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WHITE PAPER

Design and specification drives sustainable roofing

By Yves Bradet and Robert Venasse, Soprema Inc.

A great many articles have been written about sustainable roofing, but most skirt around the heart of the issue. How is it actually attained? This paper looks at the "how-to", giving practical guidance in designing and specifying a sustainable roof within the definition of the The Sustainable Low-Slope Roofing Workshop, Oak Ridge National Laboratory, 1996.

What is the roofing industry, and those designing and specifying roofing systems, actually trying to achieve? Using environmentally friendly materials is very popular today, but the ultimate goal should also aim to extend the service life of the roof, delaying demolition and disposal in landfill for as long as possible. Double or even triple a 20-year life expectancy should be achievable if sustainability is the guiding principle of the initial roof design and specification.

A definition

What do we mean by a sustainable roof? Proceedings of the Sustainable Low-Slope Roofing Workshop held at the Oak Ridge National Laboratory (ORNL) facility in Oak Ridge, Tenn., in October, 1996 provides this definition "*… a roofing system that is designed, constructed, maintained, rehabilitated and demolished with an emphasis throughout its life cycle on using natural resources efficiently and preserving the global environment".*

How is this achieved?

Designing for sustainability incorporates materials and details that extend the service life of the roof system beyond its currently accepted service life expectancy and provide future rehabilitation options to minimize consumption of new resources and delay demolition. Future rehabilitation is key in designing for sustainability. Design for sustainable recovery from premature failure must be part of the original concept. It has to be realistically expected that a roof will eventually fail at some point for some reason. Sustainable recovery minimizes damage impact, reduces material wastage and consumption of new materials. It also facilitates repair and renews roof performance. (As an example of sustainable recovery, see the article *A Profile in Sustainable Roofing* at the end of this document.)

Roof design for sustainability entails more than membrane selection and detailing. It also includes specification of components and their attachment within the roof assembly that can impact the membrane's long term performance. Outside influences, although often beyond the designer's control, must be anticipated. Issues of winter construction, rooftop equipment servicing, building type, usage and maintenance are all contributing factors to long term performance and life expectancy.

Shifting the focus from reflective and green roofs

The USGBC (U.S. Green Building Council) and CaGBC (Canadian Green Building Council), among others, have been instrumental in promoting sustainable construction, mainly through the use of the LEED (Leadership in Energy and Environmental Design) rating program of certification. For all of its benefits, the LEED program has inadvertently put the spotlight on green roofs and reflective coatings as sustainable roofing options for obtaining specific points for certification. Obtaining points may or may not be the best solution for the environment, as well as energy efficiency. The focus should be on durability, longevity, reduced waste and renew-ability. The objective should be: the construction of a roof assembly to stay in place as long as possible, to keep the materials out of landfill as long as possible and not consume new materials for as long as possible. It should be conceived in such a way that the products will last their expected service life and can be reused, repaired or recovered to double that service life or even triple it.

That is not to say that LEED principles should be overlooked in any roofing design. Although a building's purpose and therefore its design may not lend itself to inclusion for LEED certification, there is no reason not to consider incorporating its principles. Even a low-profile, self-storage building can contribute to the environment and waste water management with a green roof. A reflective cap sheet with highly emissive ultra white slate flakes will reduce the roof's surface temperature and contribute to mitigating urban heat island effect.

Principles of sustainable roof design

Energy conservation, durability, consumption of raw materials and waste reduction should guide the design and specification of the roof assembly. Energy conservation not only relates to insulation, but to continuity of the air/vapour barrier at the roof and wall junction. Durability relates to design, material selection and good initial installation for longevity, and thus waste reduction.

Conserving energy

To understand the magnitude of insulation's value, a U.S. study Green and Competitive: The Energy, Environmental and Economic Benefits of Fiber Glass and Mineral Wool Insulation Products prepared in 1996 for the North American Insulation Manufacturers Association (NAIMA) by Energy Conservation Management, Inc., Alliance to Save Energy, and Barakat & Chamberlin, Inc., states that it saves U.S. commercial building owners more than $9.6 billion in energy costs annually. In addition, the report also states that insulation reduces energy use in U.S. buildings by 12 quadrillion Btu, which is roughly 15 per cent of the amount of energy used annually, and reduces power plant emissions, cutting carbon dioxide by 780 million tons annually. These figures would now have increased with new construction in the intervening years.

Insulation is less than 1 per cent of the building cost, and there is a relatively short payback period in relationship to building life depending on the properties of the insulation chosen, energy prices, local weather conditions, building size and age. Roof insulation is a fraction of that cost. Consider the r-values for various insulation types.

Product	L.T.T.R.-value/inch
Mineral wool	4.20
Polyisocyanurate	6.00
Expanded polystyrene 16 kg/m3 (1 pcf)	3.85
Expanded polystyrene 20 kg/m3 (1.25 pcf)	4.00
Expanded polystyrene 24 kg/m3 (1.5 pcf)	4.17
Expanded polystyrene 28 kg/m3 (1.75 pcf)	4.17
Expanded polystyrene 32 kg/m3 (2 pcf)	4.35
Extruded polystyrene	5.99
Glass fiber (faced)	4.17
Perlite	2.70
Polyurethane	6.00
Wood fiberboard	2.78

Data from NRCA's (National Roofing Contractors Association) EnergyWise Roof Calculator

Continuity of the air barrier in the roofing system is even more critical in a building's energy performance. Much of an insulation's value can be negated by a break in this barrier. And it is not that uncommon for this to occur. Design for construction must include detailing and specification that allows easy coordination of trades people on the job site. For example, carpenters may build the parapets long before the roofers appear on the scene. The design may require the air/vapour barrier membrane be placed underneath the parapet to achieve continuity between the roof and the walls. This work may be specified in the section for the carpenter or the roofer, but the former causes less confusion in co-ordination if the carpenter can be involved at this stage. Rather than installing plywood at the perimeter which ties into a gypsum board thermal barrier and mopping down an air/vapour barrier before the parapet is constructed, a self-adhesive barrier with a sanded surface can easily be applied which the roofer can tie into when his work begins. It's easier for everyone concerned if a product and specification clause for the self-adhesive air/vapour barrier under a parapet is included.

In a retrofit project, there is no simple panacea for establishing air/vapour barrier continuity between the wall and roof. The roof designer must use the arsenal of detailing solutions available to limit air/vapour movement as much as possible.

Coordination of the trades to ensure air/vapour barrier continuity is simplified if a self-adhesive barrier is installed by the carpenter before the parapet is constructed.

Roofing system durability

In order to discuss durability of roofing systems, it is necessary to explore the world of life expectancy of roofing systems. The life expectancy can best be defined as the age at which the reliability falls below an acceptable level of risk. However, this acceptable level of risk of a given roof design will vary from project to project based on many other factors such as building type and occupancy, system type, owner profiles and economic situation. Initial design and installation quality, environmental conditions and maintenance will also affect long-term performance.

Life expectancy is difficult to predict. The National Research Council's BELCAM study of PWGSC (Public Works and Government Services Canada) roofs uses a database of actual roofing systems and their historical performance to predict optimal economic performance and manage maintenance based on this historical data. Historical data, however, does not take into consideration constant technical and design improvements.

It is commonly agreed within the roofing industry that regardless of the tool selected to assess life expectancy and maintenance issues, different roofing systems provide different service lives. However, very few of these tools incorporate environmental issues into the calculation.

It is estimated by the Freedonia Group that over 31.8 million m2 (340 million ft^2) of re-roofing was undertaken in the Industrial/Commercial / Institutional (ICI) sector in Canada in 2003. According to a report prepared for the Athena Institute, more than 80 per cent of re-roofing projects consist of total removal and replacement. Assuming an average weight of 36 kg/m2 (7.4 lb/ft^2), this corresponds to over 920,000 metric tonnes (1.01 million tons) of waste generated from re-roofing activities. Obviously some of this waste (ballast, for example) is recyclable but much is not. To put this number into perspective, the entire province of Ontario generates 10.5 million metric tonnes (11.6 million tons) of garbage annually.

Incorporating service life estimates for a future of 40 years and assuming an average recycling rate of 50 per cent, one can compare the quantity of raw materials consumed for roofing operations and the amount of landfill waste generated simply by selecting different roofing systems.

Re-roofing projects in 2003

Total re-roofing: 31 833 900 M² (342, 300, 000 ft²)
Total removal projects: 25 467 120 M² (273, 840, 000 ft²)

Roofing system	Life Expectancy (years)*	Roofing systems installed over 40 year life	System weight	Consumed material**	Potential landfill waste
EPDM ballasted	13	3.08	17.3 kg/m (11.6 lb/ft)	4,441,816 t (4,897,261 tons)	2,220,907 t (2,448,630 tons)
BUR	16	2.50	11 kg/m (7.4 lb/ft)	2,302,277 t (2,538,343 tons)	1,151,139 t (1,269,172 tons)
Modified Bitumen	21	1.90	4.8 kg/m (3.2 lb/ft)	758,536 t (836,314 tons)	379,267 t (418,156 tons)
PVC/TPO	13	3.08	2.5 kg/m (1.7 lb/ft)	650,956 t (717,702 tons)	295,268 t (325,544 tons)

** Life expectancy based on Clayton Research, 2001*
*** assuming 50 per cent waste to landfill*

From the above table it can be seen that the selection of the roofing systems used in 2003 will have a tremendous impact on the consumption of raw materials and waste management in the future of these buildings. Millions of tons of raw materials and waste could be saved simply by selecting a longer-lasting, more lightweight roofing system. And these totals don't even include the materials consumed in roofing overlay applications. This environmental impact has rarely been considered in choosing a roofing system.

Good initial design and construction combined with proper, cost-effective maintenance will increase the service life of a roofing system. In the following table, we compare the potential savings when optimizing the service life of the same roofing systems, assuming a uniform 50 per cent increase in service life.

Potential savings with a 50 per cent increase in service life

Roofing system	Life Expectancy (years)	Roofing systems installed over 40 year life	System weight	Consumed material*	Potential landfill waste
EPDM ballasted	19.5	2.05	17.3 kg/m (11.6 lb/ft)	2, 961, 211 t (3,264,841) tons	1,480,605 t (1,632,420 tons)
BUR	24.0	1.67	11 kg/m (7.4 lb/ft)	1,534,851 t (1,692,229 tons)	767,726 t (846,115 tons)
Modified Bitumen	31.5	1.27	4.8 kg/m (3.2 lb/ft)	505,690 t (557,542 tons)	252,845 t (278,771 tons)
PVC/TPO	19.5	2.05	2.5 kg/m (1.7 lb/ft)	433,970 t (478,468 tons)	216 985t (239,234 tons)

** Assuming life expectancy increase of 50 per cent*

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As a result of the system selection undertaken and the proper maintenance of the roofing systems installed in 2003, it would be possible to reduce the future demand for raw materials by almost 4 million metric tonnes (4.4 million tons) over 40 years, for these roofs alone. Obviously, improvements in recycling methods will reduce landfill waste. More importantly, designing for future recovery could eliminate much of the need for recycling, while greatly reducing the demand for new materials.

Extended life expectancy design

What happens to the roof when it comes to the end of its expected life cycle is an important roof system design consideration. Being able to repair and/or re-cover the roof as opposed to replacing it with a new one decreases cost for the building owner, but more significantly enables insulation and other components to be reused, along with the original waterproofing membrane.

Selecting the materials that go under the roofing membrane - insulation and cover board – and the method in which they are installed are determining factors in a roof's longevity. Stable products will not degrade, and good adhesion or fastening will prevent unforeseen movement in the roofing assembly - a leading cause of premature roof failure. The materials chosen should also facilitate repair or roof rehabilitation for extension of life span.

Proper maintenance should be taken into account at the design stage as it facilitates ease of repair, reduces the cost of extending the roof's service life and provides the potential for reusing original components. This is a part of roof system selection. The supplier should be required to provide maintenance scheduling and procedures for the particular roofing system, which can be given to the building owner as part of sustaining its waterproofing properties.

Materials selection

Choosing moisture resistant materials increases the possibility of reuse. This includes asphaltic cover boards, which can standup to a leak without complete disintegration requiring replacement. While slightly more expensive initially, the materials won't necessarily have to be replaced. The longevity of the insulation should also be considered. Is the insulation's life expectancy as long as that of the other materials? This is particularly critical if the objective is to re-cover the roof in the future to increase longevity.

Fastening

Specification of the installation or fastening of the roof system components is also a significant aspect of sustainable design. If components are not well adhered, movement caused by expansion and contraction of the materials can lead to deterioration. The type and quantity of adhesive, and the time of year impact on installation performance of cold and hot applied products. In a mechanically fastened roof system, the quantity and spacing of the fasteners are critical in preventing movement of the components, and most importantly in withstanding wind uplift. Designers can refer to manufacturer's recommendations, FMG (Factory Mutual Global) or the recently published A Guide for the Wind Design of Mechanically Attached Flexible Membrane Roofs, Dr. A. Baskaran, P.Eng. and T.L. Smith, AIA, RRC, Institute for Research in Construction, National Research Council of Canada, 2005.

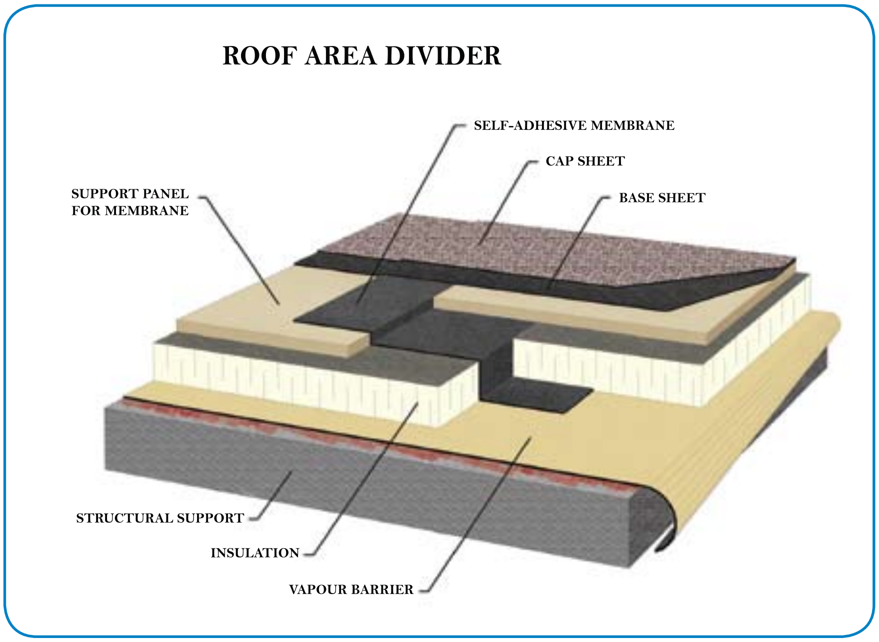
The quantity of adhesive is critical for proper adhesion. Manufacturer's recommendations must be followed and quality control carefully monitored.

Proper quantity and spacing of fasteners prevents movement of roofing system components, and most importantly in withstanding wind uplift.

Sustainable detailing

Providing proper drainage, designing for live and dead loads, and protection of the membrane in high traffic areas must also be addressed at the design stage. Roof hatch entry locations need to be protected with sacrificial membranes where maintenance personnel will be accessing the roof. There are, however, other aspects less often considered at this juncture.

Area dividers (water cut-offs) aren't used as commonly as they should be - that is in every roofing installation. Some roofing association warranties require area dividers usually between 743 and 929 m2 (8,000 and 10,000 square foot) sections. This may entail a small water-proofed wood parapet extending 203 mm (8 in.) above the membrane. If a leak does occur, the water damage is contained, leaving a smaller area of the roof to repair or re-roof. While this type of area divider is required under the association warranties, specification of a simpler approach is a good design practice for any roofing project. In many roof systems, the area divider is installed by using a narrow strip of self-adhesive membrane to tie in the air/vapour barrier on the deck to the underside of the roofing membrane. A simple procedure that designs sustainability into the roof system.



The simple application of area dividers contains water damage if a leak should occur and minimizes the extent of repair to a small section of the roof. In many roof systems, the divider is installed by using a narrow strip of self-adhesive membrane to tie in the air/vapour barrier on the deck to the underside of the roofing membrane.

Are there any other details to add?

Details which can be overlooked are those "odd" penetrations which can occur, for example, where an angle iron or an I-beam penetrates a parapet. Additional attention at these details will help add service life to the roof and reduce the chance of premature failure.

Quality installation

No matter how good the design or the products selected, the service life of roofing systems depends on the quality of installation and inspection. Many roofing system manufacturers provide training programs for roof applicators and inspectors, both in a classroom setting and on-site for which they provide a certification document. Other opportunities for training are provided by roofing associations. Manufacturers train roofing contractors on their products and recommended installation procedures. When specifying a roofing system and installation method, look to those who have had practical instruction with these products and methods, and include specification clauses requiring specific training of installers and inspectors.

Recover considerations

Where the original roof provides the option of re-covering, the potential for reducing waste and consumption of replacement products is substantial. Local bylaws should be reviewed as to re-cover requirements and limitations. The option is only viable if the components underneath the membrane are in good condition (part of the original design for sustainability), and the structure can resist any additional loads from the recover materials. Non-destructive testing should be followed by strategic core testing to confirm original findings as to whether re-cover is a viable choice. Non-destructive evaluation includes electrical capacitance, infrared thermography, nuclear hydrogen detection and electronic field vector mapping.

When re-covering, a mineral wool board with a factory-laminated membrane has sufficient compressibility to provide a smooth surface for membrane installation over existing roofing materials.

In selecting re-cover materials, compensation must be made for the condition of the existing membrane. On a tar and gravel roof, for example, the uneven surface left after removal of loose gravel may present difficulty in achieving a smooth substrate with a rigid cover board. To alleviate this problem, mineral wool with a factory-laminated membrane has sufficient compressibility to provide a smooth surface over which to apply the waterproofing membrane.

Other roofing options

No discussion on sustainable roofing can be concluded without a look at reflective roofing and green roofs.

Reflective roofing

A great deal of information is available on the pros and cons of reflective (cool) roofing, which the specifier can review within the context of specific projects. Aging and weathering can reduce the reflectance of some types of cool roofing materials. A high percentage of reflectance can be restored through a regular maintenance program, but the use of detergents and possibly algae cleaners require evaluation as to the their environmental impact. Reflective cap sheets, consisting of small flakes of slate, which is a highly durable material, will retain reflectance without the need for cleaning. At the Roofing Consultants Institute (RCI) Foundation May 2005 symposium, "Cool Roofing – Cutting through the Glare", James L. Hoff, chairman of ERA (The EPDM Roofing Association) noted in his presentation "The Economics of Cool Roofing: A Local and Regional Approach" that reflective roofs may offer minimal or even a negative benefit in cold and cloudy regions. The value of a reflective roof needs to be evaluated with respect to local climatic conditions.

Garden (green) roofs

Garden (green) roofs are becoming more readily accepted in Canada in recognition of their environmental attributes and the availability of complete pre-engineered systems, which overcome co-ordination issues of the past. These systems have been refined to make garden roofs suitable for more existing buildings. For example, some manufacturers have developed growing medium, which reduces its water-saturated weight by up to 50 per cent.

At National Research Council's Institute for Research in Construction Field Roofing Facility in Ottawa, a reference roof (two-ply modified bitumen) and garden roof 152 mm (6 in.) of growing medium and grass) have been evaluated for temperature, rain and runoff. It was found that when the outdoor temperature was between 28 and 35° C (82 and 95° F), the garden roof surface temperature was 35° C less than the reference roof, reducing the urban heat island effect. Over a six-month period from April to September, an overall runoff reduction of 54 per cent from the garden roof was recorded.

Most importantly, the garden roof reduced the total runoff from the roof by over 50 per cent and substantially delayed the runoff to an off peak period, reducing the demand on the storm drainage system. If enough garden roofs were in existence, there would possibly be a reduction in backing up of storm drains and significant savings in waste water treatment.

While a garden roof in itself is considered a sustainable roof, consideration must be given to its sustainability. With only 152 mm of soil for plant survival, the choice of growing medium and plant material can be critical. Rooftops create unique micro-climates very different from common plant hardiness zones, so one should select only the growing medium and plants recommended by an expert in rooftop landscaping. The garden roof owner must be committed to maintenance until plant material coverage is complete, and the specification should include the first two years of maintenance and scheduling (include plant establishment and maintenance in warranty requirements).

While reducing the urban heat island effect, a garden roof makes a significant contribution to the environment in delaying and reducing peak storm-water runoff.

Tools for sustainability

The products and technologies are available today to design a roof assembly for reuse, repair and recover to provide the potential of double or triple life expectancy. At the time of writing, a durability credit has yet to be implemented in a LEED project because of the difficulty in evaluating and predicting service life of building envelope components. But this doesn't mean that trying to attain the most durable, long-lasting roof possible isn't worth undertaking. This exercise starts with roof design and specification and finishes with good maintenance after installation. Looking beyond the life expectancy of the original roof is to incorporate choices that provide an option for its extension in the future.

Learn more

Soprema's complete line of building envelope products is supported by over 40 technical sales representatives and technicians through 11 regional offices to assist building professionals in selecting and specifying waterproofing solutions, and designing for sustainability. In addition, Soprema's North American R&D Centre located in Drummondville, Quebec, continually develops innovative new technologies to deliver superior performance and high resistance to weather-related stresses.

Soprema Inc. is a world leader the development and manufacturer of SBS modified bitumen roofing systems, air/vapour barrier and waterproofing membranes, and garden roofing systems to meet the requirements of industrial, commercial, institutional and residential applications. Soprema offers a variety of roofing membranes - pressure sensitive self-adhesive, cold adhesive, mechanically-fastened or heat-welded, as well as re-cover options for extending the service life of existing roofs. Soprema also supplies a full range of liquid, self-adhesive and heat-welded air/vapour barrier and foundation waterproofing products, and protection and drainage boards.

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A profile in sustainable roofing

The 27-year old, concave roof at Colisée (Arena) Jean-Belliveau in Longueuil, Quebec is getting a facelift and a new lease on life. After experiencing several years of problems with the original roof construction in 1968, the City decided in 1978 to re-roof with the following components on the existing mill deck (wood): 41.3 mm (1 5/8 in.) of concrete, a built-up vapour barrier, 50 mm (2 in.) of fiberglass insulation applied in hot asphalt, and modified bitumen base and cap sheets installed in hot asphalt. Since 1978, the maintenance cost on the roof has been $5,000.

The City is now retrofitting the entire building. After evaluating the condition of the 27-year old roof, the designer is specifying re-cover of the existing assembly. Improper detail at the drain/scupper has caused leaks in two areas which will be repaired, before re-covering with a mineral wool board with factory-laminated membrane and a modified bitumen cap sheet. In doing so, the roof's life expectancy will be extended and tons of waste diverted from landfill.