FIELD EXPERIENCES WITH SINGLE-PLY ROOFING SYSTEMS

Richard J. Wallace
Daniel Construction Company

This paper discusses how the performance of single-ply roofing systems is affected by installation procedures, design concepts, and material selection. The roofing industry's future confidence in single-ply roofing systems depends on the following:

- Continued technical training of roofing designers and roofing system installers.
- Designers' and manufacturers' knowledge of field practices, the interdependence of the single-ply roof system components, and the system components' dependence upon the substrate.
- The marketing of only proven materials and systems, tested both in the laboratory and the field.

INTRODUCTION

Introduced to the American market shortly after World War II, single-ply roof systems have experienced slow growth, with fluctuations in the number of both systems and manufacturers. Since the beginning of this decade, their usage has grown rapidly, with a concurrent increase in the number of systems and manufacturers.

Single-ply roofing materials are installed in either liquid or sheet form. These materials are usually classified as thermosetting, thermoplastic, or modified bituminous. Fluid applied membranes are generally placed on concrete substrates or sprayed urethane foam. Sheet materials, generally installed over board stock insulation, are secured by full adhesion, spot or strip mechanical anchorage or with ballast.

Owners and designers initially resisted acceptance of single-ply roofing systems because of the lack of design criteria, lack of performance criteria, and failure of systems not suitable for exterior exposures or substrate condition. Until this decade, economic attrition caused by system failures had forced these systems from the market. Within the last several years, however, the success of several systems over a 20-year period has increased the confidence in single-ply systems, despite a general lack of design and performance criteria. The recent advent of many new materials and manufacturers, combined with the improvement of older systems, demonstrates the need for design and performance criteria for selection of single-ply systems and installation methods.

The performance of a single-ply system depends upon the suitability of the system's components, the designer's knowledge of the system, the installation methods, and maintenance of the installed system. This paper is based upon my experiences observing installation of single-ply membranes, implementing single-ply roofing maintenance inspection programs, and investigating their failures.

COMPONENTS

Each of a single-ply system's several components serves at least one specific purpose. Any component that does not completely fulfill its function impairs overall system performance. System components are discussed in the following order:

- Membrane
- Membrane Lap
- Thermal Insulation
- Methods of Attachment
- Flashing Termination

Membrane

Primary factors affecting membrane performance are:

- Durability under weathering and chemical exposure
- Adequacy of manufacturer's quality control programs
- Owner's maintenance programs

The observed performance of thermosetting sheet membranes has been generally good. Failure modes include:

- Swelling of EPDM sheets exposed to oils and plastic roofing cement
- Swelling of neoprene sheets exposed to oils
- Pin holes in cured neoprene sheets received at the construction site
- Punctures caused by roof traffic

The observed performance of thermoplastic sheet materials has been generally poorer than for thermosetting materials. Instances of poor performance are as follows:

- Exposed polyvinyl chloride membrane embrittling, shrinking, and pulling free of gravel stops.
- Ballasted polyvinyl chloride membrane installed over a recover board and a coal tar pitch membrane embrittling with impact fractures, and pulling flashing from parapet walls.
- Polyvinyl chloride membrane developing an "orange peel" surface texture, shrinking and pulling open field laps.
- Polyvinyl chloride membranes exhibiting impact fractures.

Observed difficulties with liquid applied membranes have been related to the insulation, impact damage, and substrates. These problems will be discussed in later sections.

Poor performance has been related to chemical and weather exposure, inadequate product testing, inadequate quality control by the manufacturers, traffic damage, and inadequate maintenance.

Membrane Lap

Single-ply sheet membranes have laps where sheets are bonded together. Laps are fabricated on the roof or in the factory.

Laps of thermoplastic sheets are fabricated by hot air welding, solvent welding, or adhesive. Laps of thermosetting sheets are generally fabricated by a moisture curing adhesive or uncured thermosetting strips. Laps of modified bituminous sheets are sealed by heat, contact adhesive, or bitumen.

The observed performance of factory-fabricated lap seals has been good.

The observed performance of field laps has also been generally good.

Instances where lap performances have been poor include:

- EPDM sheet laps with fishmouths because of excessive amounts of solvent wash or excessive amounts of adhesive have swollen the sheets.
- EPDM laps pulled apart. The laps not yet open could easily be pulled apart by fingers.
- Thermoplastic laps formed with adhesive had pulled apart and were unsuccessfully resealed at least twice.
- Thermoplastic laps pulled apart by membrane shrinkage.
- Modified Bituminous end laps inadequately secured because factory wrapping labels were bonded to sheet and prevented bonding of field asphalt mopping with modified bitumen.
- Modified Bituminous side and end laps contained air pockets because thickness of sheets did not allow full embedment into asphalt.

Thermal Insulation

Thermal insulation is generally applied prior to the installation of the single ply membrane, either sprayed in place or installed in board form.

The observed performance of membranes over low-density foam insulation has been poor. Membranes have been damaged by traffic and tools. This type of damage has been observed in liquid-applied membranes over sprayed urethane, and thermosetting and thermoplastic sheet membranes over expanded polystyrene insulation. Such problems for the thermosetting sheet membranes appear to have been caused by heavy rooftop traffic and disregard for membrane integrity.

Observed problems with liquid-applied membranes applied over sprayed urethane foam include:

- Crazing over rough-surface textured urethane foam insulation.
- Thin coatings, resulting from flow off ridges of rough-textured substrate, with ultimate exposure of the underlying urethane.
- Apparent impact damage.

Methods of Attachment

Methods of attachment of the membrane include ballasting, mechanical attachment by batten strips or spot attachments, and fully adhering. The observed performance problems of single-ply methods of attachments are as follows:

- Sheet metal screws without locking threads installed through metal battens have backed out of steel decks and punctured thermoplastic sheet membranes.
- Thermoplastic materials installed with asphalt and plastic roofing cement per manufacturers' recommendations have shrunk and split.
- Spot screw fasteners have worked free of the steel deck, apparently through a combination of corrosion and wind loads.
- Liquid membranes blistering and peeling from sprayed urethane foam. The urethane beneath freshly peeled membrane appears to have been exposed to the weather for an extended period of time prior to the application of the liquid coating.

Flashing Termination

Terminations along roof perimeters and penetrations are subject to the following observed flaws:

- Thermoplastic welds broken along factory coated metal gravel stop and curb flanges.
- Thermoplastic flashings applied with asphalt not bonded fully to the wall, embrittled, sagging, with holes in sags.
- Uncured neoprene flashings along architecturally grooved concrete wall hardened and pulled free of grooves.
- Uncured neoprene strip flashing along gravel stops inadequately adhered and without a sealant applied along the edge on the metal flange.
- Liquid, thermosetting, and thermoplastic flashings at pipe penetrations have split, apparently from differential vertical movement between the pipe and the membrane support.
- Termination edge of liquid and thermosetting flashing not bonded to walls and pipes.
- Metal counterflashings not protecting the termination edge of liquid, thermosetting and thermoplastic flashings.
- Modified bituminous flashings inadequately bonded to masonry walls.

Termination problems are generally attributable to poor workmanship and possibly to materials not adequately designed for outdoor exposure.

DESIGN

The designer lacks performance criteria to evaluate the many single-ply systems on the market. In making a selection, he must accept the manufacturer's or distributor's data. Blind acceptance of such data can be disastrous, as shown in the following example:

> Upon the recommendation of a roofing contractor, a designer considering use of a single-ply roof contacted the distributor and requested technical data. The data showed an impressive number of ASTM tests to which the material had been subjected. The material had tensile strength exceeding 2,000 psi, elongation exceeding 400% and a non-failure impact test. The distributor

gave a five-year guarantee with a five-year extension. The designer, thus reassured, specified the single-ply system. During installation, the distributor provided quality assurance inspections. About one year after completion of the roof work, the membrane had hardened, and its laps were pulling apart. During a windstorm, the membrane was scattered in fragments across the country side. The distributor, when contacted in regard to the guarantee, was found to have filed bankruptcy some months earlier. The manufacturer of the product could not be identified.

This designer could have avoided this fiasco by requiring a list of reference jobs installed over several years, and by conducting a telephone survey to determine the performance of the roofing system.

However, because of the many new systems on the market and the recent changes in existing systems, most systems do not have a long track record, and even telephone surveys may not indicate how successful current systems may be.

The designer, after choosing a specific roofing material, must then choose the required details. Each manufacturer generally has several details from which to choose for a specific usage. Because of the termination problems discussed earlier, the designer should choose the more conservative details, even though they are probably more expensive.

The designer should show atypical details, such as flashing intersections and terminations, as well as typical details. The designer should not only evaluate the initial cost of a roofing system, but also the potential life-cycle cost to the owner.

INSTALLATION

The roofing contractor's task of installing single-ply membranes is made difficult by the large number of manufacturers and systems currently on the market. Not only do different manufacturers have different installation recommendations for similar products; they have different installation procedures for each product they manufacture. Thus, the roofing contractor must keep crews informed of the current installation procedures for each manufacturer's single-ply roof system. Many single-ply manufacturers offer courses for this purpose, at their corporate headquarters and in the field. The importance of refresher courses is stressed to reinforce proper installation procedures and to be kept abreast of changes in the industry.

Performance of single-ply systems can be affected by the following observed installation errors:

- Overlooking defects in materials delivered to jobsite.
- Installing perimeter nailers of greater thickness than insulation, creating steps and stress concentrations and increasing the damage risks to the membrane.
- Use of leaded gasoline instead of white gasoline to wash thermosetting laps.
- Inadequate cleaning of laps.
- Pouring gasoline on thermosetting sheets to clean laps.
- Failure to roll laps.
- Using inappropriate rollers along sheet laps.
- Failure to apply sealant bead along thermosetting laps.
- Failure to install clamping ring on flashing around pipe penetrations.
- Terminating thermosetting material short of building perimeter and securing the sheet to the perimeter with semicured thermosetting material.
- Melting through thermoplastic sheets with hot air welders.
- Installing loose laid thermoplastic membranes without a perimeter fold to accommodate shrinkage.
- Installing sprayed urethane foam over wet built-up roofing membrane.
- Installing sprayed urethane foam in excessively high relative air humidities.
- Leaving sprayed urethane foam exposed to the weather several days prior to the installation of the liquid, single-ply membrane.
- Installing final lift of sprayed urethane foam with very rough surface texture.
- Installing liquid membrane over rough textured surface and not returning to recoat those areas with pinholes and thin areas.
- Dragging removed built-up roofing system across installed thermoplastic membranes.
- Failure to inspect lap edges.

As single-ply membranes provide only one layer of waterproofing, a single defect can provide a source of water entry into the building. Therefore, installation procedures must conform to the manufacturer's recommendations and contract documents to assure the single-ply membrane will perform as designed.

Not only is the performance of the single-ply membrane dependent upon competent workmanship, but also upon the construction and maintenance traffic. Unfortunately, non-roofing construction trades and maintenance crews do not usually understand the nature of a roofing membrane. Hazards to the single-ply system have been observed as follows:

- Gasoline, oil, and solvent spillage on the membrane.
- Dropping tools and equipment on the membrane.
- Welding over the membrane.
- Installing equipment on the roof surface (possibly years after the original installation).

Such actions can only be controlled by the general contractor and owner. In order to do so, the designer must caution and instruct the general contractor and owner in procedures for acceptable work and traffic over the membrane. The best procedure is to limit and control all traffic over the membrane.

CONCLUSION

Historically, the single-ply membrane industry has had many failures. Despite these failures, the industry as a whole commands a certain degree of confidence at this time. Manufacturers, designers, contractors, and owners must make a cooperative effort to prevent future failures, and to insure an increased confidence in the system.

My personal recommendations for the industry are as follows:

Manufacturers

Manufacturers need to continue and further develop:

- Field-performance tests prior to marketing new and improved products and systems.
- Improved quality control during the manufacturing process.

- Training programs for both roofing contractors and designers.
- Product development test programs oriented not only toward minimum acceptance standard for built-up roofing, but to the unique demands of single-ply systems.
- Competent acceptance inspection during and following roofing installation.

Designers

Designers must select single-ply systems not just on the basis of first cost, but also on long-term economics. To do this, the designer must:

- Know the history of the single-ply industry and the products being evaluated.
- Research the strengths and weaknesses of not only the system, but also the individual components.
- Prepare details that provide the best probable performance, for atypical terminations and intersections as well as typical conditions.
- Caution the general contractor and owner with regard to work and traffic expected on the roofing system.

Roofing Contractors

Installers must provide installation procedures that conform to design specifications, details, and the manufacturers' requirements. To do this, the installer must:

- Maintain the manufacturers' current literature, installation procedures, specifications, details and technical data on file.
- Provide training programs and review programs to keep crews abreast of the latest changes in installation procedures.
- Instruct crews in inspection procedures to emphasize what is acceptable and what is not acceptable.