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Conference Report

FOURTH INTERNATIONAL SYMPOSIUM ON ROOFING TECHNOLOGY Gaithersburg, MD September 17-19, 1997

Report prepared by

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1. Introduction

The National Institute of Standards and Technology Building and Fire Research Laboratory (BFRL) and the National Roofing Contractors Association (NRCA) have joined in sponsoring Symposia on Roofing Technology on a biennial basis since 1969. These Symposia are the major industry forums for the dissemination and discussion of research results and for the presentation of the latest advances in roofing technology. In 1977, 1985, 1991, and 1997, the Symposia were international in scope with international co-sponsors, authors, and audience. In 1997, NIST and NRCA were joined by CIB,[1] RILEM,[2] the International Waterproofing Association (IWA), the National Research Council Canada (NRCC), and the Canadian Roofing Contractors Association (CRCA) in co-sponsoring the Fourth International Symposium on Roofing Technology—a summary of which is presented in this report. This Symposium was held on September 17-19, 1997 in Gaithersburg, Maryland.

2. The Symposium

The theme of the 1997 Symposium was "Challenges of the 21st Century." Advances in technology have contributed significantly to improvements in roofing performance since the beginning of the Symposia series. The theme of this Symposium was appropriate as the roofing community faces the continuing challenge of using science and technology to overcome current weaknesses and limitations in roofing performance, and to put sound solutions into practice.

Approximately 450 individuals were in attendance from 22 countries. Fifty-nine papers grouped into 18 sessions were presented over 2 1/2 days of concurrent sessions with simultaneous English, French, and German translations. Because of the Symposium size, not all sessions are summarized in this report. Instead, a summary of selected sessions is presented to provide a flavor of the topics addressed. *Proceedings* of the Symposium are available from the NRCA.[3] A bibliography of the Symposium papers with the session titles is given in Section 12.

The Symposium began with welcoming remarks on behalf of the sponsors including those of Dr. Robert Hebner, Acting Director of NIST. Dr. Hebner reviewed the role of NIST in promoting industry's global competitiveness. He reminded the participants that the long-standing relationship between NIST and NRCA in

[1] *C*onseil *I*nternational du *B*âtiment pour la Recherche, l'Étude, et la Documentation. (International Council for Building Research, Studies, and Documentation).

[2] *R*éunion *I*nternationale des *L*aboratoires d'*E*ssais et de Recherches sur les *M*atériaux et les Constructions (International Union of Testing and Research Laboratories for Materials and Structures).

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co-sponsoring symposia is a fine example of industry and government cooperation in addressing national needs. Two keynote addresses were made to open the technical sessions. William A. Good, NRCA Executive Vice President, made the presentation, “The North American Roofing Industry: 20th Century and Beyond.” Paul Newman, IWA Chief Executive, presented, “The European Roofing Industry: 20th Century and Beyond.” Both presentations strongly emphasized the importance of enhancing the technical capabilities of the roofing industry.

3. Session on Single-Layer Roofing

In many regions of the world, membranes comprised of single-layer synthetic sheets are used as alternatives to bituminous products for waterproofing low-slope roofs. This session focused on performance aspects of the single-layer systems. Two papers [1,4] addressed seams in ethylene-propylene-diene (EPDM) membranes. In recent years, adhesive tapes have begun to supplant contact-type liquid adhesives in forming seams in service. One paper [1] reported the results of a study comparing the creep-rupture response (i.e., time-to-failure under load) of these two types of adhesive systems. A main conclusion was that the tape samples had mean times-to-failure that were, in most cases, comparable to, or greater than, those of the liquid-adhesive samples. The second paper [4] described a testing protocol that may be used to evaluate any adhesive used for EPDM membranes. Comparative data were presented on tape samples and liquid-adhesive samples. In general, the tape samples had comparable, if not greater values, in the tests conducted.

Thermoplastic polyolefin (TPO) membranes have been recently introduced into the roofing industry. One paper [2] discussed the importance of selecting proper flame retardants when formulating TPO sheet materials and also discussed a study on the environmental impact of the TPOs. In presenting background information for the paper, it was pointed out that bromine-containing compounds are commonly used as flame retardants. However, data presented indicated that membrane products with non-brominated compounds have higher uv stability, and recommendations were made that formulations not use bromine compounds. The study investigating the environmental impact considered all steps of a non-brominated TPO’s life cycle, and showed the material to be environmentally friendly. This ecological study provided an example of the extensive efforts that might need to be undertaken in examining the environmental impact of a roofing membrane material.

A fourth paper [3] in the session addressed the performance of poly(vinyl chloride) (PVC) roofing. In the past, nonreinforced PVC membranes, which are not installed today, experienced performance problems associated with loss of plasticizer from the sheet. In evaluating existing roofs for signs of potential problems, visual examination has often been conducted without support of laboratory testing. The author presented data from a variety of test methods including thickness, tensile strength, elongation, plasticizer content, specific gravity, and hardness. He offered that use of these methods enhances the evaluation process and should complement visual examination.

4. Session on Asphalt Shingles

Asphalt shingles comprise the most commonly used watershedding covering for pitched roofing in the United States. A major problem facing the industry is unsightly discoloration due to algae growth on the shingle granules. In a recent development [12], steps have been taken to overcome the problem through the use of copper-containing granules on the shingles. These granules release cupric ions in a controlled fashion uniformly over the roof with time. A mathematical model of the controlled release correlates well to real-time exposure studies of copper-granule performance.

Another presentation was a paper on the application of the performance concept to shingles [13]. The authors proposed a model, which they designated as the Assessment of Performance Tests (APT) model, for identifying perspective performance tests for shingles. They proposed five criteria that need to be satisfied by a performance test: logic, validity, material independence, repeatability and reproducibility, and cost-effectiveness. By way of example, the authors applied the APT model to three tests currently used to evaluate asphalt shingles. They concluded that none satisfied the five criteria totally. They recommended that the further development of tests for asphalt shingles be consistent with the APT model.

5. Session on Low-Slope Roof System Performance

Statistical data on the service lives of low-slope roofing systems have not been readily available to the industry. A prime reason is that, historically, mechanisms for tracking performance of systems that may be in service for 15 years or more have not been in place. Now, with the common use of computers for keeping data, data files on service lives of roof systems are beginning to appear. Three papers [15-17] gave examples of the use of databases for tracking and analyzing service performance-techniques that will undoubtedly make an impact on the industry in the years ahead.

One paper [15] discussed the relative durability of membrane roofing systems based on a 1996 nationwide survey that the author conducted of the U.S. roofing industry. Using data from the survey, the mean and minimum service lives, and durability ranges for common roofing membranes were calculated. The data were further analyzed, based on the Arrhenius concept, to determine the effect of thermal exposure on durability. It was found that mean durability decreased significantly for some systems with increase in temperature; whereas the service lives of other systems did not appear to be affected.

A second paper [16] presented data from the roofing warranty database of a major manufacturer. The database covered more than $2\times10^{8}\,m^{2}$ of EPDM and polymer-modified bitumen roofing installed between 1982 and the present. Because the data were from warranty files, roof repair costs over time were known. Roof performance was defined as the repair expense per unit of membrane surface area for a specified period of time. Using this definition, comparative performance of the two types of roofing was discussed. Examples of improvements in performance based on changes in technology such as the use of EPDM seams tapes in lieu of liquid-adhesives (see Sec. 3) were noted.

The final paper [17] reported on a database that has been under development by the authors since 1975. To date, the database contains about 24 000 files on low-sloped roofing systems and shingle roofing. All files in the database include information on actual lifetime; that is, it is known when the roof in question was replaced. The authors presented examples of the information that may be obtained from the database. Comparative service lives of the different types of low-sloped roofing systems were noted. In addition, initial costs versus life cycle costs for these systems were compared. The authors intend to expand and refine the database in the years ahead.

6. Session on Wind Engineering

The performance of roofing systems subjected to high wind events has been topical in the roofing industry in recent years—partially motivated by destructive storms such as Hurricane Hugo and Hurricane Andrew that caused extensive roofing damage. Moreover, test methods historically used by the roofing industry for evaluating the wind uplift resistance of bituminous membrane systems are not applicable to many of the newer systems such as mechanically attached synthetic membranes. Consequently, new methods for uplift resistance are being sought. Three papers [21-23] in this session addressed the uplift resistance issue.

The static uplift resistance of EPDM and TPO mechanically-fastened synthetic membrane systems was the subject of one paper [21]. Tests were performed using various sized chambers to determine whether a minimum size could be identified. Uplift loads on fasteners were measured during the testing, and compared with calculated loads based on the pressures to which the system was subjected during testing. It was concluded that a chamber with minimum dimensions of 2.4 m by 2.4 m would suffice to allow calculated fastener loads to reasonably approximate the measured fastener load.

The National Research Council of Canada has constructed a facility for the dynamic uplift evaluation of roofing systems. A paper [22] described the facility and presented initial data developed using three different loading protocols on a mechanically-fastened PVC system. Comparative performance of the system was discussed. Investigations are continuing using other synthetic membrane systems.

A paper [23] presented by the Asphalt Roofing Manufacturers Association (ARMA) summarized research in developing an improved test method for evaluating the uplift resistance of asphalt shingles. Wind tunnel studies were conducted to determine single uplift pressures. These results were validated from wind experiments on a single-story test house constructed outdoors at a windy location in Colorado. Based on the tests, a model was developed for calculating the uplift pressure on a shingle for a specified wind condition. Laboratory testing conducted on shingle specimens prepared to simulate in field application practices can be conducted to determine whether the shingle has adequate resistance to withstand the predicted uplift pressure. At present, the necessary test method is under development by ASTM Technical Committee D 08 on Roofing, Waterproofing, and Bituminous Materials.

7. Session on In-Service Performance

Technion, the Israel Institute of Technology, has been measuring the properties of membrane samples—PVC, EPDM, and polymer modified bitumens—collected from all parts of Israel [31]. The performance of the roofs, having ages ranging from 4 years to 12 years, were well documented. In general, it was found that the membranes maintained much of their original properties over the exposure periods.

In the early 1980s, the U.S. Army Corps of Engineers initiated studies to evaluate new roofing systems for installation on Army facilities as alternatives to the conventional bituminous roofing systems commonly used at the time [33]. One system evaluated was PVC. In that study, experimental roofs having PVC membranes from three suppliers were installed at three Army facilities. For 10 years, samples were obtained periodically and subjected to laboratory testing. Also, annual visual inspections of the roofs were conducted. It was found that most test results could not distinguish between the comparative performances observed at the different locations. Only in the case of thickness and tear strength measurements were significant property changes found for the better performing roofs. It was concluded that further work needs to be conducted to determine whether the two tests may be used as performance indicators for PVC membranes.

For about 30 years, sprayed polyurethane foam (SPF) roof systems have been used in the United States. These roofs offer significant benefits for energy conservation due to the high thermal resistance of the polyurethane foam and lack of joints and mechanical fasteners. To further the understanding of the performance of these systems, a field study was undertaken [34]. One hundred and forty roofs were inspected from different climatic regions and samples were obtained for laboratory testing. The ages of the roofs ranged from 0.5 years to 27 years. In general, it was found that the measured properties of the samples were acceptable. Design guidelines were recommended for enhancing SPF performance including a need to provide better drainage.

8. Session on Moisture Detection and Insulation

Moisture in low-slope roof systems can have detrimental consequences including accelerating the deterioration of material components and reducing the energy efficiency of the system. Roofs must be kept dry and, when moisture accumulates, its presence and source must be recognized early. When leaks are the source, the locations need to be identified so that repairs can be made. Two papers [47,49] discussed techniques for detecting moisture in low-slope roof systems. The first [47] reviewed a method known as the electrical earth leakage technique, which is in practice in the United Kingdom, but not in the United States. Using the method, an electrical potential difference is set up between a wet roof surface and a grounded roof deck. If leaks are present, a small electric current flows across the roof surface and through the membrane leak to the grounded deck. Using two probes connected to an ammeter, the direction of the current is identified; by moving the probes, the location of the leak is identified. The author provided rooftop examples of using this technique, and discussed its advantages and limitations.

The second paper [49] described two experimental techniques, designated the metallic time-domain reflector (MTDR) method and the passive resonance roof moisture detector (PRMD) method, that have been developed for detecting the presence of moisture in a low-slope roof system. The MTDR method is based on generating an electromagnetic pulse that propagates along a sensing cable that is set within the membrane roof system and consists of two parallel conductors. A boundary between two media with different dielectric constants, such as dry and wet materials surrounding the cable, causes a portion of the propagating pulse energy to be reflected back to the source. The remaining portion continues along the cable encountering other boundaries, if present, or reflecting at the end of the cable to the source. Knowing the nature of the dielectric media through which the pulse travels and the travel time allows calculation of the distance from the source to each of the boundaries encountered. The PRMD method is based on incorporating individual sensors in the membrane roof system. These sensors are comprised of two passive electronic components, a capacitor (C) and an inductor (L), assembled to form a parallel LC circuit. If the inductor is initially fully charged from an external electromagnetic source of energy and the capacitor is uncharged, the inductor will discharge inducing a potential to exist across the capacitor causing it to become charged. Once complete, the process reverses itself and is periodic, oscillating from one energy storage state to the other at a resonance frequency until “circuit” (e.g., heat) losses dissipate the energy. Sensors located in dry regions of the roof resonate at a different frequency than those in wet regions. Accessory equipment is used for energizing the circuit in the roof, and detecting the resulting oscillations. Both methods have been demonstrated to be feasible in the laboratory. The authors concluded that the MTDR method is ready for refinement using rooftop experiments, whereas the PRMD method needs further laboratory development.

A third paper [48] addressed an issue associated with the deterioration of roof system materials in the presence of moisture; namely, the freeze-thaw cycling of insulations. In this study, insulations commonly used in low-slope roofing practice were subjected up to 948 cycles of freezing in air and thawing in water. The moisture contents, and the effect of the moisture on thermal resistance, were quantified. Most insulations became very wet, and lost much of their insulating ability; some were extensively damaged.

9. Session on Modeling of Moisture Control

Recent studies have resulted in the emergence of analytical models for predicting the transfer of moisture in roof systems. Two papers [53,54] in this session were based on roofing applications of the model, *MOIST*, which had been primarily developed at NIST. *MOIST* predicts both heat and moisture transfer in building cavities such as roofs, attics, and cathedral ceilings. In the first paper [53], the model was used to simulate the performance of a roof of a double-wide manufactured house constructed in accordance with the standards promulgated for manufactured-housing by the U.S. Department of Housing and Urban Development (HUD). Parametric studies examined practices that deviated from those recommended. Among the findings, the analysis showed that airflow from the house into the roof cavity, as opposed to water-vapor diffusion, was the dominant moisture transfer mechanism into the roof cavity during the winter. The analysis predicted that the rate of mechanical roof cavity ventilation, as specified in the HUD standards, is too small for removing moisture during the winter, and needs to be increased.

In the second paper [54], *MOIST* was applied to the analysis of 15 open attic and cathedral ceiling designs that the U.S. Department of Energy (DoE) had suggested as suitable for minimizing moisture problems in such roof constructions. The *MOIST* analysis focused on predicting the peak values of the moisture content of the plywood roof sheathing and the relative humidity at the bottom of the insulation adjacent to the ceiling. Parametric studies investigated practices that differed from the DoE practices. Among the findings, the analyses showed that the moisture contents of the wood sheathing for the 15 DoE suggested constructions were within allowable limits. However, some of the parametric studies, for example, with closed attic vents, revealed cases where moisture accumulation could be problematic.

The third paper [55] reported the results of a Danish investigation on the performance of unventilated tile roofing systems that have come into common practice in Denmark. In such systems, the use of underlayments to control moisture transfer is important. The investigation focused on the performance of the underlayments, and their effects on winter time moisture accumulation in the roof system. Laboratory and full-scale field testing were complemented by computer simulations on moisture flow. These simulations were performed using a program named *MATCH*. From the results of the investigation, a number of design guidelines for use of unventilated tile roofing systems in Denmark were drawn.

10. Summary

The Symposium was successful in a variety ways. The *Proceedings* provides a valuable reference document containing recommendations on improving roofing performance. Many papers addressed problems and concerns that the roofing industry has faced in recent years. Solutions for correcting or alleviating such problems were proposed. Other papers reviewed longstanding industry practices with emphasis on using the lessons learned to promote satisfactory performance. The participants listened attentively to the papers, as demonstrated by the number and depth of the questions asked of the authors after their presentations. This is important, because the individuals in attendance are those who will put the speakers' recommendations into practice.

The Symposium demonstrated that roofing technology continues to advance for the betterment of the industry—particularly in the use of computers to further the understanding of roof performance. This was evidenced in a number of papers such as those describing the use of databases on roof service lives and mathematical analyses of system specific issues such as moisture migration. The hope is that these papers will serve as examples for many more such papers to come in future years.

13. Dedication

William Cullen's paper, "Hail Damage to Roofing: Assessment and Classification," [27] was published in the *Proceedings* but not presented by him due to illness. Subsequently, he passed away on November 5, 1997. Bill, as he was known to all, had an illustrious 50-year professional career dedicated to improving the performance of residential and commercial roofing. He joined the National Institute of Standards and Technology (then the National Bureau of Standards) in 1948 upon graduation from Canisius College, and retired in 1981. In his early years at NIST, he was a project leader on numerous studies on the development of test methods for characterizing and predicting the performance of roofing and waterproofing systems. In his later years, Bill served in administrative capacities in the Building Research Division, and the Center for Building Technology. From 1967 through 1972, he was Chief of the Materials Durability and Analysis Section. From 1973 through 1978, he served first as Acting Chief and then as Assistant Chief of the Structures, Materials, and Life Safety Division. From 1978 until his retirement, he was Deputy Director of the NIST Office of Engineering Standards. Among his notable accomplishments, in 1969, he co-founded with the National Roofing Contractors Association the NIST-NRCA Symposia on Roofing Technology—this Fourth International Symposium on Roofing Technology was the most recent in the series. After leaving NIST, Bill became a Research Associate for the National Roofing Contractors Association. He retired from that position in September 1997. During his 16 years with NRCA, he continued to work tirelessly for the success of the Roofing Technology Symposia.

This overview of the Fourth International Symposium on Roofing Technology is dedicated to William Cullen. The Roofing Technology Symposia series is his legacy to the roofing industry. He will be missed.

12. Bibliography of Symposium Papers

Session 1A—Single-Layer Roofing

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[2] Beer, H., Longevity and Ecology of Polyolefin Roof Membranes.
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Session 1B—Service Life Evaluation

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Session 2A—Technology Review I

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[10] Portfolio, D., and Dutton, E., The Future of Roof Coatings.
[11] Litow, E., Practical Experiences in Design, Application and Field Performance.

Session 2B—Asphalt Shingles

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Session 3A—Low-Slope Roof System Performance

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Session 3B—Metal Roofing

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Session 4A—Wind Engineering

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[22] Baskaran, A., and Lei, W., A New Facility for the Dynamic Wind Performance Evaluation of Roofing Systems
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Session 4B—Practice and Design I

[24] Jerga, L., Re-covers: Reroofing by Superimposing New Roof Systems Over Existing—A Dissenting Opinion.
[25] Sommerstein, M., The National Archives Building Roof in Gatineau, Quebec, Canada.
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Session 7A—Modified Bitumen I

[41] Oba, K., and Part, M., Performance of Mechanically Fastened Polymer Modified Bitumen Roof Membrane Seams Subjected to Wind Uplift.
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Session 7B—Moisture Control

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[51] Bruder, A., and Boivin, M., Extensive Green Roofs/La Toiture Avec Vegetalisation Extensive.
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Session 9A—Modeling of Moisture Control

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