LABORATORY TESTING OF ROOFING SYSTEMS UNDER FIELD CONDITIONS

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The need for performance testing of roof membranes is now well recognized, but the industry still lacks generally recognized test procedures that accurately measure and predict performance (1, 2).

Most performance investigations to date have concentrated on laboratory testing, as opposed to field testing, because of the relative ease of controlling variables in the laboratory. The laboratory has its limitations, however, and the authors have had better success predicting some aspects of field performance by moving the study into the field.

The laboratory-in-the-field procedure involves the application of two or more variations of the system under evaluation to the **same** roof. It thus provides side-by-side comparisons under generally identical conditions of exposure.

In the lab, one routinely makes side-by-side comparisons of roof components such as glass, organic, and asbestos membranes. Similarly, comparisons are frequently made of several different insulations such as fiber glass, perlite, and polyurethane.

In the field, we evaluate a roof's performance each time we inspect a roof. These field evaluations are inadequate, however, because we lack a basis for comparison. Most roofs use only one type of membrane, one type of insulation, and so on. The problem is the same when we try to compare performance of one roof with performance of another roof.

VARIABLE	DIFFERENT TYPES	NUMBER
Roof Deck	Metal, Wood, Concrete	3
Insulation	Perlite, Fiber Glass, Urethane	3
Fastener	Adhesive, Mechanical	2
Insulation C Value	.20, .10, .05	3
Membrane Type	Glass, Organic, Asbestos	3
Interply Adhesive	Type II, Type III, Cold	3
Surfacing	Gravel, Aluminum, Emulsion	3
Location	North, South	2

TABLE I
Roof Construction Variables

Many roof systems are unique.

The mathematically possible component combinations shown in Table I make it possible to inspect thousands of roof systems without seeing two identical systems.

The above eight roof system variables yield 2916 possible combinations, and the number multiples if we include other parameters—e.g., building occupancy, specialty roof decks, unusual ponding conditions, and application variables.

This paper examines four commercial roofs where carefully planned comparisons of **different** materials on the **same** roof provided decisive performance evaluation through direct comparisons.

EXPERIMENT NO. 1

Objective: Develop an improved cold process roofing system that would not buckle after application to lightweight concrete (poured-in-place wet mix) decks.

Background: Lab and field studies had shown that cold-process, asphalt-coated organic felts absorbed 1-3% moisture when applied over wet mix decks. Moisture expansion caused the membranes to buckle.

Location: Pensacola, Florida

Roof Construction:

Deck—Lightweight Insulating Concrete, 8000 ft^2
Insulation—None
Membrane—Cold process felts (organic), asphalt-coated
Surfacing—Cold process mastic & granules

Procedure: The 8,000 sq. ft. roof was subdivided into 8 equal sections, as shown in Figure 1, with test applications as follows:

1. **Control 1**—Nailed base and 2 plies of coated felt in mastic.
2. **Control 2**—Same as 1, except for a different mastic supplier.
3. **Phase Application**—Same as 1, except for phased application of top two plies.
4. **Adhesive Attachment 1**—First ply attached to deck with mastic rather than mechanical fasteners.
5. **Adhesive Attachment 2**—Same as 4, except for packaging modification.
6. **Glass Base**—Nailed glass base sheet, two plies of coated felt (organic) in mastic.
7. **Polyethylene 1**—Same as 6, except for 6-mil polyethylene installed between deck and base sheet.

8. **Polyethylene 2**—Same as 1 (control), but with 6-mil polyethylene installed between deck and base sheet.

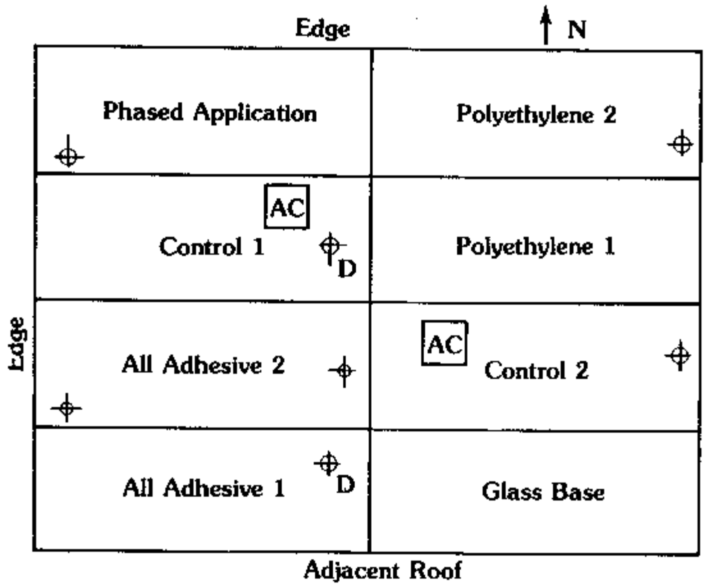

FIGURE 1

Results: Semi-annual inspections over a 2-year period yielded the following conclusions:

1. The two sections with 6-mil polyethylene showed the least moisture-induced buckling.
2. Mechanical fastening provides better anchorage to lightweight concrete decks than mastic.

Significance: Application specifications were drafted to require the installation of 6-mil polyethylene between the deck and the mechanically fastened base sheet.

EXPERIMENT NO. 2

Objective: Compare application characteristics and general weathering performance of glass versus organic cold-process systems over wet mix decks in southern U.S.

Background: Lab and field studies had shown that the use of 6-mil polyethylene sheet between a wet mix deck and a nailed base reduced buckling of the cold-process membrane, but further improvement was sought.

Glass cold-process systems were known to have good moisture-absorption resistance, but were difficult to apply without wrinkling during application.

Location: Pensacola, Florida

Roof Construction:

Deck—Lightweight insulating concrete—9,200 ft.^{2}

Insulation—None

Membrane—Asphalt-coated glass membranes in cold process mastic. Asphalt-saturated and coated organic membranes in cold process mastic.

Surfacing—Cold-process mastic and granules.

Procedure: The 9,200 sq. ft. roof was divided into 4 sections, as shown in Figure 2, with test applications as follows:

1. **Control**—Nailed base and two coated-felt plies in mastic over polyethylene vapor barrier.
2. **Glass Base**—Nailed glass base sheet and 2 coated-felt plies (organic) in mastic.
3. **Heavy Glass**—Nailed glass base and two plies of 20-lb. coated glass in mastic.
4. **Light Glass**—Nailed glass base and two plies of 10-lb. coated glass in mastic.

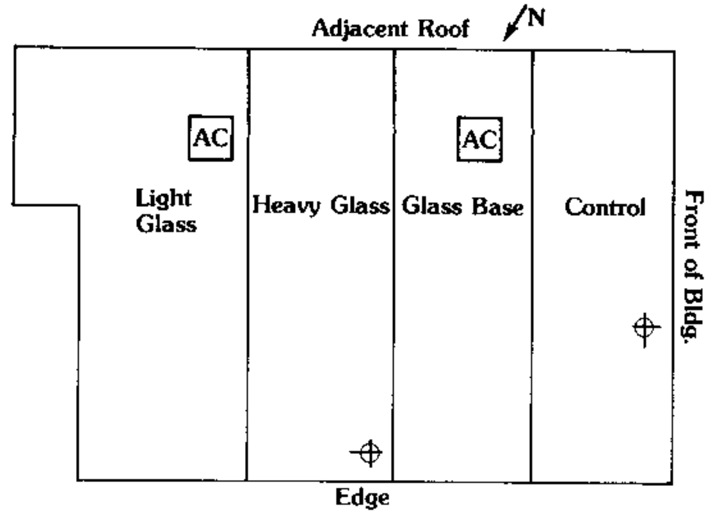

FIGURE 2

Results: After 2⅓ years, the section of roof with lightweight glass was in excellent condition, with a very smooth surface completely free of wrinkles or other distortions.

The section with heavyweight glass had slight wrinkling across the felts, which had occurred during application, but was unchanged since application.

The glass base/organic ply system showed slight-to-moderate buckling, mainly across the felt plies.

The control section (over polyethylene film) showed slight buckling in various directions.

Significance: An application specification was written permitting the use of the 3-ply, 20-lb. glass membrane over wet mix decks.

EXPERIMENT NO. 3

Objective: Compare weathering characteristics of hot-applied glass vs. organic BUR membranes.

Background: Since field surveys had indicated improved durability of glass shingles compared with organic felt shingles in southern U.S., we decided to test for similarly improved durability in hot-applied built-up roofing.

Location: Burnnell, Florida

Roof Construction:

Deck—Existing gravel-surfaced roof over wood deck.

Insulation—Wood fiber board.

Membrane—1. Asphalt saturated and coated organic felt.
2. Asphalt-saturated organic felt.
3. Heavyweight coated glass membrane. (20 lb.)
4. Lightweight coated glass membrane. (10 lb.)

Surfacing—1. Cold process mastic and granules.
2. Glass based mineral surface cap sheet.

Procedure: The old gravel-surfaced roof was power broomed and wood fiber insulating board was anchored to the deck with galvanized roofing nails. The various plying membranes were adhered with hot steep asphalt directly to the insulating board. The cap sheet was applied perpendicular to the plying felts. This allowed all plying felts to be partly covered with cap sheet, and the remainder was surfaced with cold process mastic and granules.

The 3,000 sq. ft. roof was divided into 4 sections and the various membranes installed in hot asphalt, as follows:

1. **Coated Felt**—Three plies of asphalt-saturated and coated organic felt.
2. **Saturated Felt**—Three plies of asphalt-saturated felt.
3. **Heavy Glass**—Three plies of asphalt-coated heavy glass membrane.
4. **Light Glass**—Three plies of asphalt-coated light glass membrane.

All sections were covered with both surfacing methods, thus providing 8 test variations, shown in Figure 3.

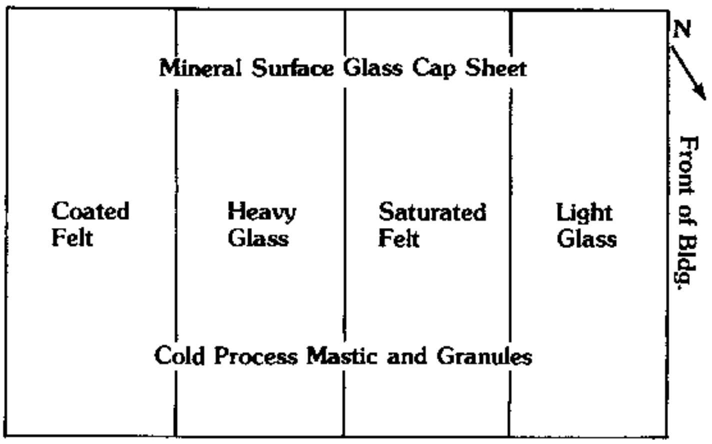

FIGURE 3

Results: Because of poor drainage, a large portion of each section was ponded to a depth of several inches for an estimated 50% of the time.

After 2 years, the two glass sections were in excellent condition. The mastic-surfaced portions of the organic felt sections showed moisture-induced deterioration: notably edge curling of the saturated felt section and blistering of the coated felt section. The cap sheet was unaffected by the ponding condition and provided good protection to the underlying felts.

Significance: Based on this field test, plus several other confirming tests, glass membranes have been introduced for marketing. Under the severe moisture conditions encountered on this roof, glass membranes are preferred over organic systems. Organic systems are, of course, functioning satisfactorily on millions of roofs. And ponding is not recommended on glass roofs.

EXPERIMENT NO. 4

Objective: Evaluate performance of urethane and perlite preformed roof insulations in a hot-applied roof system.

Background: This was one of a series of test roofs with polyurethane insulation made prior to entry into the commercial manufacture of this type insulation board.

Roof Construction:

Deck—Steel

Insulation—1. Perlite insulation, 1 and 2 in. thick.
2. Urethane/perlite insulation, 1¾ and 2½ in. thick.

Membrane—Asphalt-saturated and coated organic felt base sheet with three plies of asphalt-saturated organic felt installed in hot asphalt.

Surfacing—Gravel embedded in hot asphalt.

Procedure: The 13,500 sq. ft. roof was divided into 4 sections for application of several roof insulation combinations, as follows:

1. **Perlite Board A**—2 in. thick perlite insulation board adhered to deck with hot asphalt.
2. **Perlite Board B**—Two layers of 1-in. thick perlite insulation board adhered to deck and between layers with hot asphalt.
3. **Urethane/Perlite Board A**—1¾ in. thick urethane/perlite composite insulation board adhered with hot asphalt.
4. **Urethane/Perlite Board B**—2½ in. thick urethane/perlite composite insulation board adhered with hot asphalt.

All sections were covered with a coated-felt base sheet and three plies of saturated felt in hot asphalt with gravel surface.

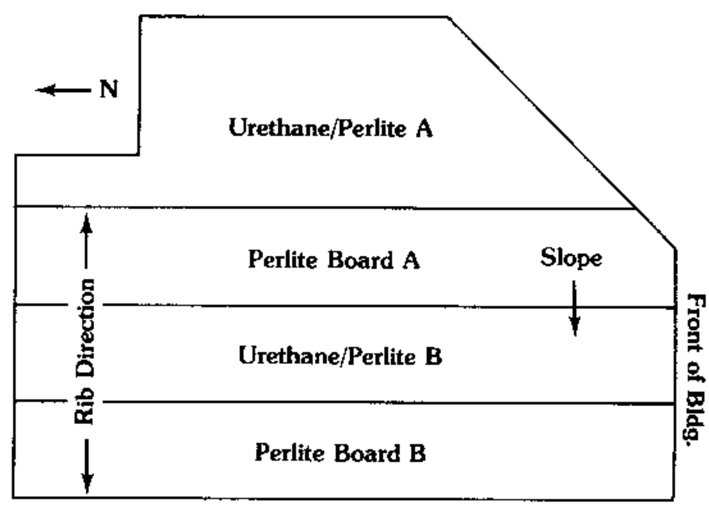

FIGURE 4

Results: After 2½ years, all sections were in good condition, with no significant difference in serviceability between the perlite-insulated sections and the urethane-insulated sections.

GENERAL CONCLUSIONS

In the above experiments, side-by-side installations on the same roof subjected different roofing systems to essentially identical environmental conditions. In Experiment No. 3, for example, extensive ponding occurred fairly uniformly over all test variations. The side-by-side comparisons made the visible superiority of the glass membranes clear-cut.

This laboratory-modeled, field-sited test approach merits greater utilization by roofing contractors and building owners concerned with selecting the most appropriate roofing system for repeated use from among the pretested specifications published by the major roofing material manufacturers. The following recommendations may be helpful when making such installations:

1. Choose a roof that will be available for follow-up inspection visits over a period of years.

2. Since future roof cuts may be desired, select a cooperative owner.
3. Avoid roof areas cluttered with vents, cooling towers, etc., or partially shaded roofs.
4. Avoid roofs with poor drainage, unless "service under ponding conditions" is part of the experiment.
5. Before the test materials are installed, brief the roofing crew so they can plan their approach.
6. Prepare a detailed sketch of the planned layout before starting the job.
7. Keep detailed notes during application and record application details after the roof is completed. Take photographs.
8. Since accelerated weathering is desirable, select climatic extremes when possible, i.e., southern Florida and northern New England.

The authors' experience indicates that rooftop testing of the type described is essential to fully evaluate the performance of roofing. Performance evaluations usually start in the laboratory, but they should end on the roof.

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