about actual beyond 20-year performing roof systems to participants in the roofing community who design, construct, maintain, manufacture and manage their roof systems.

This paper will highlight a case study of a customer's quest for the best low-slope roof system performance with least overall cost. The author predicts 40-year low-slope roof performance based on roof performance history.

Author Biography

Gary Patrick is Vice President of Roofing Design and Waterproofing at INSPEC, Inc. and is a licensed architect in the states of Minnesota and Illinois. Mr. Patrick's Bachelor or Architecture degree was obtained at the University of Minnesota. In the 24 years of employment at INSPEC, INC., he has been involved in all aspects of roof related services, including: surveys, forensic investigation, on-site inspection and testing, with an emphasis in the area of design. Mr. Patrick is a member of the American Institute of Architects (AIA) and Construction Specifications Institute (CSI) and has conducted seminars on low- and steep-slope roof design for AIA and building code officials.

Introduction

The National Roofing Contractors Association (NRCA) defines low-slope roofing as follows:

Low-slope roofs: A category of roofs that generally include weatherproof membrane types of roof systems installed on slopes at or less than 3:12 (14 degrees).

The roofing industry benchmark of a successful performing low-slope roof system is about 20 years. It has been experienced that owners are satisfied with 20-year roof system performance, however, many owners want to obtain even greater roof system life to better match their facility's life expectancy of 60 to 100 years, to provide cost savings and to provide other benefits.

The first part of this paper presents data, from the author's 29 years of experience, about actual roof system projects that have performed beyond 20 years. Why those roof systems have performed that long will be discussed along with the benefits to the building owner and others involved in the design, manufacturing, and construction of the work.

The second part looks at a particular customer of the author whose requirement is to have a maximum roof system life with the lowest life cycle cost. The roof program that developed, including roof system performance predictions along with results and benefits after 16 years will be presented.

This paper's specific roof system performance data, and other related information that the author has experienced, is shared so that others in the roof system creation process and those that own and manage roof systems:

- Can be aware of what roof systems have performed beyond 20 years, the reasons why, and with what outcomes.

- Can better understand the concept of enhancing roof design, construction and roof management standards to maximize roof system performance to obtain better performance out of any roof system.

- Can apply the enhanced standards process to possibly create roof systems with beyond 20-year performance.

Roof System Performance Data

1973 – 1981 (21-29 Years Ago)

- Approximately 200 low-slope reroofing projects were designed and periodically observed during construction by the author. Total roof area is approximately 3.6 million square feet (334,440 square meters).

- Results of roof type and performance are shown on the following chart. Roof area is in square feet (square meters).

Roof System Type	Square Footage	Beyond 20-Year Performance	Reached 29-Year Performance
Gravel-Surfaced Built-Up Roof System	3,060,000 sq. feet (284,274 sq. meters)	2,800,000 sq. feet (260,120 sq. meters)	420,000 sq. feet (39,018 sq. meters)
Ballasted EPDM Roof System	360,000 sq. feet (33,444 sq. meters)	0	0
Smooth-Surfaced Built-Up Roof System	180,000 sq. feet (16,722 sq. meters)	80,000 sq. feet (7,432 sq. meters)	0
Total	3,600,000 sq. feet (334,440 sq. meters)	2,880,000 sq. feet (267,552 sq. meters)	420,000 sq. feet (39,018 sq. meters)

In summary, approximately 80% of the total projects performed satisfactorily beyond 20 years, 97 percent of which was the gravel-surfaced built-up roof system. Approximately 15 percent of the beyond 20 years are still performing satisfactorily after 29 years.

This data was obtained by the author during various site visits which included physical roof observations and owner input on leakage and repairs. The roof system projects are located in Minneapolis-St. Paul, Minnesota, USA. They predominantly cover school buildings. The type of roof system originally installed on these buildings was typically a gravel-surfaced built-up roof system that performed an average of 25 years.

Beyond Basics

Why did the gravel-surfaced built-up roof system perform beyond 20 years? It is the author's opinion, based on their actual project data and observations of other long-term performing roof systems that:

- The gravel-surfaced built-up roof system had an established history of long-term performance.

- Roofing fundamentals, which have been around for decades, consisting of sound design, good construction and roof maintenance were present.

- In the case of the author's projects, fundamentals were guided by standards of quality that went beyond minimum standards set by the industry and/or manufacturers.

The following are the author's definitions of the three key fundamentals for maximizing roof system performance followed by the author's standards of quality. For the gravel-surfaced built-up roof, the performance that has resulted is up to 29 years. For the adhered and ballasted EPDM single-ply roof system, and the adhered reinforced PVC roof system, the author's data indicated performance results were between 15 and 18 years of satisfactory performance.

Sound Roof Design

Creating an appropriate roof system for the conditions/structure using time-tested materials. Visualized through construction documents where drainage, detailing, material selection and installation are delineated. Addressing code requirements along with the needs/expectations of the client and roofing contractor.

Quality Construction

An experienced roofing contractor working with the construction documents to build the roof that was desired. Construction observation and testing by an independent party to verify conformance to the construction documents and contract.

Proactive Maintenance

Protection of the roof asset. Annual surveys of the roof system followed by maintenance so that it stays on track with its performance expectation. Nondestructive testing, when applicable, to catch small problems and avoid surprises.

Key Design Standard Requirements:

- Material performance history of 5 years minimum on the same type projects in the same climate as the project.

- Built-up roof membrane meeting ASTM requirements, consisting of four plies of Type IV fiberglass felts with asphalt interply moppings.

- Minimum 60 mil EPDM membrane with minimum six inches (152 mm)wide field seams and perimeter securement at six inch (152 mm) on-center, for a ballasted single-ply system.

- Ponding elimination via tapered insulation, added drains or sloped structure.

- In the built-up roof system, 1 inch (25 mm) thick wood fiberboard or perlite insulation beneath membrane. 4- by 4-foot (1.2- by 1.2-meters) maximum insulation size. Multi-layer insulation.

- Eight inch (203mm) minimum base flashing heights (except at canted roof edge design). No gravel-stop roof edge sheet metal.

- Sheet metal flashings designed to meet Factory Mutual Research. Concealed flashing (i.e., EPDM) beneath sheet metal.

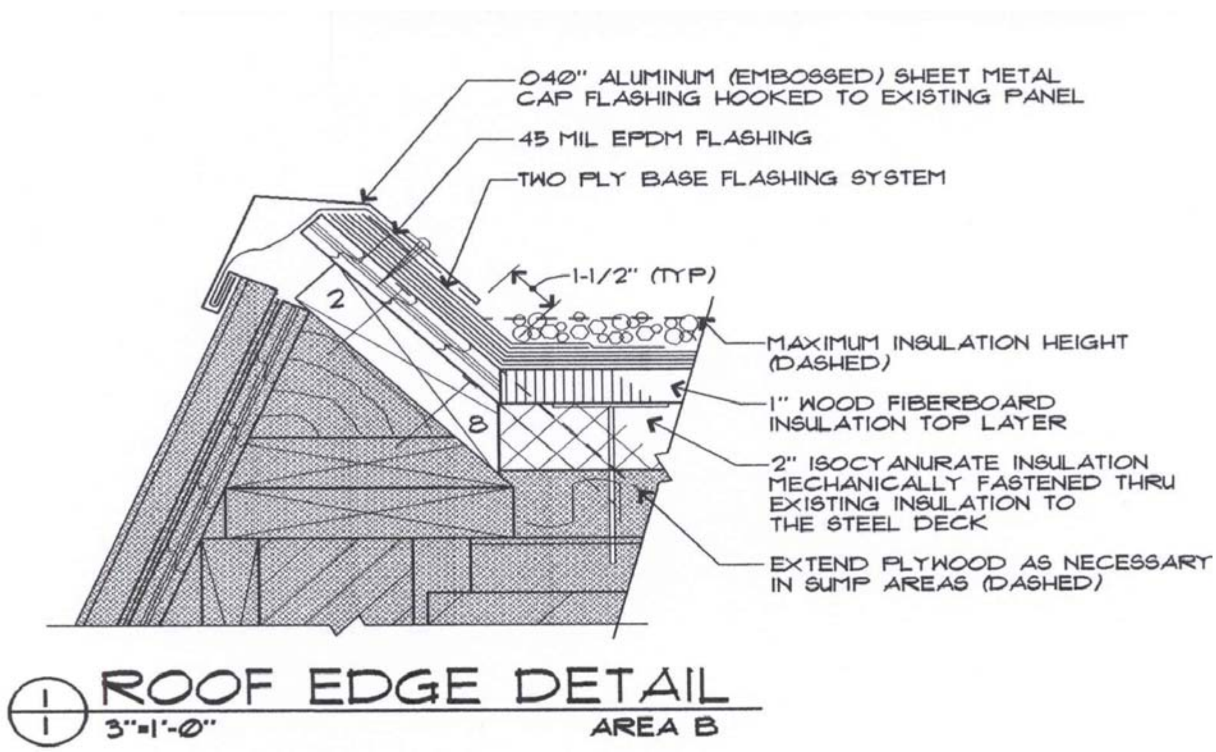
- 3 inches equals 1 foot, 0 inches (76mm equals 304mm) scale details.

- Details designed with solid wood blocking to support the roof components.

- Roof system technical specifications following Construction Specific Institute (CSI) format.

- Construction document preparation under direct supervision of a licensed professional engineer or architect.

- Pre-bid conference with contractors and building owner prior to opening bids.



Design Detail Example, 25-Year Roof

Key Inspection and Testing Standard Requirements:

- Testing of materials and review of submittals prior to construction.

- Reviewing construction documents with the roofing foreman.

- Pre-construction conference.
- Periodic inspection during construction.
- Moisture and temperature testing of materials during construction.
- On-site testing of the four-ply membrane construction quality using a 4-by 36-inch (102- by 914-mm) test cut with immediate results. Lab testing follow-up.
- Fastener withdrawal testing as required.
- Written daily inspection reports to all parties.
- Warranty and other contract closeout work.

Reviewing construction documents during an inspection.

Key Roof Management Standard Requirements:

- Annual roof system walkovers by a trained person.
- Infrared evaluation (on applicable system) every two years.

- Survey walkover with roofing contractor and owner prior to five-year contractor warranty expiration.

- Roof management report every two to five years with repair/replacement recommendations, including all costs and time frames.

Infrared Evaluation

Benefits of a gravel-surfaced built-up roof system that perform beyond 20 years include:

- The roof system life better matches the building's life which means fewer reroofing constructions and less leakage occurrences which results in less building disruption.

- Low lifecycle cost savings can result even if the initial cost is greater. For example, comparing a 25-year roof system (A) to a 15-year roof system (B) on a 25,000 square foot (2,250 square meter) roof system in the Minneapolis, MN area, shows the following:

	Roof A	Roof B
1986 Reroofing	$5.50 sq. ft.	$4.00 sq. ft.
2001 Reroofing	$0.00	$5.50 sq. ft.
Maintenance costs through 15 years	$0.20 sq. ft.	$0.40 sq. ft.
Investments after 15 years	$5.70 sq. ft.	$9.90 sq. ft.

$9.90 - $5.70 = $4.20 sq. ft. x 25,000 sq. ft. = $105,000 savings so far for Roof A.

These roofs are actual projects the author has been involved with. Roof A is performing well at age 16 and is predicted to perform into it's mid—twenties. Roof B performed fair until its replacement at age 15. The subsequent reroofing is predicted to last another 15 years.

- Maintenance, such as observing deficiencies, infrared scanning and making repairs are not difficult or costly to do. The gravel-surfaced built-up roof has demonstrated a sustaining characteristic allowing time to plan for replacement.

Benefits not only of a gravel-surfaced built-up roof, but of any long-term roof system that sustains to or beyond the owner's expectations:

- Satisfied owners of buildings are beneficial to all those in the roofing industry such as designers, manufacturers and contractors because owners will likely want those results on other projects or again on the previous project. Owner's may spread the good news to others.

- Long-term low-slope roof system performance validates the process of those involved in its creation. The designer achieves what he/she predicted, the contractor establishes a high quality work ethic and has few call-backs, and the manufacturers see their product perform in real life situations, versus speculation or short-term tests results.

- The longer the low-slope roof system performance the fewer the number of reroofings, thereby lessening the impact on the environment (i.e., landfills). Reusing roof system materials reduces landfill impact even further.

Experience Meets Expectation

In 1984, the Minnesota State University System (SUS), which later became the Minnesota State Colleges and Universities (MnSCU) in the mid 1990s, was experiencing less than 20-year roof system performance on approximately 50 percent of their low-slope roofs systems. According to SUS data and the author's roof observations, many roof systems constructed in the 1970s were failing within 10 to 15 years, and leakage was disrupting facility functions. SUS reported initial construction costs were low, however, roof life-cycle costs were high because of frequent repairs to the roof and to the building contents plus the need to reroof again after only 10 to 15 years.

There was an estimated 4 million square feet (371,600 square meters) of low-slope roof systems on seven campus settings across Minnesota in 1984. The typical building life expectancy was reported by SUS to be about 80 years.

Southwest State University

Because of what SUS was experiencing in 1984, they established a new roofing program and an expectation that remains today:

> *To provide maximum performance life with the least cost to the taxpayer over the life of the building.*

When the author was hired by SUS, the gravel-surfaced built-up roof system and the ballasted single-ply EPDM roofs were selected based on requirements of the project.

The author's data (previously discussed) and survey and investigation experience with ballasted single-ply (EPDM) roof systems and gravel-surfaced built-up roof systems by the late 1980s showed gravel-surfaced built-up roof systems demonstrating better life-cycle cost because they were lasting longer than the ballasted single-ply (EPDM) types and requiring less maintenance costs. SUS was interested in the gravel-surfaced built-up roof system because it was not easily susceptible to physical abuse, and roof deficiencies were easy to identify and repair.

In the late 1980s, based on the author's roof system performance experiences and the program's goal, the gravel-surfaced built-up roof system became the preferred roof system. The author was predicting 25 years of service life and the roof system was identified as the Minnesota State University System Standard Roof (MSR).

During the 1990s the author's standards for design, construction, and maintenance, previously outlined in this paper, were enhanced from experience gained by 20-25 year performing roof systems, along with the continued focus by SUS to seek even better performing roof systems, resulting in the author's prediction of 40-year low-slope roof performance.

It is the author's opinion, and the client's understanding, that the 40-year roof system prediction requires all of the enhanced standards for design, construction and maintenance to be met throughout the life of the roof. Otherwise the life expectancy prediction is reduced.

The Minnesota State Universities combined with the State Community Colleges and State Technical Colleges in 1995 to form the Minnesota State Colleges and Universities (MnSCU). Presently, there are about 12.5 million square feet (1.16 million square meters) of low-slope roofing covering MnSCU facilities.

A typical MnSCU Standard Roof (MSR)

The following are highlights of the author's enhanced standards for the predicted 40-year MSR. The author's previously described standards apply but are not included in the following information. The most stringent standard applies.

Key Design Standard Requirements:

- Unobstructed positive slope to drain (i.e., drains added, roof top equipment relocated).

- Roof system R-value of between 25 and 30. A vapor retarder is required.

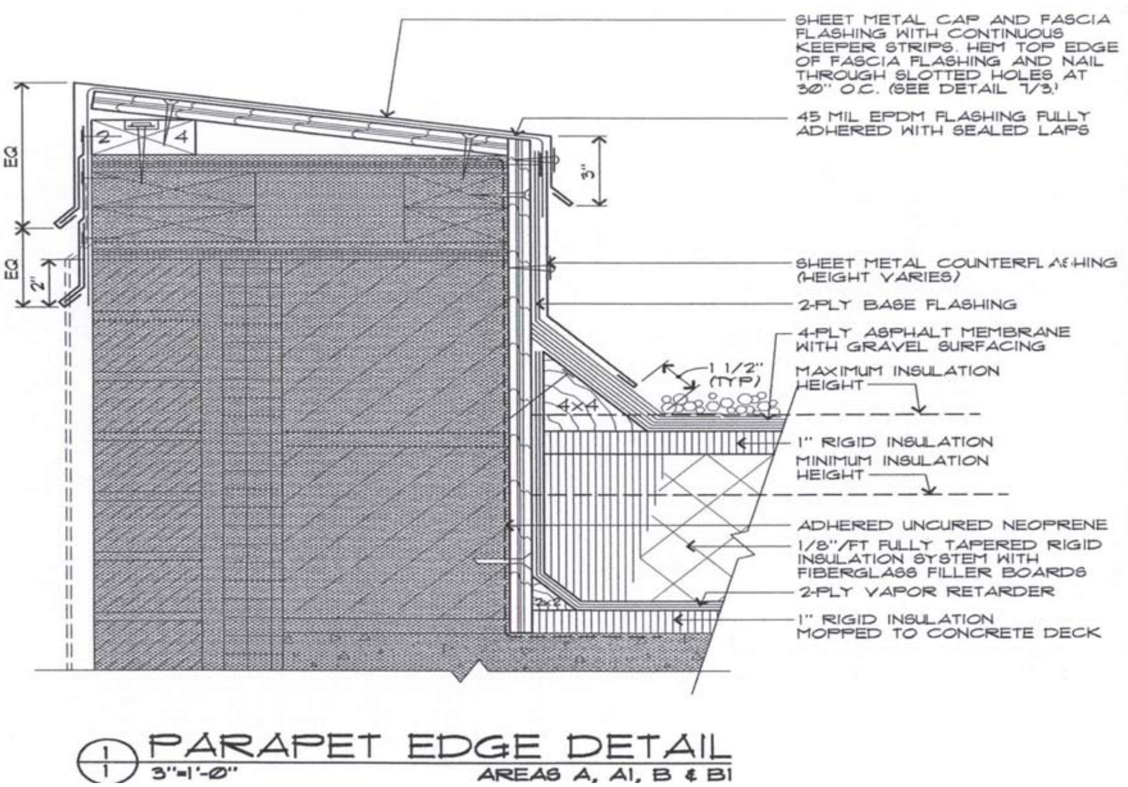
- Roof penetrations minimized. 12" (305mm) minimum base flashing heights created. No gas lines or electrical piping runs permitted on the roof.

- No "or equals" in the specification.

- Material performance history of 10 years minimum.

- Details that could allow moisture entry from an adjacent condition (i.e., window or door sill, a skylight) incorporate a membrane to envelope the roof system.

- Through-wall flashing, window and door sills are to be a minimum of 24" (610mm) above the deck (new construction).



Design Detail Example—MSR

Key Construction Inspection Standards Requirements:

- Pre-construction conference with job foreman prior to construction.

- All roofing and sheet metal work shall be inspected full time 100% during construction to meet the construction documents requirements. Highlights from daily inspection include:

    - Moisture verification of materials and verification of proper asphalt temperatures.

    - Removal of wet, damaged, or rejected materials from the site.

    - Inspection of daily seal-offs, roof drains, edges, and penetrations for water tightness every day before leaving job site.

- Coordination of sub-consultant's inspections.
- No surprises for the owner.
- Membrane test cuts for analysis of material weights, lapping and lamination.

Roof Membrane Test Cut

Key Annual and Ongoing Roof Management Program Requirements:

- The facility shall maintain historical records for each roof system.
- The facility should visually inspect roofs immediately following severe weather, documenting any signs of damage and schedule repairs as soon as possible.
- Annual roof survey conducted by a MnSCU designated Roofing Consultant. These will include infrared roof moisture surveys and a comprehensive report. Schedule repairs as soon as possible.
- Verify that roof access is minimized and that roof drainage is unobstructed.
- Check and secure any loose metal flashing.

- Do not allow the installation of any additional roof top equipment including mechanical units, conduit, antenna, satellite dishes, etc. without approval by MnSCU Facilities Department.

Annual Roof Survey

After 18 years of the author and MnSCU creating the roof program where roof systems are looked at as assets, the following are some key accomplishments:

- Approximately one third of all the MnSCU low-slope roofs have been reroofed to MnSCU standards, with the author's performance prediction, as outlined below:

    - 75%, or 3.1 million square feet (287,990 square meters) are 20-30 year life expectancy roof systems.

    - 25%, or 1 million square feet (92,900 square meters) are 40-year life expectancy roof systems.

- All are performing very well. The author remains confident of the life expectancy predictions. The single-ply roof systems (EPDM) are predicted to reach 20 years, the oldest is currently about 16 years.

- Three wet insulation anomalies detected from infrared scanning on three different roof systems were identified and repaired before they became a larger problem.

Taxpayer Savings—One less reroofing cycle

At the end of 2001, approximately 400,000 square feet (37,160 square meters) of roof systems meeting MnSCU standards had reached 15 years of service life. The author's prediction for life expectancy was 20-25 years when they were initially designed and constructed. In the summer of 2001, these roof systems were examined by the author's firm and all are expected to perform at least to the predicted service life, in the author's opinion.

If MnSCU continued to experience 10-15 year roof life as in the 1970s, this 400,000 square feet (37,160 square meters) would have needed replacement by now resulting in additional cost and disruption.

A ballpark cost savings of $1.6 million to the Minnesota taxpayers is realized by not having to replace 400,000 square feet (37,160 square meters) of roof systems by year 15. The following chart takes a look at this savings.

- Roof A is an MSR (20-30 year life expectancy prediction).
- Roof B is not an MSR (15 year life expectancy and it was replaced).
- Each are approximately 25,000 square feet (2,323 square meters).
- The costs are per square foot.

	Roof A	Roof B
1986 Reroofing	$8.00	$5.00
2001 Reroofing	$0.00	$7.00
Current Maintenance Cost	$0.20	$0.30
Total Investment after 15 Years	$8.20	$12.30

$12.30 - $8.20 = $4.00 per square foot approximately

$4.00 per square foot x 400,000 square feet = $1,600,000 savings.

Taxpayer Savings—Fewest reroofing cycles over the building's life.

The following chart looks at potential savings for the taxpayers of Minnesota if the predicted 40-year low-slope roof system versus 20-year or 16-year roof systems performs over a 79 year period of time (two 40-year cycles).
First reroofing cost source for the MnSCU Standard roof system is based on over 930,000 square feet (86,397 square meters) of roofing the author was involved with in 1998 and 1999.

First reroofing cost source for the Industry Standard and Substandard roof systems are based on over 100,000 square feet (9,290 square meters) of roofing for each system where the author reviewed roofing bids for owners and contractors in 1998 and 1999.

Cost and Cost Comparison

The following chart compares long-term (79-year) costs of three reroofing approaches on a 25,000 square foot (2,323 square meters) flat roof.

Roof System Construction/Maintenance Cost Comparison (Year 2000 Dollars) **25,000 Square Foot Roof**					
MnSCU Standard Roof		**Industry Standard Roof**		**Substandard Roof**	
▪ Slope-to-drain (no standing water) ▪ 40-year life expectancy (with annual maintenance) ▪ Stringent design standards ▪ Exceeds current energy requirements ▪ Thorough roof review and design issues addressed ▪ Quality assurance inspection and testing ▪ Low change order costs ▪ Easy to maintain		▪ Marginal/no slope-to-drain (ponding water is acceptable) ▪ 20-year life expectancy (with some maintenance ▪ Industry design guidelines ▪ Meets current energy requirements ▪ Some roof-related issues not addressed ▪ Periodic construction inspection and testing ▪ Moderate change order costs ▪ More expensive to maintain		▪ No slope-to-drain ▪ 16-year life expectancy (with minimal maintenance) ▪ Less than industry design ▪ May not meet current energy requirements ▪ Many key roof-related issues not addressed ▪ Little to no construction inspection, testing and quality control ▪ Higher change order costs ▪ Excessive maintenance	
Cost per Square Foot		**Cost per Square Foot**		**Cost per Square Foot**	
First Reroofing	$12		$8		$7
Year 20	$0		$8	Year 16	$7
Year 40	$4		$8	Year 32	$7
Year 60	$0		$8	Year 48	$7
				Year 64	$7
Maintenance Costs	$2		$3		$4
Year 79 Subtotal	$18		$35		$39
79 Year Cost	$450,000		$875,000		$975,000
Increased Roof Cost			$425,000		$525,000
Percent Increased Cost			94.4		116.6
Increased Cost Per Square Foot			$17		$21

Looking at 1998 and 1999, over 930,000 square feet (86,397 square meters) of roof systems were constructed to MnSCU standards (approximately 7% of the total roof square footage inventory). These roof systems are predicted to achieve the projected cost savings of $17 per square foot and the total savings to the State of Minnesota after 79 years will exceed $15.8 million. If the comparison roof had a life expectancy of only 16 years, the savings would be $19.5 million.

Other benefits of the MSR

- Energy savings because the R-value exceeds code by up to 35% depending on campus location.

- Less occupancy disruption because of fewer (up to 50%) reroofing constructions.

- Subsequent reroofing takes less time and cost less because a majority of the existing materials can remain due to the enhanced standards.

- Reduced environmental impact resulting from reuse of roof materials where applicable.

- Demonstrated durability against wind and airborne debris, maintenance and general traffic.

Conclusion

In order to be able to achieve long-term low-slope roof performance, the author has experienced the necessity to go beyond basic fundamentals and minimum manufacturer requirements. Those fundamentals, which are not necessarily new, are still central to understand. Standards for design, construction and maintenance that address the reduction of risk or failure modes in a roof system is how roof system service life can be maximized.