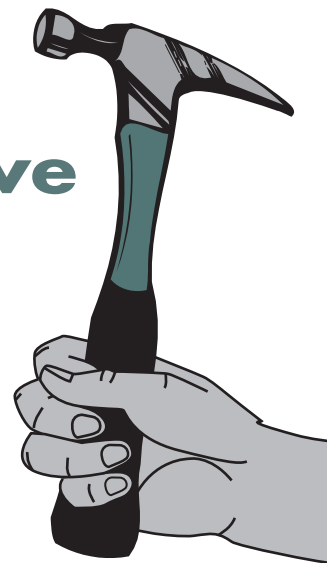
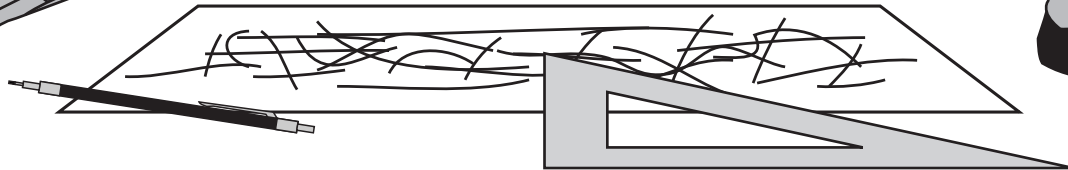
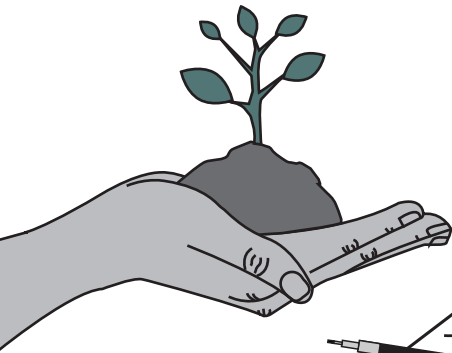


DESIGNING Environmentally Responsive LOW-SLOPE Roof Systems

By Thomas W. Hutchinson



ABSTRACT

There is a genuine interest among enlightened building owners and roof system designers in adopting environmental objectives. In many countries, a whole generation has grown up in a culture sympathetic and supportive to "green" issues, and many colleges and universities include environmental studies as part of their normal course work. The challenge facing the roofing industry is to translate this interest and goodwill into practical guidelines that will lead to improvements in the long-term performance of roof systems—within a given financial budget.

This author's experience has shown that designing low-

slope roof systems to exceed anticipated service life is possible. Introducing environmental responsiveness also is possible. The purpose of this paper will be to review concepts, products, and roof system design for achieving lengthy service life while being environmentally responsive. A case study based on the tenets of sustainable roofing prepared by the combined committee of the International Council for Building Research Studies and Documentation (CIBW 83) and the International Union of Testing and Research Laboratories for Materials and Structures (RILEM166RMS) will be reviewed.

INTRODUCTION

The International Conference on Climate Change held during 1997 in Kyoto, Japan, challenged governments to improve on their national environmental performance in terms of reducing both pollution and energy demand. To work toward these desirable goals, the concept of "sustainable development" is being actively promoted in the contractor and property industries in some countries.

The challenge facing the roofing industry is to translate this interest and goodwill into practical guidelines that will lead to improvement in the incorporation of environmentally respectful procedures and products in roof system design. It is unrealistic to believe that any product or procedure will be adopted if it results in reduced performance. As an architect specializing in roof system design, this writer finds his greatest challenge to be designing environmentally responsive low-slope systems to exceed an anticipated service life.

DEFINING THE CONCEPT

Before beginning any discussion of roof systems and the environment, a definition of the concept is needed. As roof systems should be considered the sum of all their parts, so should

environmental concerns. Consequently, environmental issues should be considered as only part of a more holistic approach—that of sustainability.

In 1987, the Brunatland Report was presented to the United Nations Commission on the Environment and Development, and it defined **sustainable development** as:

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Attendees at the First International Conference on Sustainable Construction, held in Florida in 1994, defined **sustainable construction** as:

The creation and maintenance of a healthy built environment based on ecologically sound principles and resource efficiencies.

In regard to roof systems, several conceptual definitions have been proposed. Perhaps the best working definition of what this author understands to be a **sustainable roof** was one used in the *Proceedings of the Sustainable Low-Slope Roofing Workshop*, held at Oak Ridge National Laboratory in Oak Ridge, TN, in October 1996:

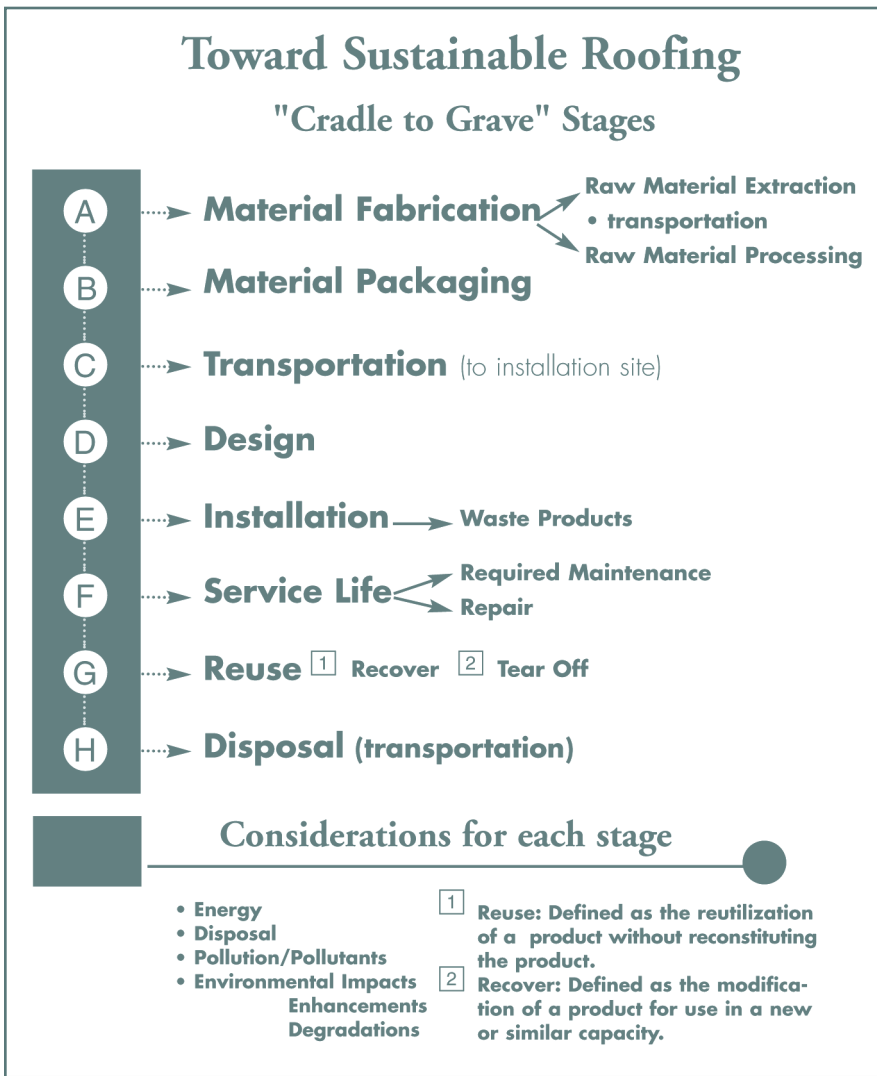


Figure 1. A "Cradle to Grave" model diagrams each step in the life of matter: from raw material extraction or processing, through production, to installation, to removal and reuse or disposal.

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.

These definitions are difficult not only to implement but to comprehend. Their value lies in their far-reaching scope. Sustainable development supposes that construction methods and their relationship with the environment, life cycle analysis, and environmental quality must all be taken into account. Consequently, it is an all-encompassing concept that provides a stable framework for new design methods. It is about taking the "long view."

Life cycle analysis involves an examination of each step in the life of matter: from raw material extraction or processing, through production, packaging, transportation, design, installation, service life, re-use, recover or tear-off, and, ultimately, disposal. This is typically illustrated in a "Cradle to Grave" model. See *Figure 1*.

At each stage of the model, various environmental attributes can be defined in terms of energy demand, CO₂ emission, types

and quantities of pollutants, volume of waste, and other parameters. The final "score" is related to the number of years service the roof gives (which will not be known at the design stage), but can be no more than a best estimate based on published data, assuming good standards of workmanship and maintenance.

Another difficulty is in weighting the various environmental data. This raises questions such as: How important is it to reduce CO₂ emissions? What is the impact of transportation? Which types of pollutants are hazardous, and in what concentrations do they become harmful to health? In the real world, the standards of workmanship in assembling the individual components are not perfect, and the subsequent long-term maintenance is often poor. Concerns about the manufacture of one component of a roof system are only a small part of the whole picture when the in-service performance and ultimate replacement of the roof are considered.

TENETS OF SUSTAINABILITY

While environmental studies have laudable goals, designers and contractors alike seek basic, practical advice in sustainable development. Since 1995, the CIBW.83/RILEM166RMS Committee (Tom Hutchinson, Legat Architects, USA; Keith Roberts, Roberts Consulting, United Kingdom; co-chairs) has been constructing this practical advice. This committee is a voluntary and independent group of recognized experts and roofing specialists from almost 20 countries who meet on average once a year to exchange results and findings of international research and studies into low-slope membrane roofing. The committee identified three key areas where improvements could be identified.

- **Minimize the Burden on the Environment**, being responsible stewards of the earth's resources.
- **Conserve Energy**, recognize the savings benefits and importance of improving thermal efficiency of roofs.
- **Extend Roof Lifespan**, realizing the value of seeking long-term performance.

In October 2000, the task group finalized a summary of what appear to be the best practices for sustainable low-slope membrane roofing, based on published reports, technical papers, and the experience and expertise of the members. It is felt that the following summary will be of practical, everyday use for designers, manufacturers, and contractors alike. Each tenet may appear to be simplistic, often common sense; however, when they are considered as a whole, they make a considerable contribution to promoting sustainable roof system design, construction, and maintenance of membrane roof systems.

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 could 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 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, trades people, 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. See *Photo 1*.



Photo 1. This roof system, composed of three modified layers on tapered insulation, was designed by the author and recognizes the value of a robust and durable roof. Taking the long view is the single most important concept in sustainable roofing. Meets Tenet 8, 9, 10, 13, 14, 16, and 18.

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 work in progress, taking corrective action as necessary.
20. Control access onto completed roof to reduce puncture and other damage, providing defined walkways and temporary protection.

NORMAS DE TECHADO SUSTENTABLE

Octubre de 2000

Reducir Al Mínimo La Carga Sobre El Medio Ambiente

1. Usar productos elaborados con las materias primas cuya extracción sea menos perjudicial para el medio ambiente.
2. Adoptar sistemas y métodos de trabajo que reduzcan al mínimo el desperdicio.
3. Evitar los productos que generan residuos peligrosos.
4. Reconocer los factores climáticos y geográficos regionales.
5. Cuando sea lógico, usar productos que puedan reutilizarse o reciclarse.
6. Promover el empleo de 'techos verdes' que admitan vegetación, especialmente en los centros urbanos.
7. Estudiar diseños de techos que faciliten la selección y recuperación de los materiales al final de la vida útil del techo.

Conservar La Energía

8. Optimizar el rendimiento térmico real, reconociendo que la aislación térmica puede reducir considerablemente los gastos de calefacción o refrigeración a lo largo de la vida útil de un edificio.
9. Mantener seca la aislación para conservar el rendimiento térmico y la durabilidad del techo.
10. Emplear mano de obra, materiales y servicios locales siempre que sea práctico para reducir el transporte.
11. Reconocer que los valores de energía incorporados son una medida útil para comparar construcciones alternativas.
12. Tener en cuenta el color y la textura de la superficie del techo en relación con el clima y su efecto sobre el rendimiento energético y del sistema del techo.

Prolongar La Vida Del Techo

13. Recurrir a proyectistas, proveedores, contratistas y comerciantes suficientemente instruidos y que posean la competencia apropiada.
14. Adoptar un enfoque responsable en cuanto al diseño, admitiendo el valor de un techo sólido y durable.
15. Reconocer la importancia de una estructura de apoyo correcta.
16. Proporcionar un drenaje eficaz para evitar el estacamiento de agua.
17. Reducir al mínimo la cantidad de perforaciones a través del techo.
18. Asegurarse de que los elementos de mantenimiento elevados sean accesibles para repararlos o cambiarlos.
19. Supervisar las obras de techado mientras se ejecutan y adoptar las medidas correctivas que sean necesarias.
20. Controlar el acceso a los techos terminados para reducir las perforaciones y otros daños, previendo pasajes definidos y protección transitoria.
21. Adoptar un mantenimiento preventivo, con inspecciones periódicas y reparaciones oportunas.

NOTAS

- I. Estas normas son aplicables a los sistemas de techado con membrana en edificios permanentes.
- II. A medida que aumenten nuestros conocimientos sobre el comportamiento de los techos y la manera en que afecten el medio ambiente mundial, las normas también evolucionarán.

Figure 2. It's a global environment. The dispersion of the Tenets of Sustainability to the worldwide roofing community in the local vernacular is critical to building common goals among global partners. Above, the Spanish version.

21. Adopt preventative maintenance with periodic inspections and timely repairs.

As the committee is international in makeup and it desires to communicate these tenets to the international roofing community, the tenets have been translated into numerous languages, including Chinese and Spanish. See *Figure 2*.

INDUSTRY TRENDS AND CONCEPTS

As owners and designers raise issue over environmental concerns, the roofing industry has responded with a number of often viable roof design considerations. Following is a short summary of these trends and concepts. Those roof system designers wishing to incorporate these concepts are encouraged to investigate their appropriateness and potential for success.

Garden Roofs: Green roof systems, while prevalent in Europe, are only now making a presence in North America. There are two categories of green roof systems: intensive and extensive.

- **Intensive systems** are the more substantial "garden roof," incorporating trees and bushes in an overburden (growth medium) up to one meter. Substantial roof decks and structure are required.
- **Extensive systems** are much less of a structure burden, incorporating plants with shallow root structure. Technologies have been developed so that now even lightweight roof decks can support extensive roof gardens. Environmental benefits include reducing rainwater runoff, often to less than 50 percent of normal; reduced pressure on the ground-level drainage system; and longer roof life service due to the inherent protection of the roof membrane from UV radiation, hail, wind, and foot traffic. The second *Building Failure/Damage Report* issued by the German government in 1988 documents membranes below garden roofs lasting up to 50 years in environments where the average roof life is 10 – 15 years.

Roof Surface Reflectivity: Recent studies have found that on sunny days, temperature excursions occur because of the heat-absorbing properties of the built environment. It is hypothesized that a small reduction in the heat gain will result in substantial energy consumption savings. As roofs are often black, heat-absorbing surfaces, the concept of reflectivity has been proposed as a way to reduce urban heat temperatures.

Reflectivity is defined as the roof's ability to reflect solar energy. Reflectivity is influenced by color and texture of the roof surface. The greater the roof's ability to reflect, the cooler the roof surface, which could result in lower air conditioning demands. However, reflectivity will decline over time due to dirt accumulation on the roof



Photo 2. The installation of reflective membranes or coatings meeting the EPA's Energy Star® Roof Products Program has the potential to reduce urban heat gain as well as pollution by lowering air conditioning loads. Meets Tenet 13.

surface. Physical changes in the properties of the roof membrane or coating can also decrease reflectivity. The U.S. Environmental Protection Agency (EPA) has become involved and developed the Energy Star® Roof Products Program. Products meeting the EPA reflectivity criteria can carry an Energy Star® label. See *Photo 2*.

Utilizing Solar Energy: Photovoltaic panels, which convert sunlight energy to electricity without consuming fuel or creating pollution, are no longer tacked-on appendages begging to be concealed. There are photovoltaic materials available for virtually all surfaces of the building envelope: e.g., photovoltaic shingles and standing seam metals. More and more clients are willing to pay an additional one or two percent of a building's total construction cost to obtain this enduring symbol of environmental responsibility. In some instances, excess solar energy is "sold" back to the utility company.

MATERIAL TRENDS AND IMPROVEMENTS

Roof system material manufacturers have gradually responded to the "Green Movement" in developing materials and products that support sustainable roof system design. Government mandates are responsible for much of the push toward development, but more and more clients/owners are requesting designs that respect the environment in their material manufacturing, installation, and performance.

Following is a brief overview of some of the major material developments in recent years.

Insulation: The Montreal Protocol, which bans the production and importation of HCFC 141-b by the end of 2002, has had a major impact on the polyisocyanate insulation industry. Reformulations are always challenging, especially when products

with years of satisfactory performance must be altered. Atlas Roofing Corporation has taken the lead here in the U.S.A. with its development of ACUUltra, an HCFC-free product incorporating a hydrocarbon (HC) blowing agent in 1998.

Expanded polystyrene (EPS) and extruded polystyrene insulations offer environmental benefits that need to be considered when making insulation selection. EPS, in its manufacturing process, emits no CFCs or HCFCs into the atmosphere. EPS is also recyclable. Extruded polystyrene has an extremely low water absorption rate and as such often lends itself to potential reuse even after decades of service, consequently saving money, conserving insulation, and minimizing contributions to waste sites.

A recent innovation in the Midwest marketplace has been the introduction of multi-layer composite tapered insulation panels. The manufacturer lays out the entire insulation system in a warehouse, then adheres the layers together, packages, and delivers them to the site, identified for correct installation location. This author recommends utilizing a base layer to offset joints to provide a thermal break. See *Photo 3*.



Photo 3. Tapered insulation with offset joints in sufficient thickness to provide substantial thermal value is an important consideration in the design of environmentally friendly roof systems. These sections of tapered insulation were prefabricated offsite, installed over a vapor/air retarder on two inches of polyisocyanurate, and overlain with a Perlite board. Meets Tenets 2, 7, 8, 9, 15, and 17.

Wood Blocking: An integral part of almost all roof systems is the use of wood blocking. Wood, pressure-treated to enhance protection against rot, decay, and termite attack, is generally recommended. Traditionally CCA treated wood was utilized, which contained arsenic and chromium, both of which are EPA classified hazardous chemicals. There are now alternatives available. Wood treated with ACQ® preservative, a copper plus quat system, provides the same level of protection as CCA preservatives without the arsenic and chromium. Worker safety is a prime benefit of utilizing this product, and disposal into ordinary waste sites is acceptable.

Asphalt: Odor is probably the most troubling aspect of working with asphalt, particularly when working on sensitive facilities such as hospitals, schools, and restaurants. Low-fuming, no-waste packaged asphalt is now available. Asphalt packages are in containers that do not require removal and that melt away without affecting performance, thus reducing waste. Formulations that introduce a polymer that creates odor-trapping skim layers now create a more friendly environment in the vicinity of the kettle.

Adhesives: Foam adhesives have gained in popularity and use in recent years. Foam roof adhesives are available that contain no HCFCs, and there are no EPA restrictions on their use in congested areas.

Cold process adhesives for use with bituminous products can now be formulated for use in areas where extreme environmental and volatile organic compound (VOC) emissions concerns mandate the use of the most environmentally benign product possible.

EPDM: Primers, Adhesives, and Tape

Adhesives: The requirements of achieving a quality adhesive seam have changed little in the past decades. Clean surfaces, positive bonding, and mating of materials are still required today. What has changed, though, are the products utilized in achieving this bond. Splice primers are now formulated without isocyanate. Liquid adhesives are being replaced with tapes, and flashing materials are even becoming manufactured with tape adhesives laminated to the product.

Reinforcements: Several roofing felt and modified bitumen vendors are now manufacturing reinforcing mats made from reprocessed polyester, recycling, and reducing waste to benefit the environment.

White Membranes and Coating: The manufacture and marketing of white membranes and coatings in response to "Cool Roof" concepts and the EPA's Energy Star® Roof Products Program have increased greatly in the last two years. Thermoplastic polyolefin (TPO) membranes were

introduced and marketed heavily in the U.S. marketplace. These materials have a variety of formulations. The designer is cautioned to research each product thoroughly for its appropriateness in a particular design.

ROOF SYSTEM DESIGN EXAMPLE

When designing roof systems, this author firmly believes that the greatest environmental good he can perform is to take the long-term view and design roof systems that have extended ser-

vice lives. While no exact data exists, an article in the November 2000 issue of *RSI*, entitled, "EPDM: a Labor-saving Alternative for Reroofing," suggests that the average life of single-ply roofs is less than 18 years and less than 14 years for BUR roofs (discounting roofs on buildings designed for 10-year lives and those that have leaked for years prior to replacement). It is felt that these service life averages are unacceptable. Following is a case study of a project that strives to comply with the tenets of sustainable roofing to achieve a service life greater than 20 years. It should be noted that all roof systems require maintenance in order to achieve these extended service lives, but maintenance will not be discussed here.

Component	Justification	Tenet of Sustainable Roofing
Moisture Protection Design Team	Team of professionals educated in moisture protection	13, 14
Steel Structure, structurally sloped	Locally fabricated, knowledgeable local installers, positive slope guaranteed	10, 13, 15, 16
Metal Roof Deck (Exposed)	Locally manufactured, installation familiarity	10, 13
5/8" Dens Deck set in foam adhesive	No penetrations through roof deck desired, foam adhesive allows for ease of installation	14
Self-adhering 2-ply vapor/air barrier	Provides construction surface for other trades. Barrier against moisture drive, especially during construction. Allows for larger, more monolithic sections of final roof to be installed at one time	8, 9, 14
2 Layers of 2", 1 layer 1-1/2" polyisocyanurate set in foam adhesive, R = 5.67/in, 20psi min.	Achieve R30, non HCFC product, locally produced. 20psi min. offers a greater degree of stability than 18psi nominal-commodity product	8, 9, 10, 14
1/2" high density wood fiber board set in hot asphalt	Offers separation between membrane and polyisocyanurate (outgassing); provides firm substrate underfoot	14
60 mil reinforced EPDM fully adhered <ul style="list-style-type: none"> • isocyanate-free primers • tape adhesive use where practical • all seams to be overlaid with cover strip 	Extensive successful experience of contractors and designers, north facing slope Use of environmentally friendly materials No VOCs Provides redundancy	10, 13, 14, 12 3 3 14
Coordinate with HVAC consultants to limit penetrations	Minimize the possibility of mistakes in flashings	17
ACQ Pressured Wood Blocking	Rot and decay resistant treatment, environmentally safe	3, 14
Heavy-gauge aluminum coping, fascias, and counterflashings	Provides superior wind uplift resistance, nice aesthetic look	4, 14
Preapproved roofing contractors	Optimize probability of success	10, 13
Monitor installation	Optimize probability of success	19
Control Access on completed roof	Optimize probability of success	20
Review with owner the maintenance requirements	Optimize probability of success	13, 14, 21

Figure 3: Roof System Design Solution —While not every tenet was fulfilled, many were, and that is the intent of the above list.

Case Study:

Project: Highland Park High School
Science Classroom Addition
Highland Park, IL

- Goals: 1. 20-year roof life, minimum
2. Achieve energy conservation
3. Where economical, be environmentally responsive

See Roof System Design Solution, *Figure 3*.

CONCLUSION

We must all realize that the reality of our time is the supreme vulnerability of our planet. As we enter the twenty-first century, the ideals of sustainable architecture and being environmentally responsive will manifest themselves via government mandate, codes, and owner desires. Obtaining environmentally responsive roof systems can be achieved by becoming educated to the possibilities and utilizing a straightforward approach in adapting the

tenets of sustainable roofing where possible.

Materials, products, and construction techniques will continue to evolve, and with them the tenets of sustainable roofing. The manifestation of this evolution will be the concept of designing environmentally responsive low-slope roof systems for the long term. Those who take an active role in this endeavor and embrace concepts of sustainable roofing will be ready for the environmental challenges of the twenty-first century. ■

Acknowledgements:

The author would like to thank Dr. Walter Rossiter (chairman), Ed Kane (secretary), and the members of the CIBW-83/RILEM166RMS Committee who, with their contributions over the past five years, have brought the concept of "sustainable roofing" to the world-wide roofing community.



RCI, Inc.
800-828-1902
www.rci-online.org

ABOUT THE AUTHOR

Thomas W. Hutchinson is a graduate of the University of Illinois with masters degrees in both architecture and civil engineering. He is a licensed architect and registered roof consultant specializing in roof design, contract document preparation, specifications, inspections, and the determination of moisture penetration and failure of existing roof system. He has made numerous presentations in Europe, South America,



THOMAS W. HUTCHINSON

North America, and Asia on architectural contract detailing for single-ply membrane roof systems, roofing removal and replacement, steep-slope roof systems, design, restoration, and roof system maintenance. Hutchinson is currently Director of Moisture Protection for Legat Architects, Palatine IL. He is Co-Chairman CIB/RILEM's International Committee on "Toward Sustainable Roofing," and is responsible for all moisture-related concerns for its six studios in the Chicago area. He is a member of ASTM Committee D-08 on Roofing, Waterproofing, & Bituminous Materials, NRCA, Firestone Building Products Roof Consultant Advisory Council, and is a past President of the Barrington Rotary and a past Region Director of RCI.