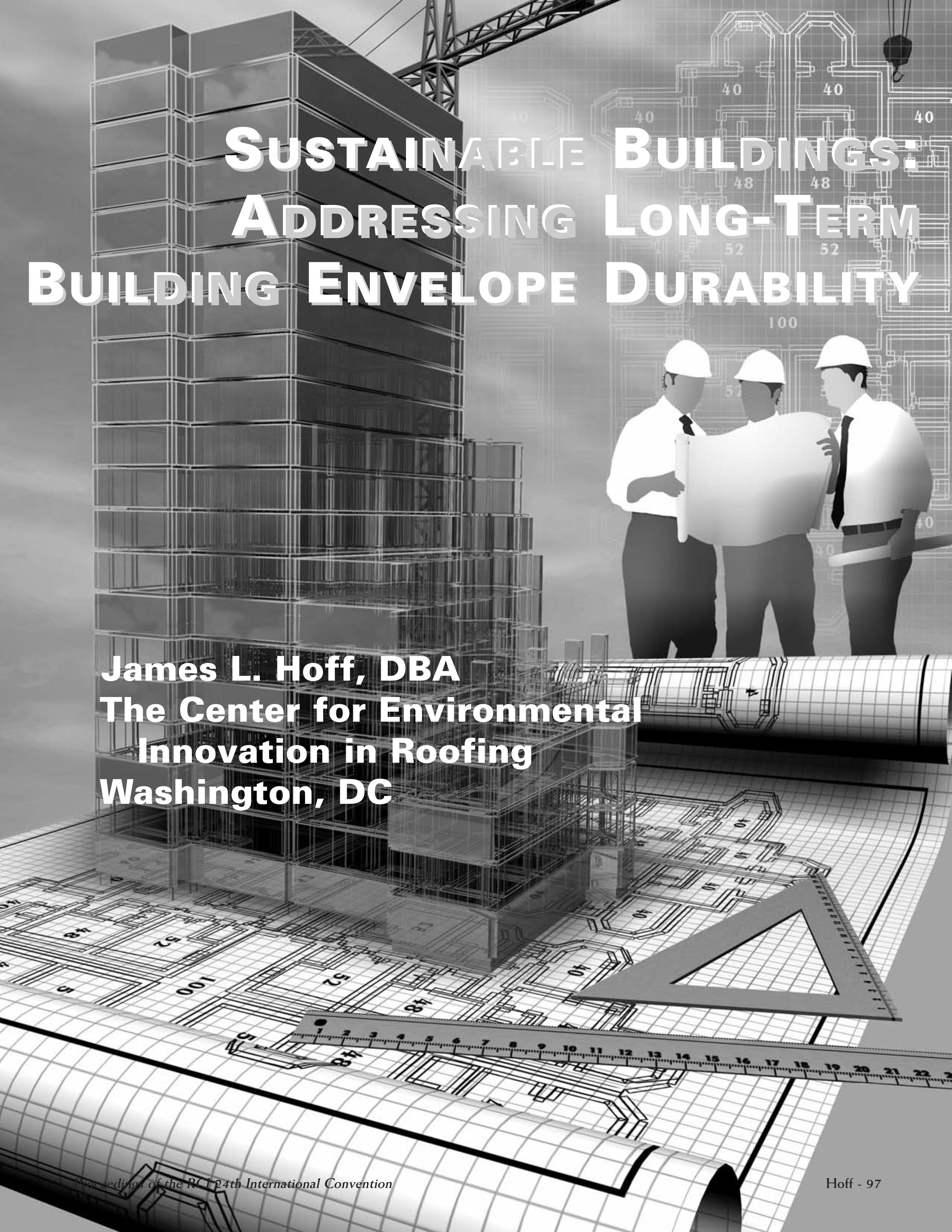

SUSTAINABLE BUILDINGS: ADDRESSING LONG-TERM BUILDING ENVELOPE DURABILITY

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ABSTRACT

Green building assessment tools provide a means of measuring the “greenness” of buildings to help building designers make effective decisions regarding long-term sustainability. Because these tools typically are employed during the early phases of the building process, they may tend to place more emphasis on initial building design rather than long-term operating life. As a result, current assessment tools may fail to properly consider durability and the potential consequences of premature deterioration on long-term building sustainability. Starting with a review of current green building rating systems from the perspective of building durability, this paper will discuss the importance of designing for durability and how durability should be defined, measured, and incorporated into the building process. The objective of the paper will be the development of a practical approach to building envelope durability that can be used to help designers, owners, and managers achieve truly sustainable building design and operation.

SPEAKER

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Sustainable Buildings: Addressing Long-Term Building Envelope Durability

INTRODUCTION

By providing a means of measuring the "greenness" of buildings and key building systems, rating programs such as the LEED Green Building Rating System™ may help building professionals make effective decisions in the design of sustainable buildings. Because they are usually employed during the early phases of the building process, however, such assessment tools may tend to place more emphasis on the initial design of a building rather than its long-term operational life. As a result, current rating systems may fail to adequately consider durability and the potential consequences of premature deterioration on building sustainability.

Because the materials that make up the building envelope are constantly exposed to harsh weather conditions and expected to perform without failure for many decades, some researchers have expressed concern that the current green rating systems may place too little emphasis on product durability. This concern was clearly articulated in a paper presented at the 11th Canadian Conference on Building Science and Technology by Jamie McKay, a LEED Accredited Professional (LEED AP):

> The majority of green building assessment systems focus on the design of the constructed building, with little focus on the effect of the building system's life during operation. This tendency has resulted in a failure of many rating systems to properly consider durability, lifecycle cost, and the effects of premature building envelope failures. (McKay, 2007, p.1.)

The concern articulated by McKay and other researchers appears to be shared by the majority of construction professionals who design, specify, and manage today's buildings. According to a *Building Design & Construction* survey of over 70,000 building designers and owners, the strongest opinion regarding sustainable construction was that building materials should be evaluated on the basis of life cycle cost, long-term durability, and maintenance, and not just environmental impact and energy savings ("White Paper on Sustainability," 2003, p. 17).

In response to these concerns, this paper will examine the concept of durability and its relationship to effective green building assessment. Using examples from the commercial roofing industry, the paper will also explore possible strategies to effectively incorporate consideration of durability into the assessment of buildings and building envelope systems.

WHAT IS DURABILITY?

According to most dictionaries, the broad definition of durability is the ability to exist for a long time without significant deterioration. When applied to buildings and building components, durability is typically defined in a similar manner, but with several important distinctions. The Canadian Standards Association's "Guideline on Durability in Buildings" (CSA S478-95, Rev. 2001) provides one of the most recognized definitions of building durability in North America. According to this standard, durability is defined as the ability of a building or any of its components to:

- perform its required functions
- in its service environment
- over a period of time
- without unforeseen cost for maintenance or repair.

In contrast to the simpler dictionary definition, durability as applied to buildings must offer more than mere survival: it must also be capable of performing required functions. In addition, these functions must be performed not only for a long time, but for a specified period of time. And finally, although normal deterioration will obviously occur, there should be no unforeseen cost associated with this normal deterioration. Given the importance of these distinctions, each of these concepts should be carefully examined in order to fully integrate durability into the overall building envelope design process.

Perform Required Functions

Although some building components and systems may have a single required function, the modern building envelope must fulfill many roles. First and foremost, the building envelope must serve as a moisture barrier to resist the intrusion of moisture in many forms, including rain, snow, hail, ice, and vapor. In addition to resisting moisture, the building envelope plays an important role in the redirection of moisture, both stormwater drainage and condensation. As one of the most significant contributors to a building's thermal efficiency, modern building envelopes also must resist the movement of heat and cold, and at ever-increasing levels as energy costs continue to rise. Building envelope components also must resist wind, snow, and service and seismic loads, effectively transferring these loads to the building's structural system. The building envelope also must provide a satisfactory level of fire resistance to facilitate evacuation of the building and to reduce the spread of fire to adjacent buildings. Finally, the building envelope may serve as an important work platform for the building, housing critical mechanical equipment that must be serviced periodically. And with the development of "green" (vegetated) and photovoltaic wall and roof systems, the concept of the building envelope as a service platform continues to expand. Each of these important functions must be addressed within any truly sustainable design. And if any of these required functions are omitted or ignored, the long-term sustainability of the entire building may be adversely compromised.

In Its Service Environment

The phrase "service environment" suggests a two-fold approach to the external factors affecting a roof system. First, the building envelope is surrounded by a unique climatic "environment" consisting of a constantly changing mix of sun, wind, temperature, and moisture in many forms. Depending on the specific location, some of these climatic forces may be much more severe compared to other climates and locations. As a result, special measures frequently must be taken to ensure that the long-term durability of the building is not jeopardized by unique and extreme weather factors. Examples of such extreme environments include severe hailstorm zones, coastal areas subject to hurricanes and wind-blown debris, cold climate regions subject to rapid temperature drops, and desert areas subject to extreme ultraviolet degradation.

A roof also performs its "services" within this environment; and to the extent that these services involve human support, the roof system may also be impacted by a variety of human behaviors. And just like unique and severe climatic conditions, human impacts on some buildings may be much more severe than other situations. Examples of critical human impacts may include frequency/density of use, motivation and attitudes of occupants, and frequency of equipment and maintenance service.

Over a Period of Time

The period of time in CSA S478-95 is commonly referred to as the service life of the building component or system. Obviously, any failure of any element of the building envelope to achieve its intended service life will seriously compromise the effectiveness of green assessment tools in directing design choices and materials selection.

Without Unforeseen Costs

The use of the word "unforeseen" suggests several key considerations for the full integration of durability into sustainable building envelope design. First, the possibility of unforeseen costs suggests that planning is required to ensure that no costs are unforeseen. In addition, there is an equally strong suggestion that some level of cost should be expected (foreseen) for a building component or system to achieve meaningful durability. As a consequence, the lack of a detailed plan regarding ongoing monitoring and maintenance or the lack of a realistic budget for these activities may compromise the ultimate sustainability of any building.

GREEN BUILDING DESIGN AND DURABILITY

Green Design and Service Function Expectations

Although green building rating systems may be useful in identifying the environmental impact of a construction product or system, these tools may not be as effective in determining which product will best perform the required service functions. As a result, effective green building design still requires value judgments regarding the suitability of the products analyzed and the validity of the green rating values. An example of such critical value judgments may be illustrated by the low-slope roofing industry's best-practice recommendation for the use of a cover board over all foam roof insulation materials (NRCA, 2007, p.46). Resistance to thermal transmission and accommodation of traffic loads are two of the key required functions of a roofing assembly. By reducing the potential for crushing of foam insulation under traffic loads, a cover board may help to extend the thermal efficiency and useful service of the underlying insulation, and even facilitate its recycling or re-use. However, if a "green" assessment of roof assemblies with and without a cover board is conducted without any differentiation in the useful service life of the two assemblies, the assessment may erroneously conclude that foam insulation without a cover board offers a lower environmental impact. This apparent contradiction may occur because the inclusion of a cover board (and all of the related man-

Table 1 – Service Life Estimates for Low-Slope Roofing Systems (Years)

	Data Source:			
System Type:	**Opinion Survey (Cash[a])**	**Historical Study (Schneider[b])**	**Approval Agency Reports[c]**	**Manufacturer Warranty Offerings[d]**
Asphalt BUR	16.6	13.6	20	20
SBS Modified	16.6	17.3	20	20
PVC	n/a[e]	n/a[e]	35	15
EPDM	14.1	16.8-18.4	20	30
TPO	no data	no data	20	30

Notes:

a. Mean service life from Cash (1997), based on an opinion survey of industry participants.
b. Mean service life from Schneider & Keenan (1997), based on end-of-service field reports .
c. Estimated service life from British Board of Agrément Technical Approvals (BBA, 2008):
   1) Asphalt BUR: BBA Certificate 94/3062 Chesterfield Roof Waterproofing Systems
   2) SBS Modified: BBA Certificate 91/2618 Icopal HT Roof Waterproofing Systems
   3) PVC: BBA Certificate 08/4532 Sarnafil PVC Roof Covering System
   4) EPDM: BBA Certificate 92/2791 Carlisle Syntec Systems
   5) TPO: BBA Certificate 87/1849 Anderson SureWeld Systems
d. Published warranty offerings from *NRCA Low Slope Roofing Materials Guide*, 2006-07, Vol. 2, Section 5, Roof Membrane Warranties.
   1) Asphalt BUR: GAF Materials Corp. "Diamond Pledge™ Roof Guarantee."
   2) SBS Modified: GAF Materials Corp. "Diamond Pledge™ Roof Guarantee."
   3) PVC: Johns Manville International, Inc. "UltraGard Roofing System Guarantee."
   4) EPDM: Firestone Building Products Co. "Platinum Roofing System Limited Warranty."
   5) TPO: Firestone Building Products Co. "Platinum Roofing System Limited Warranty."
e. Data from the Cash & Schneider studies involved discontinued formulations of PVC that do not allow the data to be meaningful.

ufacturing, installation, and disposal inputs) merely adds to the total environmental impact of the roofing assembly without contributing any acknowledged benefit for the potential increase in service life of the insulation. Similar examples of materials and practices that may add to durability and service life but may be overlooked based on initial environmental impact include the use of stone protection mats with ballasted roofing systems, the incorporation of secondary membranes or other redundancy in hurricane-prone regions, and the use of thicker or redundant membranes in high hailstorm regions.

Green Design and Service Life Expectations

The accuracy of any green building rating system may be highly dependent on the validity of the service life assigned to the products and systems being evaluated. To the greatest extent possible, the assignment of a service life period should be based on reliable and reproducible data developed from rigorous scientific or empirical research. Unfortunately, little such service life data are available for modern building envelope systems, and what data are available appear to contain many limitations and contradictions. An example of these limitations and contradictions can be illustrated by a review of various service life estimates available for low-slope roofing systems. As illustrated in *Table 1*, estimates for the service life of almost all major low-slope roofing systems vary from slightly more than a decade up to 30 years, depending on data source and methodology.

Given this sizeable variation, how can the building designer establish an appropriate service life to conduct a meaningful "green" assessment? The best answer to this question may lie in several important distinctions among these estimates.

One of the most apparent differences among these estimates is their temporal perspective. The relatively low service life estimates from the opinion survey and historical study may be considered "backward looking" because the estimates are based on the performance of previously installed roofs that may or may not meet today's design and installation standards. In contrast, the relatively higher estimates based on product certifications and published warranty offerings may be considered more "forward looking" because the estimates may be based on the expected future performance of roofing systems utilizing the most recent improvements in materials and installation methods.

These estimates of service life may also be differentiated based on the quality level they assume. As an example, the roof populations from survey and historical studies may include a mix of roofs that were poorly designed, constructed, and maintained, as well as those that included superior design, installation, and maintenance. In this regard, the roof populations covered by these models are more likely to represent “average” quality rather than the best that the industry should strive for. In contrast, the quality level expected by the agency certifications and published warranty offerings may be much higher because these estimates likely assume the best in both materials and practice. In this regard, agency certifications and manufacturer warranties are more likely to represent “ideal” results that may neglect to consider chronic problems or unusual difficulties that must be overcome by truly sustainable roofing systems.

In regard to service life estimates based on warranty term, it should be noted that warranty length may not be a representative indicator of durability, since warranties represent both a contractual promise as well as a model specification. However, it is also worth noting that previous studies of roofing warranties suggest that warranty length may be related to the redundancy or durability of the components used (Hoff, 2005); and research from other industries suggests that warranties may be a reasonably accurate directional signal of product longevity (Weiner, 1985; Kelly, 1988).

DURABILITY TOOLS FOR A SUSTAINABLE FUTURE

The contrast between forward-looking versus backward-looking service life estimates and average versus high quality levels may help identify a critical decision point for the building envelope industry. Should the industry move forward with the assumption that the roofs and other elements of the building envelope installed on the green, sustainable buildings of the future will be average in performance, or should the expectation be set higher? And if the industry decides to move forward with higher expectations, how does it develop and implement processes and controls to ensure this higher level of performance is attained? Although current understanding of long-term durability and service life may be limited, there are several tools that may be used and promoted by the building envelope industry to improve the durability of building systems and effectively integrate building envelope durability into sustainable building practice.

Failure Analysis/ Best Practice Guidelines

One area of research that appears to have yielded useful results involves the evaluation of important failure mechanisms within modern building envelope systems. And although the relationship between these failure mechanisms and overall service life is not fully quantified, understanding of these failure mechanisms has fostered the development of effective countermeasures to prevent, mitigate, or quickly repair these failure locations. One of the most comprehensive examinations of building envelope failure mechanisms was conducted by Bailey and Bradford in 2005. This study of over 24 million square feet of asphalt and single-ply roof systems managed by the U.S. Army identified critical defects ranging from initial material selection to long-term maintenance activities that accounted for approximately 75% of all observed roof performance problems. In turn, the identification of these key defects was used by the authors to develop best-practice recommendations for all stages of roof system asset management.

Although little research is available to correlate failure analysis to eventual service life, it is likely that the defects observed by Bailey and Bradford contribute to the unusually wide variation in roof service life estimates previously discussed in this paper. And if the defects observed in this study were effectively addressed using the countermeasures identified in these studies, it is also likely that service life would quickly start to climb toward the higher end of current estimates. It is also important to note that almost all the recommendations from the Bailey & Bradford study are available in many current roofing industry best practice guidelines for roof system design, installation, maintenance and repair.

An emerging example of the best practice approach to durability can be found in the recent activities of the Performance Council for Constructed Roofing Systems (PCCRS). The objective of PCCRS is "to provide building owners and the roofing industry with conservative and dependable criteria for constructed roof systems that achieve cost-effective, long-term performance relative to the roof system type.”(Bailey, 2004.) In order to achieve this goal, PCCRS has developed a consensus process that will allow the accumulated experience of the roofing industry to be identified, validated, and incorporated in best-practice guidelines for all major low-slope roofing system types.

This process begins with a Criteria Council composed of recognized and experienced roofing professionals representing all major industry stakeholders, including roof consultants, roofing contractors, building researchers, materials manufacturers, and building managers. The council appoints and oversees criteria development groups (CDGs) responsible for developing performance criteria for specific roof system types, addressing roof system design, materials, installation and maintenance issues. After the development of draft performance criteria for each roof system type, the criteria are subject to extensive public review and comment before they are formally published.

At the time of the drafting of this paper (August 2008), the first two performance criteria, (for built-up membrane roof systems and for spray polyurethane foam roof systems) are approaching the end of public review and should be formally published early in 2009. These two published documents will be followed by the development of performance criteria for PVC and EPDM roof systems, which hopefully will be published in 2010. Although the PCCRS criteria documents may provide one of the best ways to consolidate the "best of the best" in industry practice, the criteria do not specifically address the issue of service life in a quantifiable manner. However, these documents may provide a productive platform to deal with service life expectations through the use of a second potential tool: durability planning.

Durability Planning

Roofing industry research in failure analysis combined with proven best practice guidelines may set the stage for the effective use of planning to maximize roof service life and minimize environmental impacts. In addition to providing a useful definition of building durability as discussed previously, CSA S478-95 also provides a comprehensive methodology and framework to make decisions on durability. The guideline addresses important elements of durability planning, including quality assurance, methods to predict service life, design and construction considerations, and operating and maintenance programs. The guideline also provides helpful overall procedures and sample project formats that can be utilized to develop and implement an effective durability plan for any building or building system.

Generalizing from the durability planning recommendations in CSA S478-95, the following processes appear to be the most important steps in developing an effective durability plan for a roofing system:

1. **Identify the critical durability determinants.** Failure analysis from studies such as Bailey & Bradford (2005) will help building designers identify which design, material, installation, and service factors hold the most value in optimizing the service life of the roof system.
2. **Identify the critical durability interventions.** Using the recommendations derived from failure analysis research and industry best practice guidelines, the building designer can identify specific interventions or countermeasures to prevent or mitigate degradation of roof service life due to critical durability determinants. These countermeasures may take a number of forms, including initial design enhancements, ongoing inspection and maintenance procedures, and major renewal or repair initiatives of key roof system components and details.
3. **Develop an action plan and timetable.** Using the recommendations and the suggested formats of the CSA durability guideline, the building designer can develop a long-term actionable plan that can be incorporated into ongoing building maintenance activities.

These key steps for effective durability planning may appear obvious. But the wide variation in service life data of roofing systems previously discussed suggests that what may be obvious has never been seriously implemented on a large scale by building designers and owners. And if green building rating systems are to fulfill their long-term potential to reduce environmental impact, durability planning must become a vital and integrated part of these rating systems.

In addition, because these steps may provide an effective way to evaluate different combinations of material, design, and service options to determine what combination will provide the lowest overall environmental impact, durability planning may contribute both to the identification of viable sustainable roofing options as well as the efficient evaluation and selection of the most suitable options for a particular building application. The use of key durability determinants and durability interventions may also facilitate rigorous evaluation of the trade-offs between increasing roof system durability (and perhaps increased roof system cost and environmental impact) in the initial design and installation of the roof system as compared to periodic increments of durability (at perhaps a lower overall cost and impact) provided by system maintenance and repair interventions.

An emerging example of durability planning applied to the building envelope is currently under development by one of the newest CDGs formed by the PCCRS Council. Ed Kane, the chair of the EPDM Roofing System CDG, has developed a preliminary criteria development and durability planning matrix that incorporates the key elements of PCCRS (design, materials, application, maintenance) along with the key elements of durability planning (required function, service environment, planned maintenance/repair, service life period). In addition to the previously discussed performance and durability dimensions, Kane has added the dimension of commissioning to verify and validate initial roofing installation and performance. A preliminary version of this matrix is provided in Appendix A of this paper.

Using this type of matrix, the building professional may address each key dimension of roof system performance in a methodical fashion. Starting with a delineation of the service environment and the required system functions, the matrix allows the professional to consider the best criteria to address design, materials, application, and commissioning for each critical component of the building system. After identifying the critical performance criteria, the matrix then directs the building professional to consider the long-term aspects of the roofing system for different service life periods, such as 20 years, 30 years, or longer. Critical issues addressed by the service life portion of the matrix include anticipated inspection, maintenance, and repair activities, as well as possible trade-offs between these activities and eventual service life. Finally, the matrix directs the building professional to consider end-of-service issues, such as removal, disposal, replacement, and potential recycling opportunities.

Because the new CDGs have just been established at the writing of this paper (August 2008), it is hoped that more information about this matrix approach to durability planning will be available before the formal presentation of this paper in March 2009.

Combining Best Practice and Durability Planning: The "Tenets of Sustainable Roofing."

With its emphasis on both the best practices and the planning processes necessary to achieve environmentally responsible roofs, the "Tenets of Sustainable Roofing" as developed by the CIB / RILEM Environmental Task Group (Hutchinson, 2001) may serve as a useful tool. The Tenets model uses a similar category-based approach as LEED, but only three basic categories are required:

1. Minimize the burden on the environment
2. Conserve energy
3. Extend roof lifespan

Unlike the current LEED model, the Tenets model places a significant emphasis on the durability of materials. While none of the five basic categories of the current LEED model address durability, the Tenets model dedicates one-third of its focus on durability and life-cycle performance. And, with the exception of some elements of indoor environmental quality, the remaining two categories of the Tenets model fully cover all current LEED categories. The Tenets model also contains 20 subcategories, many of which are strikingly similar to the subcategories in LEED. (See Appendix B for a full listing of the Tenets subcategories.)

RECOMMENDATIONS GOING FORWARD

Continued Development of Durability Planning

Because the lack of meaningful consideration for durability within many green building assessment tools may fatally compromise their results, the building envelope industry should insist that every green building envelope system assessment or rating be accompanied by a detailed durability plan that identifies and addresses key failure mechanisms, either through enhanced robustness or redundancy, planned maintenance and repair, or a combination of both. Given the head start CSA Standard S478-95 offers in establishing a meaningful approach to consistent durability planning, the industry should thoroughly familiarize itself with this standard and be prepared to promote it and advance it as a best-practice model. In addition, the preliminary durability planning matrix developed by Kane (2008) appears to offer a productive format to accomplish this task.

New Research Initiatives to Support Industry Best Practice

As mentioned previously, there are a number of important industry best practice standards that may require value judgments when a green building assessment is conducted. As an example, the use of cover boards appears to offer long-term sustainable value, but little scientific research has been conducted to quantify this value or relate this value to the opportunity for reduced environmental impact. In a similar manner, industry best-practice guidelines for the use of multiple layers of roof insulation, the staggering of insulation joints, and the elimination of through-fastening "thermal bridges" also appear to provide long-term value in regard to energy efficiency, but this value also lacks definitive research evidence to quantify its contribution to reducing environmental impact. Additional industry research in these and similar areas may be very helpful in ensuring that green building rating systems incorporate the very best environmental benefits of modern low-slope roofing systems.

Use the "Tenets of Sustainable Roofing" as a Template

As previously mentioned, the Tenets model offers almost every key construct contained within LEED, with the added benefit of including durability as primary category. The Tenets model also contains 20 sub-categories (See Appendix B), many of which are strikingly similar to the sub-categories in LEED. Given the succinct but comprehensive structure of the Tenets model, a credit-based rating system for roofing might be developed using the 20 Tenets subcategories as easily as (or perhaps more easily than) the current LEED model.

If the roofing industry decides to develop and advance an independent rating program for roofing, the Tenets of Sustainable roofing could provide the same broad-based but simple approach that has made LEED so popular. Or if the roofing industry decides to work within LEED to develop a "Roofing LEED" program, the Tenets may serve as a simple and effective reminder about the importance of durability.

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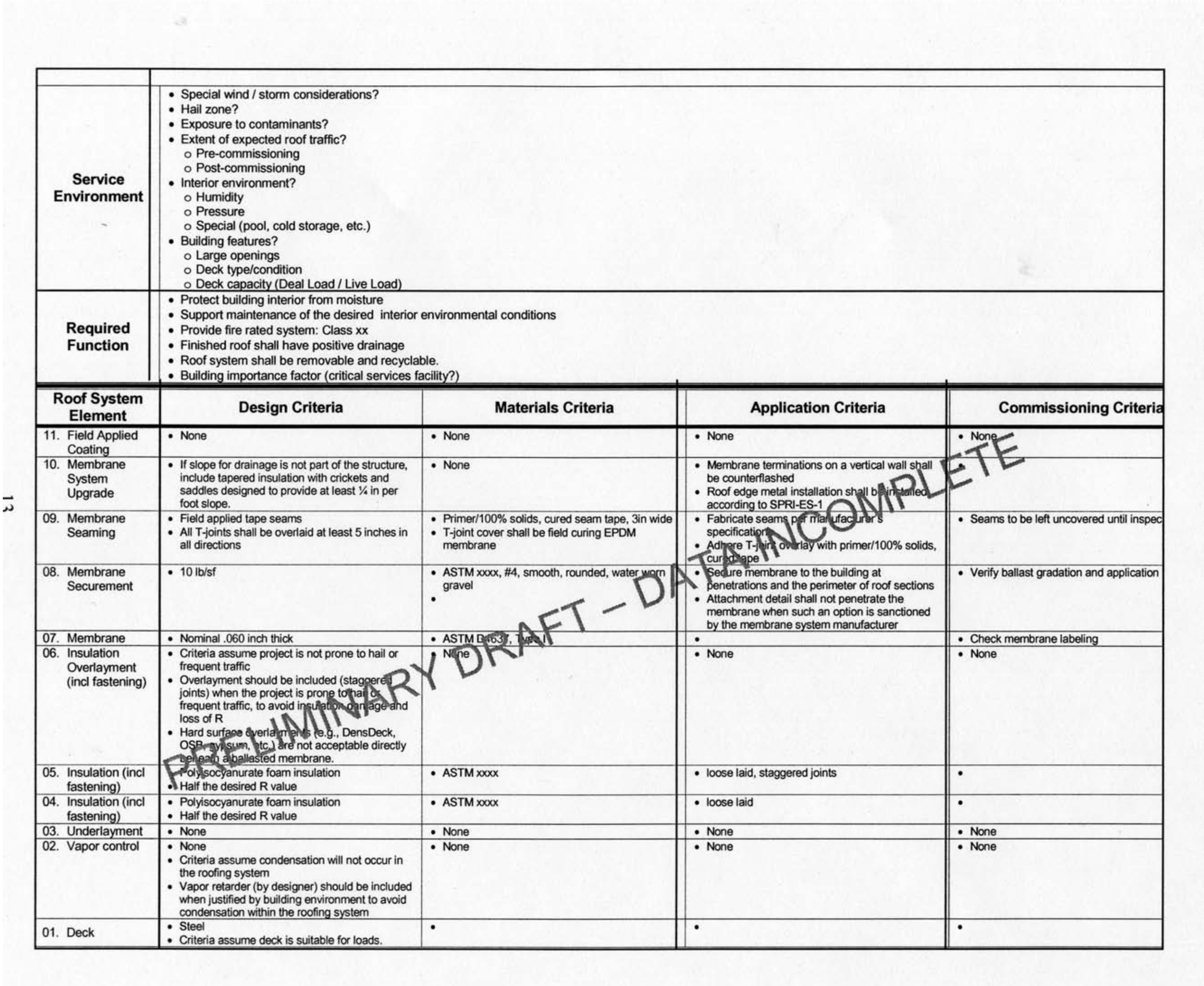
APPENDIX A

PRELIMINARY DURABILITY PLANNING MATRIX:

BALLASTED EPDM ROOFING SYSTEM



Service Environment	• Special wind / storm considerations? • Hail zone? • Exposure to contaminants? • Extent of expected roof traffic? o Pre-commissioning o Post-commissioning • Interior environment? o Humidity o Pressure o Special (pool, cold storage, etc.) • Building features? o Large openings o Deck type/condition o Deck capacity (Deal Load / Live Load)
Required Function	• Protect building interior from moisture • Support maintenance of the desired interior environmental conditions • Provide fire rated system: Class xx • Finished roof shall have positive drainage • Roof system shall be removable and recyclable. • Building importance factor (critical services facility?)

Roof System Element	**Design Criteria**	**Materials Criteria**	**Application Criteria**	**Commissioning Criteria**
11. Field Applied Coating	• None	• None	• None	• None
10. Membrane System Upgrade	• If slope for drainage is not part of the structure, include tapered insulation with crickets and saddles designed to provide at least ¼ in per foot slope.	• None	• Membrane terminations on a vertical wall shall be counterflashed • Roof edge metal installation shall be installed according to SPRI-ES-1	•
09. Membrane Seaming	• Field applied tape seams • All T-joints shall be overlaid at least 5 inches in all directions	• Primer/100% solids, cured seam tape, 3in wide • T-joint cover shall be field curing EPDM membrane	• Fabricate seams per manufacturer's specifications • Adhere T-joint overlay with primer/100% solids, cured tape	• Seams to be left uncovered until inspec
08. Membrane Securement	• 10 lb/sf	• ASTM xxxx, #4, smooth, rounded, water worn gravel •	• Secure membrane to the building at penetrations and the perimeter of roof sections • Attachment detail shall not penetrate the membrane when such an option is sanctioned by the membrane system manufacturer	• Verify ballast gradation and application
07. Membrane	• Nominal .060 inch thick	• ASTM D4637, Type I	•	• Check membrane labeling
06. Insulation Overlayment (incl fastening)	• Criteria assume project is not prone to hail or frequent traffic • Overlayment should be included (staggered joints) when the project is prone to hail or frequent traffic, to avoid insulation damage and loss of R • Hard surface overlayments (e.g., DensDeck, OSB, gypsum, etc.) are not acceptable directly beneath a ballasted membrane.	• None	• None	• None
05. Insulation (incl fastening)	• Polyisocyanurate foam insulation • Half the desired R value	• ASTM xxxx	• loose laid, staggered joints	•
04. Insulation (incl fastening)	• Polyisocyanurate foam insulation • Half the desired R value	• ASTM xxxx	• loose laid	•
03. Underlayment	• None	• None	• None	• None
02. Vapor control	• None • Criteria assume condensation will not occur in the roofing system • Vapor retarder (by designer) should be included when justified by building environment to avoid condensation within the roofing system	• None	• None	• None
01. Deck	• Steel • Criteria assume deck is suitable for loads.	•	•	•

APPENDIX A

PRELIMINARY DURABILITY PLANNING MATRIX:

BALLASTED EPDM ROOFING SYSTEM (continued)

	Management			
	Beginning with Commissioning	**At 20 Years**	**At 40 Years**	**At 60 Years**
Service Environment	• Control roof access; maintain access log; • Inspect roof every spring/fall, after threatening activities on, above or near the roof, after new equipment or penetrations are installed, and after any activity that may have jeopardized the roof	•	•	•
Required Function	• Log leak reports along with related conditions • Confirm clean drains and good roof drainage • Any new rooftop installation shall be reviewed with the roofing contractor for its impact on the roof system	•	•	•
Roof System Element	**Beginning with Commissioning**	**At 20 Years**	**At 40 Years**	**Removal/Recycling**
11. Field Applied Coating	•	•	•	• None
10. Membrane System Upgrade	• Review roof traffic patterns and add walkway pads where needed	•	•	• Peel up walk pads; recycle (similar to tires)
09. Membrane Seaming	•	•	•	• Cut seams out of membrane (6" per 30-50 ft width); recycle as energy source or into application to be developed
08. Membrane Securement	• After a high wind event inspect roof ballast for points of scour and evenly redistribute ballast to original coverage	•	•	• Vacuum ballast; stockpile for re-use
07. Membrane	•	•	•	• Route to processor for grinding and incorporation into walk pads or other application to be developed
06. Overlayment (incl fastening)	•	•	•	• None
05. Insulation (incl fastening)	•	•	•	• No fasteners; inspect boards for re-use or route to existing recycling applications
04. Insulation (incl fastening)	•	•	•	• No fasteners; inspect boards for re-use or route to existing recycling applications
03. Underlayment	•	•	•	• None
02. Vapor control	•	•	•	• None
01. Deck	•	•	•	• Do not remove unless necessary

APPENDIX B

THE TENETS OF SUSTAINABLE ROOFING

(CIB / RILEM Joint Committee on Roofing Materials and Systems –
Environmental Task Group, October, 2000)

MINIMIZE THE BURDEN ON THE ENVIRONMENT

1. Use products made from raw materials whose extraction is least damaging to the environment.
2. Adopt systems and working practices that minimize waste.
3. Avoid products that result in hazardous waste.
4. Recognize regional climatic and geographical factors.
5. Where logical, use products that can be reused or recycled.
6. Promote the use of "green roofs" supporting vegetation, especially on city center roofs.
7. Consider roof designs that ease the sorting and salvage of materials at the end of the life of the roof.

CONSERVE ENERGY

8. Optimize the real thermal performance, recognizing that thermal insulation can greatly reduce heating or cooling costs over the lifetime of a building.
9. Keep insulation dry, to maintain thermal performance and durability of the roof.
10. Use local labor, materials and services wherever practical to reduce transportation.
11. Recognize that embodied energy values are a useful measure for comparing alternative constructions.
12. Consider the roof surface color and texture with regard to climate and the effect on energy and roof system performance.

EXTEND ROOF LIFESPAN

13. Employ designers, suppliers, contractors, tradespeople and facility managers who are adequately trained and have appropriate skills.
14. Adopt a responsible approach to design, recognizing the value of the robust and durable roof.
15. Recognize the importance of a properly supported structure.
16. Provide effective drainage to avoid ponding.
17. Minimize the number of penetrations through the roof.
18. Ensure that high maintenance items are accessible for repair or replacement.
19. Monitor roofing works in progress and take corrective action as necessary.
20. Adopt preventative maintenance, with periodic inspections and timely repairs.