New Focus for Using Two Layers of Insulation in Single-Ply Roof Systems

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ABSTRACT

The remarkable gain in market share for single-ply membranes has been due, in part, to the recover configuration in which the products found wide use. A single layer of recover board insulation was commonly used for such a retrofit. Many recent new construction projects used single-ply membranes and only one layer of insulation. The recognized practice of two layers of insulation (which is common in new construction built-up roofing) somehow fell by the wayside when consideration turned to single-ply roofs. Although the origin of the practice is unimportant, the result has occasionally been unsatisfactory. This paper will explore several scenarios that produce an unwanted outcome when only one layer of insulation is coupled with a single-ply roof membrane.

INTRODUCTION

More than a decade ago, a good argument was put forth for using two layers of roof insulation in built-up roof assemblies. On metal decks, a base layer was typically fastened and topped by a second layer, solidly mopped in hot asphalt. This arrangement brought a reduction in thermal bridging (unwanted heat loss) by two mechanisms:

1. conductive, metallic screw fasteners were now insulated by the top layer, and
2. energy loss was reduced by offsetting the board joints among the two layers.

One study concluded that when using two layers of insulation, with the top layer covering the metallic fastening devices of the lower layer, the effect of the metal fastener on overall thermal resistance was reduced by a factor of three (Burch 1987).

Observations of water beneath single-ply membranes has often prompted theories about membrane perm ratings, moisture vapor drives, why the vapor retarder was omitted, lap-splice quality, original material storage practices, prevailing weather during construction, membrane pinholing, and a number of other possible explanations. This paper deals with the susceptibility to moisture gain within a compact roof assembly caused by using only one layer of insulation together with a single-ply roof membrane.

OPEN BOARD JOINTS FROM CARELESS INSTALLATION

Project specifications commonly mandate effort, on the part of the installer, to keep insulation materials dry. Material storage techniques may be dictated, overnight water cutoffs may be specified, and third-party assistance may be implemented to verify the use of dry materials. But, in certain instances, wet insulation may result after the fact if board joints are not kept tight during placement (Figures 1 and 2).

Warm, moisture-laden air rising through the assembly will condense (in the absence of effective ventilation) on a surface at or below the dew point. Two layers of insulation combining to provide the desired thermal performance (R-value) would reduce this susceptibility, providing joints are offset among the layers.

OPEN BOARD JOINTS FROM DIMENSIONAL SHRINKAGE

Condensation of free water within the compact roof assembly is possible from board joints that later open from dimensional reduction (shrinkage of insulation board units, Figure 3). This occurrence is characterized by generally uniform joint openings. Figure 4 depicts such an occurrence in a recovered roof assembly. The former example was a single-layer configuration with free water mostly concentrated near board edges.

Commonly advertised values for dimensional stability found in vendors' literature are 2% maximum and occasionally less. When 4-foot by 8-foot boards are used, the long dimension of one board may be reduced by 1.92 inches and still comply with the 2% limit. With similar behavior in the short dimension, the original 32 square feet are then covered by only 30.73 square feet of insulation, a reduction of 4% of the area. Clearly, a two-layer insulation assembly would reduce energy loss and attendant susceptibility for moisture gain.

MEMBRANE PUNCTURES FROM FASTENER BACK-OUT

Fully adhered single-ply membranes and lap-attached and plate-bonded configurations are vulnerable to puncture by the screw fastener from a number of events. Additionally, insulation may consolidate (Figure 5) due to improper factory cure or from the abuse of repeated traffic patterns. Either of these occurrences may leave threaded deck screws high in comparison to the adjacent insulation surface. The risk of puncturing single-ply polymeric membranes is then apparent (Figure 6).

It is desirable to develop some axial preload during the tooling of insulation and membrane fasteners; however, the initial load introduced is known to decay with time at a rate

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Figure 1

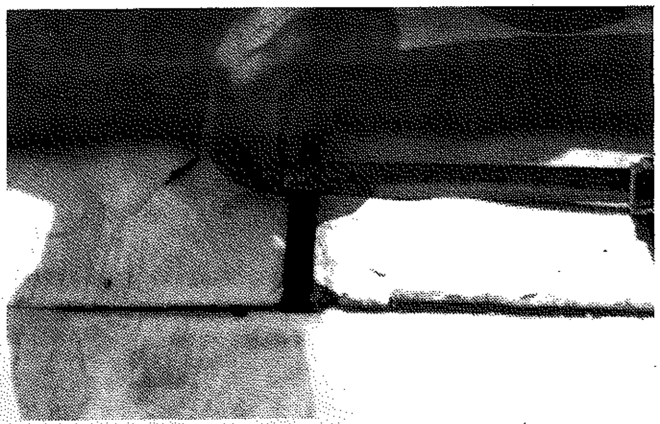

Figure 2

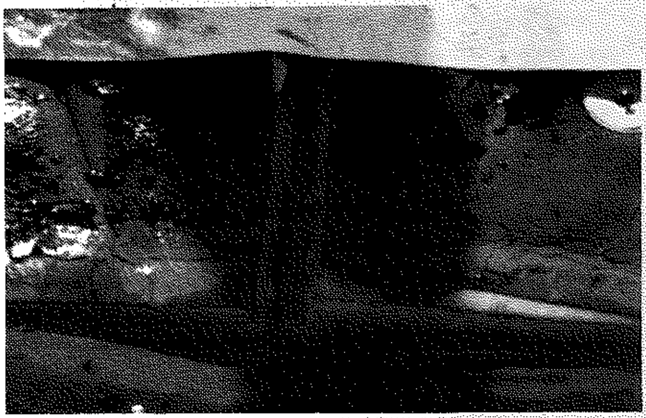

Figure 3

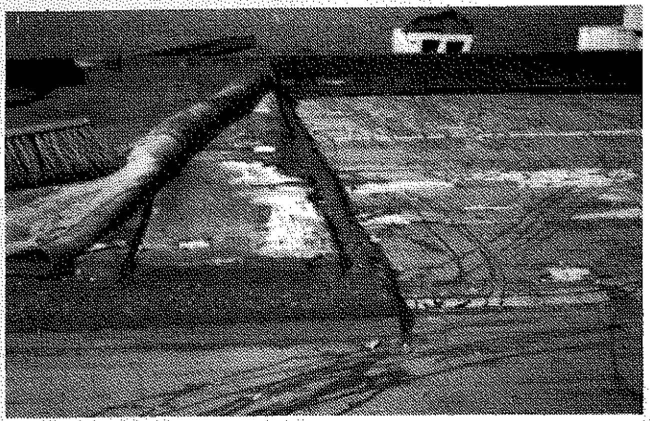

Figure 4

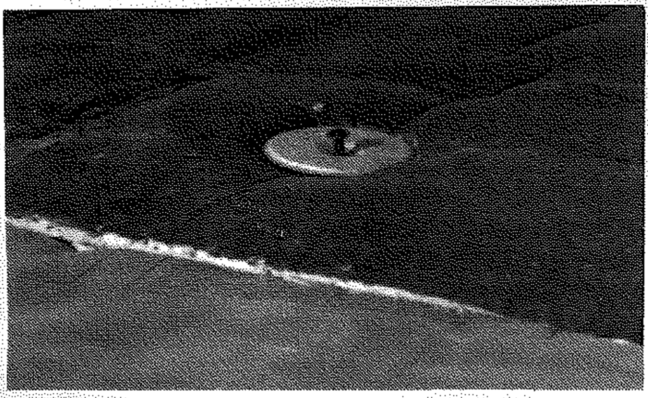

Figure 5

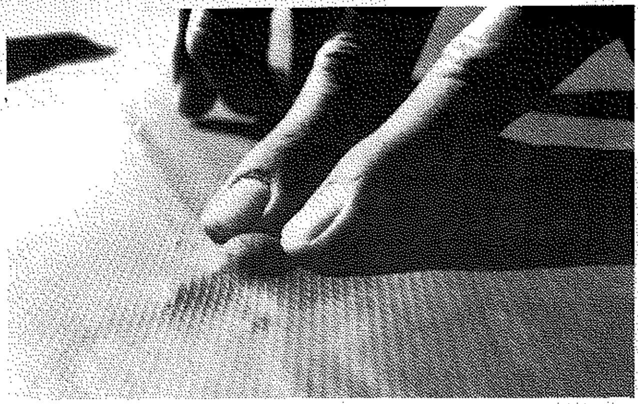

Figure 6

varying among insulation types. A study of fasteners through expanded bead polystyrene (Dupuis and Dees 1984) quantified a relaxation of compressive force of 10% to 20% of the initial load.

Fully adhered membrane systems could readily make use of two layers of insulation. The lower layer could make use of material of lesser density having the thermal properties required. The upper layer could utilize a board type more durable in a repeated traffic environment. The new aspect of this practice would be to develop functional and cost-effective adhesives to achieve a bond between the two layers. The practice would resemble that of somewhat antiquated mop and flop techniques, which used hot bitumen as adhesive. Similarly, lap-attached configurations could employ comparatively less expensive (per unit R) insulation boards below a more structurally significant top layer given to less relaxation of axial loads in fastening devices.

Loosely laid, ballasted roofs share the benefits of two layers. Ballast-dispensing equipment traffic may introduce sharply reduced thicknesses of several insulation types (MRCA, NRCA 1989).

A layer of wood fiberboard or perlite insulation above thermoplastic foams virtually eliminates damage from hot air welding devices and accidental spillage of solvent-borne adhesives at laps. Fiberboard also permits a fully adhered membrane to make use of polystyrene, which is otherwise compromised by direct application of conventional bonding adhesives (Malpezzi 1991).

Another opportunity to exploit the benefit of two-layer insulation construction is the use of perlite or gypsum board *beneath* polystyrene on metal decks. The combustible polystyrene can then be configured into a fire-resistant assembly that has greater overall thermal efficiency than the same total R-value in a single insulation layer, owing to offset board joints.

SUMMARY COMMENTS

This paper centers on substandard roof performance from unwanted (and undetected) moisture gain within the compact roof profile. Corrosive substances may develop from organic elements contained in the assembly (Baxter 1986). These substances (known as electrolytes) produce deterioration of decks and fastening devices. Electrolyte strength varies among insulation types. Some insulations, once wetted, have exhibited aggressive corrosion over galvanized metal decks (Canon 1991).

Fastener failures sharply compromise wind resistance of fully adhered and intermittently attached systems. Identifying responsible parties in the aftermath of premature roof failure is arduous at best. One component's behavior depends so heavily on satisfactory performance of the others that single-component blame can rarely be conclusively placed for purposes of remedy. Convoluted roof litigations are a continuing example of this debacle.

CONCLUSIONS

A challenge should be issued to several players in the roofing industry.

- *Owners* should be willing to fund for roof assemblies consisting of two layers when the project-specific psychrometrics indicate such a need.
- *Insulation manufacturers* should not ship material that has not been cured to stable dimensions.
- *Insulation manufacturers* should participate in the testing and development of inter-layer adhesives that permit fully adhered membranes on multiple-layer insulation profiles, only the bottom layer of which has been mechanically fastened on nailable decks.
- *Installers* should be willing to tender competitive proposals stipulating the two-layer profile and stating advantages thereof.
- *Installers* should insist on certification of engineering properties with shipments of insulation received.
- *Researchers* should investigate any corollaries that relate dimensional stability to properties such as density, compressive strength, load-strain modulus, etc.
- *Researchers* should investigate axial load relaxation of fasteners as a function of insulation type. Rate of decay curves could then be developed for specific insulations. Desired performance could be obtained by combining certain types.
- *Designers* of controlled environments (i.e., coolers, freezers, and high-humidity manufacturing processes) should make use of two or more layers of insulation. Sizing insulations and mechanical components in any assembly assumes continuity of the strata being analyzed. Roofs of these environments may be rapidly affected by designs that do not recognize and compensate for energy losses at board joints.

Failure of roof systems stemming from events *within* the compact assembly does not permit fair evaluation of membrane weathering characteristics. Perhaps the foregoing efforts will combine to lengthen the serviceable life expectancy of modern single-ply roof membranes.

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