COMPATIBILITY OF ROOFING INSULATIONS AND MEMBRANES

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As roofs continue to fail, in spite of dramatic changes and improvements in materials and technology, it becomes apparent much further work is required to identify and rectify problem areas. Certainly, the most basic requirement for successful roof performance would be compatibility of the two major components of a roofing system, the insulation and the membrane; yet, surveys and analysis of continuing roof failures tend to point towards incompatibility of insulations and membranes as a major cause of roof failure. Recent examples of insulation/membrane compatibility problems have surfaced in two NRCA/MRCA Research Reports, one dated August 1988 entitled "Application Effects of Hot Asphalt on Roof Insulation," and one dated October 1988 entitled "Results of Uplift and Crushing Resistance Tests of Polyisocyanurate and Phenolic Foam Roof Insulations when a Built-Up Roof was Directly Adhered Under Simulated Field Conditions."

C. W. Griffin wrote in his book entitled *Manual of Built-Up Roof Systems*, 2nd Edition, published by McGraw-Hill, 1982:

> *The characteristic problems of roof system designs are a combination of incompatible materials rather than isolated failures of single components. Two or more components may satisfy their individual material requirements to perfection and yet, in combination, fail disastrously. The art of roof system design has lagged far behind the introduction of new materials. Because of this lag, some new materials have left a wake of litigation pressed by building owners plagued by failed roofs.*

Alain Chaize from the Center for Building Science and Technology, Paris, France, wrote in his paper titled "Behavior of Thermal Insulations Used as Substrates for Roofing Membranes," presented at the Symposium on Roofing Technology at the National Bureau of Standards, September 1977, the following:

> *These problems have arisen primarily from the lack of knowledge about insulating materials used and their potential for being used in conjunction with a waterproof covering.*

His paper went on to study the movements of the insulations, which served as a base for an independent waterproofing. Based on this single element of insulation/membrane compatibility, he was able to demonstrate the potential for failure of the waterproof covering. His paper concluded with the statement:

> *On the practical level, this means that a thorough evaluation can only proceed from a collaboration between manufacturers of insulation, manufacturers of waterproof coatings, applicators, and project managers; that is, all those participating in the building activity.*

Clearly, the primary collaboration must be between the manufacturers of the roofing insulation and the waterproof membrane.

Over the last decade there have been many papers similar to that published by Chaize reporting on insulation/membrane incompatibility problems that have led to roof failures. As late as May 1988 an article appeared in *Professional Roofing* titled "Is High R-Value Insulation Ruining Our Roofs?" It seems incredible that we lack answers to questions such as this in this most litigious area of the construction industry.

One of the most comprehensive papers revealing an approach towards responsible roof design was presented by B. J. Williams titled "Design of Integrated Roofing Systems," presented at the 8th Conference on Roofing Technology, April 1987 at the National Institute of Standards and Technology (formerly National Bureau of Standards). Williams identified the loads and stresses imposed upon the various components of a roofing system. The most important contribution of the paper relates to its directing the industry towards a systems approach to designing roofs as opposed to the arbitrary selection of independent components that may or may not be compatible.

In response to the concerns raised in these and other papers on roof system performance, this paper was developed to identify some of the areas where roofing insulation and membrane compatibility are essential, and to explore the extent of testing and knowledge available from American manufacturers. This paper will also explore a new concern in the roofing industry: dealing with the delamination of facers from the surface of the insulation boards.

SYSTEMS COMPATIBILITY

In his book, Griffin recognized the different compatibility requirements for the roofing insulation and the membrane depending on the type of roofing system being employed. Various single-ply membranes can also be utilized in these same roofing systems, and I have attempted to expand Griffin's work to include these additional compatibility requirements.

In a protected membrane roof, an insulation loose laid over the roofing membrane transfers relatively little stress into the membrane that would affect membrane performance. There are some chemical incompatibility problems between a polyvinyl chloride membrane and polystyrene insulation, requiring the use of a separator sheet, and a separator sheet is recommended with built-up roofing to prevent bonding effected between the insulation and other types of roofing membranes. To maintain thermal efficiency in the protected membrane roof, the insulation must be moisture resistant since it is placed above the membrane, thereby substantially reducing the types of insulating materials that can be employed to high-density polystyrenes.

In the loose-laid roofing system, the insulation again exerts only minimal influence on the roofing membrane. Both insulation and membrane are free to move independently,

and the membrane is held in place by the weight of the ballast. Chemical incompatibility between insulation and membrane may be somewhat more pronounced than in a protected membrane roof, due to the effect certain bituminous binders in some insulations or insulation facers may have upon some single-ply membranes, in addition to the well established PVC/polystyrene incompatibility. Another desirable attribute for an insulation in a loose-laid roofing system would be compressive strength sufficient to reduce the chance of puncture of the membrane when subject to roof traffic. Unfortunately, no one has yet suggested what the optimal compressive strength of the insulation should be for the best performance beneath the various membranes. Because of their toughness, some membranes may be able to better tolerate lower density insulations, but to my knowledge no research has been done in this area.

The partially-attached or mechanically fastened roofing system places additional requirements on insulation/membrane compatibility. In addition to chemical compatibility and adequate compressive strength, we now add the following important attributes:

- **Compatibility with mechanical fastener** The National Roofing Contractors Association has received reports that certain roof insulations may accelerate corrosion of mechanical fasteners and, in some cases, of the steel decks themselves.
- **Dimensional stability under thermal and moisture changes** A buckling, cupping or shrinkage of the insulation may very likely transfer stress to the roofing membrane, even though the insulation is mechanically attached to the deck through a base sheet.
- **Resistant to deterioration from moisture absorption** In flat roofing, moisture is bound to find its way into the insulation at some point. If not through an infraction in the roofing membrane, it will find its way into the insulation during the cold cycle, when moisture vapor drives are outward and the dewpoint is situated beneath the roofing membrane at some point in the insulation. If the insulation deteriorates when it becomes moist, it could then affect the performance of the roofing system. A collapsing of the insulation would render the membrane more susceptible to puncture at mechanical fasteners and would seriously affect the wind resistance of the roofing system. In a loose-laid roofing system, moisture in the insulation would affect insulation performance but would have little effect on membrane performance because the membrane is held in place by loose ballast.

By far the greatest problems with insulation/membrane compatibility occur in the total adhered roofing system. When the insulation is adhered to the structural deck and the membrane is adhered to the insulation, these two primary components of the roofing system must act as one with total compatibility. C. W. Griffin enumerated the following design factors for an insulation to be used in what he termed a "conventional sandwich-style roof assembly."

- Compressive strength.
- Cohesive strength to resist delamination under wind uplift.
- The horizontal shear strength to maintain dimensional stability of the roof membrane under tensile contraction stress.
- Resistance to damage from water absorption.
- Dimensional stability under thermal changes and moisture absorption.
- A surface absorbant enough to adhere the bituminous mopping, but not so absorbant that it soaks up the bitumen.

In addition to Griffin's design factors, I would again add chemical compatibility. This is important, not only in built-up roofing applications where the mopping of asphalt must be compatible with the insulation or the insulation facer, but more particularly in single-ply roofing where there is a risk of adhesive incompatibility with insulations or insulation facers.

Another area of major concern being raised by the contracting segment of the roofing industry when applying totally adhered roofing systems relates to growing reports of problems with insulation facer delamination. When this occurs in a totally adhered roof system, the results can be disastrous. Separation of the membrane from the insulation or separation of the facer from the insulation subjects the membrane to differential loads and stresses and can lead to wind blow-off. The roofing membrane adhesive and the insulation itself may have sufficient structural integrity to remain bonded through thermal cycling and wind fluctuations, but this is of little help if the bond between the facer and the insulation is not equal or better than the cohesive strength of the insulation or that of the membrane adhesive to the facer. Facers are adhered to insulations using various adhesives depending on the type of insulation being employed, and in the case with polyisocyanurate and polyurethane insulations, the material is foamed between the facer sheets, thereby relying on the structural integrity and adhesive qualities of the foam to bond the two together.

Since insulation facer delamination is becoming a subject of increasing concern among roofing contractors (witness the NRCA/MRCA October 1988 Research Report), I attempted to research what work had been done by manufacturers to study the performance attributes of insulation facers and facer adhesives used with the various roofing membranes and membrane adhesives employed in totally adhered roofing systems. I was also interested in the effect of moisture on the bond between the insulation and the insulation facer. As a result of my review of manufacturers' literature and technical papers, I was unable to locate any significant work in this area of roof insulation/membrane compatibility.

In order to gain additional information and insights on the problem of roof insulation/membrane compatibility in general, and roof insulation facer delamination in particular, I conducted a survey in June 1988 of major roofing membrane and roofing insulation manufacturers, all of whom were listed in the *NRCA Roofing Materials Guide.*

THE SURVEY

A letter was sent to the attention of the technical director of the various manufacturers, advising them that I was preparing this paper on insulation/membrane compatibility for the 9th Conference on Roofing Technology. The letter requested that they respond to an attached survey for each generic material they produced and that they report on the test procedures contained in the survey or alternate test procedures should they not have conducted the ones included in the survey. The most revealing survey results involved information that *was not* received rather than information that *was* received.

Seventy-four letters and surveys were sent to roofing membrane manufacturers. Twenty responses were received (27 percent) from roofing membrane manufacturers represent-

ing 33 generic products. All commercially available roofing membranes, single-ply and BUR, were represented in the responses received.

The first section of the roofing membrane survey dealt with questions pertaining to the physical properties of the roofing membrane. Of the 33 products produced by the 20 manufacturers, the following results were revealed in response to survey questions:

- **Puncture resistance of membrane**—67 percent provided no response to my request for information.
- **Elongation**—18 percent, no response.
- **Tensile strength**—12 percent, no response.
- **Moisture permeability**—33 percent, no response.
- **Dimensional stability**—45 percent, no response.
- **Effect of moisture on membrane**—3 percent, no response, with 78 percent reporting that moisture had no effect on the membrane they produced.
- **Chemicals that may adversely effect membrane performance**—100 percent response, indicating various chemicals and materials that could affect membrane performance.
- **Insulations that may be incompatible with the membrane**—63 percent reported that they were unaware of any insulation incompatibility.

The second part of the questionnaire dealt with membranes that were totally or partially adhered to insulation. Of the 33 responses, 16 (48 percent) reported that they could be used in this type of roofing system. Of those responding to this portion of the questionnaire, the following responses were provided to the survey questions:

- **Moisture permeability of cured adhesive used to attach to insulation**—87 percent provided no response.
- **Effect of moisture on cured adhesive**—75 percent reported no effect.
- **Peel strength of adhesive**—56 percent, no response.
- **Sheer strength of adhesive**—56 percent, no response.
- **Solvents or other adhesives that may be incompatible with this adhesive**—31 percent, no response.

While those that did respond with information to the survey questions provided valuable data that will help in the determining of compatibility between membranes and insulations for totally adhered and partially attached roofing systems, the greatest revelation was the number of manufacturers that did not have sufficient information to respond. How can a manufacturer recommend an insulation for use with its membrane unless it knows the puncture resistance of the product it produces in order to be able to recommend the insulations with compatible compressive strengths? In addition, certain insulations experience dimensional change when subject to temperature and humidity variations; knowledge of the membrane's elongation and tensile strength is required if compatibility is to be achieved. Further, how can a membrane manufacturer be assured that its adhesive will hold its product on the insulation for the long term unless it is aware of the effect of moisture on the cured adhesive? Moisture is bound to occur on the underside of the membrane, due to the moisture vapor drive and the location of the dewpoint beneath the membrane at different points at different times through temperature cycles.

The survey of roofing insulation manufacturers was sent to 35 companies, of which 11 responded (31 percent), representing 19 products, which included all generic roof insulation materials with the exception of foam glass. The roofing insulation survey was also broken down into two parts. The first part dealt with the physical properties of the insulating material itself and the second part dealt with only those insulations containing laminated facer sheets. Of the 19 insulating product responses received, the following information was reported relating to the first part of the survey:

- **Compressive strength**—26 percent provided no response.
- **Dimensional stability**—32 percent, no response.
- **Moisture vapor permeability**—37 percent, no response.
- **Effect of moisture on insulation**—37 percent, no response.
- **Generic roofing membranes that may be incompatible with insulation**—53 percent, no response.

The second part of the insulation questionnaire was addressed to those manufacturers that produced an insulating material with a laminated facer. Of the 19 responses received on insulating products, eight included facers (42 percent). The lack of information received from those responding to the second part of the questionnaire was substantial:

- **Moisture vapor permeability of facer**—there was no response from any of those surveyed.
- **The effect of moisture on facer**—62 percent, no response.
- **Peel strength of facer adhesive**—100 percent, no response.
- **Sheer strength of facer adhesive**—100 percent, no response.
- **Moisture vapor permeability of cured facer adhesive**—100 percent, no response.
- **Effect of moisture on cured adhesive**—88 percent, no response.

The insulation manufacturers that did respond with data and had done their testing are in a far stronger position to determine the compatibility of their product with various roofing membranes. Those manufacturers that did not have the information requested would have great difficulty demonstrating the compatibility of their insulations with the various generic roofing membranes. Without knowing the compressive strength of the insulations, it would be impossible to determine whether or not a membrane with a particular puncture resistance would be acceptable for use with the product. The dimensional stability of the insulation is another extremely important criteria when selecting among the various single-ply and built-up roofing membranes exhibiting wide elongation capabilities. Moisture vapor permeability is extremely important when determining whether or not a vapor retarder must be employed in certain climatic zones in order to minimize the effect of moisture vapor condensation within the insulation at the dewpoint. In colder regions, vapor retarders are desirable under all insulations to prevent condensation on the underside of the membrane at insulation joints. Recognizing that some moisture will be present in all insulations in a low-sloped roof, it is important to know what effect the moisture will have on insulation performance. Will it remain dimensionally stable, or will moisture combined with temperature changes cause dimensional changes within the insulating product that could affect certain types of roofing membranes installed over it?

When facers are applied over the insulation it is most important to know the effect of moisture on the facer. Will it cause the facer to lose adhesion from the insulation? The peel strength and shear strength of the bond between the facer and the insulation is extremely important when considering the wind uplift requirements of the roofing system. The effect of moisture on the facer bond to the insulation

is important information when considering the long-term performance of a roofing system.

CONCLUSION

As a result of renewed concerns over insulation/membrane compatibility expressed by the roofing contracting segment of the industry, combined with a lack of testing and information available from various manufacturers of these two critical components, it is my opinion that considerable additional research is required on the part of membrane and insulation manufacturers and the roofing industry in general to determine compatibility of materials. Furthermore, manufacturers should all begin marketing roofing systems including membrane and insulations rather than separate components. They must be willing to warrant the performance of their respective products as compatible elements that will produce the results desired: a roofing system capable of withstanding water infiltration and wind blow-off, and of insulating the structure for a defined period of time. Fortunately, some forward-looking manufacturers are marketing roofing systems in this manner at this time, and they should be encouraged with industry support. However, I was appalled at the lack of information received from many major roofing membrane and insulation manufacturers. It is also incumbent upon the contracting portion of the industry to conduct further tests of roofing components to assure their compatibility. The most comprehensive study of any insulation used in roofing was conducted by the Midwest Roofing Contractors Association, the National Roofing Contractors Association and The Society of the Plastics Industry on expanded polystyrene in the "Report on Expanded Polystyrene Insulation for Use in Built-Up and Single-Ply Roofing Systems," prepared by Structural Research, Inc., published August 1984. This study has dramatically enhanced the use of expanded polystyrene in roofing systems and reduced the concerns with incompatibility for manufacturer, designer and contractor. It would be of enormous benefit to the roofing industry to see similar reports prepared on the performance characteristics of other insulations utilized in low-slope roofing systems. These reports may cost hundreds of thousands of dollars, but they could save the industry millions of dollars in the cost of litigation and the cost of reroofing projects with shortened life cycles because incompatible materials were employed.

REFERENCES

[1] Griffin, C.W., *The Manual of Built-Up Roof Systems*, 2nd Edition, McGraw-Hill, 1982.

[2] Chaize, A., "Behavior of Thermal Insulations Used as Substrates for Roofing Membranes," presented at Symposium on Roofing Technology, September 1977.

[3] Williams, B.J., "Design of Integrated Roofing Systems," *Proceedings of the 8th Conference on Roofing Technology*, NRCA, April 1987.

[4] Busching, H.W., and Porcher, J.P. Jr., "Thermal Loading of Bituminous Built-Up Roofing Membranes," *Proceedings of the 6th Conference on Roofing Technology*, May 1981.

[5] Hedlin, C., "Some Design Characteristics of Insulation in Flat Roofs Related to Temperature and Moisture," *Proceedings of the 5th Conference on Roofing Technology*, NRCA, April 1979.

[6] McCorkle, J.E., Dupuis, R.N. and LaCosse, R.A., "Membrane Integrity Depends on Characteristics of the Entire Roof Assembly," *Proceedings of the 6th Conference on Roofing Technology*, NRCA, May 1981.

[7] Busching, H.W., "Effects of Moisture and Temperature on Roofing Membranes in Thermally Efficient Roofing Systems," *Proceedings of the 5th Conference on Roofing Technology*, NRCA, April 1979.

[8] Brotherson, D., "Performance Characteristics of Roof Insulation," *Proceedings of the 5th Conference on Roofing Technology*, NRCA, April 1979.

[9] Paulsen, E.M., "Perforation Resistance of Polymeric Roofing Sheets."

[10] Gumpertz, W.H., "Properties and Performance of Polystyrene Insulation," presented at National Bureau of Standards Conference on Thermally Efficient Roofing Systems, May 4, 1978.