APPLICATION TOLERANCES OF SINGLE-PLY ROOFING MEMBRANES

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Just as the new single-ply membranes require manufacturing tolerances, they also require application tolerances. Although the building owner is the ultimate beneficiary of a good roofing system, establishment of application tolerances is most important to the roofing contractor and the roofing manufacturer, to enable the one to do a proper application job, the other to protect his reputation as a maker of quality materials, and for both to avoid litigation.

I will highlight several areas that lack application tolerances. My list will necessarily be incomplete. In view of the multitude of so-called "single-ply" systems on the market today, months might be needed to pinpoint sensitive areas of each system.

Substrate condition

"Existing roofing, insulation, and deck shall be clean, dry and sound." What is clean? In applying a vapor barrier or insulation to a steel deck with hot asphalt, a slight film of oil residue from the deck manufacturer can be tolerated. The hot asphalt can dissolve it, flash it off, or otherwise penetrate the oil film for good adhesion to the substrate. The same oil film may seriously deteriorate one or another of the components of a loose-laid single-ply system, or may substantially weaken the bond of an adhesive-applied system. Dust will probably not affect a loose-laid system, but surely will affect an adhesive bond.

So, we must establish what we mean by "clean" in regard to the specific method of applying a specific membrane system. To define the term probably means to set tolerances for the results of a standard test: possibly some sort of a "white-glove" test, or adhering ring-backed blocks of a standard size and composition to the substrate with the specified adhesive and procedure, and then testing the attachment strength to be sure that at least X% of the blocks take at least Y pounds of pull to separate them. Such a test would have a minimum limit, but not a maximum.

Now let's consider "dry", another nebulous term. Suppose the subject roofing system is applied over a wood deck. Moisture from the deck may have some effect on the roofing system. But if the wood is **too** dry, its structural strength or nail-holding values may be diminished. So, here we can set actual tolerances. For example, "the moisture content of the wood deck shall be not less than 8% or more than 14% (or 11% ± 3%) as measured by. . ." — and we then name a testing technique that can be used in the field. In this case, the minimum maintains the lumber's strength while the maximum keeps us from introducing too much moisture into the system.

The requirement of a "dry" substrate also raises the question of single-ply systems installed over existing roofing systems that may contain wet insulation. **How** wet is **too** wet? Having established a criterion, not only in terms of the effect of the moisture on the insulating value of the roofing system, but also the effect of moisture on the ability of the added single-ply system to hold together, we then must establish a practical test method. NDE methods can help, but must be confirmed and quantified with volume-based or weights-based laboratory tests of physical samples. Then, we will need to specify how many test cuts taken from a given-sized area can exceed that moisture level and by how much.

"Sound" is easier to define than "clean" or "dry". Standards can be set for substrate attachment strength and fastener distribution. Gaps are easily measured for conformance with a requirement that "no gaps can exceed X inches in width."

Field seams

Field fabrication of seams and joints is critical to the success of single-ply membranes, especially loose-laid membranes. Yet, manufacturers' instructions are often either too vague or too exact.

What, for example, is the tolerance for a specified 2 in. overlap? Is 1¾ in. enough? Is 1½ in.? Tell us, please. Many vinyl systems require that you put a little slack in the loose-laid membrane as you seam it, to compensate for possible future shrinkage. Well, how much slack is enough and how much is too much? Not less than A″, nor more than B″ for each C″ wide roll would tell us or D″ ± E″ for each F″ wide roll would do it, too.

How about solvent-welding of seams in vinyl roofs? How much solvent should be used? The instruction sheets should tell in clear, concise terms. One manual states that the material is supplied in 4½ or 10 lb. containers. It is applied at the rate of approximately 100 linear ft. per gallon for a 2 in. wide seam. That seems precise enough, but how many pounds to a gallon? And if I apply it at the specified rate equivalent to 17 sq. ft. per gallon, it would probably wash the roof away.

So, we need not only a precise application rate, but we also need a definition of "approximately". And, we need someone to proof-read the specs.

In many solvent welded vinyl systems, the following hand-welding method is recommended and employed:

- A brush wet with THF solvent is inserted into the overlap area and moved along a foot or so, so that upper and lower laps are both wet with solvent.
- Then a sandbag is placed on the seam to press the edges together.
- This is constantly repeated; wetting with the brush and moving the sandbag along over the wetted area.

There is a need for some recommended limits even in such a simple procedure. Does the size, weight or "dwell time" affect seam quality? The welding and sand-bagging steps must be properly sequenced for best results.

After the seams are welded, by solvent or by heat, they are checked for continuity, with an awl, bent ice pick, screwdriver, or other sharp implement. Voids that are found are closed with a heat-gun and roller. But what constitutes a "void", 1/8 in., 1/4 in., 1/32 in.? If there is a break that can be tolerated, it should be stated. If the minimum requirement is no void at all, this should be stated in the specification.

After seams have been welded, checked, and repaired, many vinyl systems are then caulked with a liquid PVC. This is applied out of a squeeze bottle, filling the overlap area. Are bubbles or skip laps acceptable? Are there maximum and minimum application quantity rates? As the caulking contains a great deal of solvent, too much can actually eat up the membrane. Should we guard against this? And is there a time limit recommended for the caulking application in conjunction with solvent welding?

Elastomeric membranes are usually seamed with neoprene contact cement after the lap areas are cleaned of dirt and talc or other "anti-stick" that had been applied during manufacture, with "white" (unleaded) gasoline or other special solvents. Natural fiber rags — e.g., cotton — should be used. The "how-clean-is-clean" question certainly applies here. No one has defined the degree of contamination that make a rag unsuitable for further use.

Edge lap seam width is usually specified as 4 in. minimum in most elastomeric system. If excessive lap width is not harmful, then a minimum tolerance will suffice. If overwidth is also critical, the limits — e.g., "not less than 3¾ in. or more than 5 in." — must be specified. End laps, usually greater than side laps, also require tolerances.

Contact adhesives used for lap seams of elastomeric membranes are critical. Nonetheless, instruction for their use are often imprecise. "Apply to both surfaces in thin layer", "Let dry until not tacky to the touch", or "Apply in accordance with instruction on the container" leave the applicator, in many instances, to supply his own on-the-job training and leave the estimator in the dark as to how much to figure for this often-costly item on his bid. We need optimum, minimum, and maximum application rates for the adhesive, as well as an acceptable application temperature range. They should be clearly stated in the application specification.

After contact-adhesive-coated surfaces have "set up" and have been mated, they must be rolled with a hand roller to assure full contact. What size roller, how much force? After the contact-adhesive lap seam has been made, it must be caulked at the edges, like thermoplastic sheets. Then the caulking is feathered with a spatula to assure that the material fills the lap joint and to give a smooth edge. Is there a time limit, or other critical parameter, for this operation?

In a fully adhered, single-ply roof system, the most popular adhesives are solvent-based. A few systems use water-based adhesives, and at least one is pressure-sensitive.

Good adhesion requires observance of several parameters, notably:

- Substrate condition (clean and dry)
- Weather conditions (temperature, wind velocity, relative humidity)
- Quantity and uniformity of applied adhesive
- Timing of contact between adhered surfaces

Control of adhesive quantity and timing of the seaming operation can be especially sensitive. Too much adhesive can swell the membrane or attack the polymer. Too little will not adhere the sheet to its substrate, with potential embarassment after the first big windstorm. And for good adhesion, workmen must allow some adhesives to become "dry" before joining the seam. Determining a "dry" condition requires precise guidelines.

Limited shelf life of solvents and adhesives poses another problem for roofing contractors. Shelf life must be clearly noted on containers to alert users. Storage conditions also require warning. Is shelf life shortened by high or low temperature? Partially cured membranes offered in single-ply systems — e.g., semi-cured EPDM or neoprene flashings and Hypalon membranes — pose similar problems. These materials also require date coding to prevent their use after aging has hardened them.

Modified bituminous membranes can be adhered to the substrate and lapsealed in the same operation, with one of four methods:

- Heat fusion
- Hot-mopped asphalt
- Set in cold adhesive
- Pressed into place for bonding by factory-applied, pressure-sensitive adhesive

The torch-applied system uses either open flame or hot air to melt the modified bitumen. Some modified bitumens have polyethylene backer sheets, which must be totally melted to assure adequate adhesion. Others have anti-stick dust that must be absorbed by the modified bitumen.

Again tolerances and application conditions must be specified. Ambient temperature and wind obviously affect melting behavior. Inadequate application temperature can result in fishmouths and generally irregular laps and surfaces. Excessive temperature also poses problems. How high a temperature, how long maintained, can the bitumen and membrane tolerate without degrading? If an edge lap has a 1/4 in. opening, can it be disregarded? Or must it be repaired? Edge lap dimensions are also important. According to one manufacturer of heat-fused membranes, **too wide** a seam will weaken it. So we need an acceptable maximum as well as minimum.

For modified bituminous membranes hot-mopped in place with roofing asphalt, temperatures are critical, as well as the quantity of applied bitumen. They must be sufficient to fuse the bituminous layer on the back of the roofing sheet and make the heavy sheet pliable enough to conform to the substrate, avoid fishmouths, and give smooth, tight sidelaps and endlaps. Yet, in this case also, too high a temperature can degrade the asphalt and too much asphalt can impair the final membrane strength.

Pressure-sensitive modified bituminous roofing requires precise limits for substrate cleanliness. They normally require a primer. There is a factory selvage on the sidelap, but cut edges require a mastic troweled in place over the exposed edge. Deficient mastic will leave that edge seal vulnerable.

Mechanically anchored roofing systems depend upon plates, bars, or discs attached with screws or bolts to anchor the membrane. Although many of these systems are supplied with proper hardware, specified tolerances are needed for penetration, torque, withdrawal pull, etc., for **each** type of substrate and deck — e.g., 1/2 in. minimum screw penetration into a 22 gage metal deck, 1 in. minimum into a predrilled, prestressed concrete deck. Tolerances and ranges for torque applied to the fasteners are needed to prevent stripping of the deck or fastener backout. Field tests for pullout resistance are needed to assure attainment of design strength.

Loose-laid membranes relying upon ballast for wind-uplift resistance have their own unique problems. Ballast requires a lower weight limit to assure adequate wind-uplift resistance and a maximum to avoid overloading the structure, a particular hazard on reroofed structures not designed for the additional ballast dead load of 10-13 psf. If the maximum allowable ballast weight is less than the minimum needed to resist wind uplift, a fully adhered or mechanically adhered system is the only practicable alternative.

Ballasting must observe several other limits. One is uniformity of application. Simply counting the number of loads of gravel dumped on the roof is not enough. Crews must be instructed in what constitutes the specified amount of ballast and observe what it looks like. Spot checks should be made every so many squares with a simple sampling device and scale to assure that ballast is not concentrated in too small an area, and that it falls within the allowable weight limits.

Gravel sizing is another item requiring more uniform treatment. A nominal 1½ in. round, river bottom gravel is typically specified. But tolerances range far and wide. Some specifications permit no "fines," and others permit up to 50% of the material to pass a 3/4 in. sieve.

Sharpness of the ballast stones is still another problem for specifier. Sharpness must be limited, to prevent membrane puncture.

Concrete pavers are similarly slighted in specifications — e.g., for smoothness, freeze-thaw resistance, rounded edges. What is the maximum paver spacing that will not reduce rooftop fire resistance? Paver spacing may also affect water flow, thus adding another factor for consideration. And pavers must be kept a safe distance from cants, curbs, and flashings. Is the required dimension 1 in. or 6 in.?

Flashings, the most critical aspect of single-ply roofing systems, lack uniform recommendations. There is not current agreement, for example, on minimum height, maximum height, and overlap of seams and basic membrane. Length of flashing strips for field application should be established to facilitate proper handling. Some specifications incorporate clad metal as part of the flashing system, but requirements vary for laps and spacing, cleating, and fastening. Some require a bondbreaker tape; others do not. Is there a critical tolerance to prevent the metal from moving? What happens if the wall or the metal is warped? Should corner pieces be limited to 12 in., to reduce stress concentration?

In summary, rapid growth of the single-ply market has overwhelmed even experienced roofing contractors. This has sometimes resulted in poor workmanship, at least partially attributable to the industry's lack of rational, uniform application tolerances. In America's litigious society, will juries be determining reasonable tolerances for application of single-ply membranes?

The single-ply roofing manufacturers must inform roofing applicators about critical tolerances. When reasonable tolerances are established, along with the means of verifying compliance, then contractors can be fairly judged by their peers. Training and quality control will be quantitative, based upon limits set by the roofing manufacturers. Fair but rigorous application standards should reduce both the occasions for investigating single-ply roofing failures and the futile finger-pointing that currently accompanies these failures.

Nothing will be accomplished by manufacturers out for their own self interests and quick profits. Manufacturers need to respond to the needs of the market they have created. Long term performance can be achieved by using the proper materials installed by craftsmen guided by good application tolerances.