

ROOFING PRACTICES IN NORTH AMERICA

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The materials, specifications, labor customs, and roofing practices in North America are all undergoing changes. This paper will attempt to review the significant changes and trends taking place in the last decade or so.

MATERIALS

In North America, it is quite common to find very large commercial roofs (1,000 squares or 9000 m² and up) which have extremely low slopes, on the order of 1:48 (¼ inch per foot) or even less. Because these low-sloped roofs frequently have very poor drainage, waterproofing integrity is extremely important. Traditional methods of roofing these buildings have been to use bituminous built-up roofing systems, in which the waterproofing function is provided by the layers of bitumen, asphalt or coal tar pitch, stabilized by felts or mats.

The earliest reinforcements for these BUR applications consisted of organic roofing felt derived mainly from shredded rags, waste paper and wood pulp. The dry organic felts were produced on paper machines and subsequently impregnated with bitumen to form saturated roofing felts. Later developments included the introduction of felts derived from asbestos fibers, which provided good resistance to fire and moisture attack.

Glass fiber mats were introduced in the middle 1940s. These early mats consisted of glass fibers produced by a steam process and laid-up to form a randomly oriented mat.

The mat was immediately treated with a synthetic organic resin such as phenolformaldehyde to hold the glass fibers together. The glass mats were lightly coated with asphalt to improve handling characteristics, but since the coating is discontinuous, the mats retained desirable porosity.

In the 1960s, a glass mat produced by a wet, paper-like process was introduced in the United States. This process permitted rapid production of very uniform mats, and these "wet process" mats have been widely embraced by manufacturers.

A third proprietary process which produces a mat of continuous strands of swirled glass fibers is also available. The mat has unusually high tensile and tear strength, as well as slightly improved extensibility. Like the other mats, the glass fibers are bound together with an organic binder and lightly coated with asphalt.

It is estimated that built-up roofing membranes derived from these high technology glass fiber mats produced by either the wet or continuous strand processes constitute well over 80 percent of new BUR membrane reinforcements used in the United States.

In addition to saturated and lightly coated felts and mats which are used as ply felts, a variety of specialty glass fiber-

based products is available. These include felts with heavier asphaltic coatings, used as base sheets; granule-surfaced sheets used as cap sheets; reinforced or fabric-laminated sheets used as base flashings; and embossed or button-punched products used as ventilating layers.

ELASTO/PLASTIC SYSTEMS

In the early 1960s, a family of synthetic polymeric materials was introduced in the United States from a variety of sources. These polymeric systems are sometimes called "single-ply" or "elasto-plastic", but the broadest use of the category also includes "modified bituminous systems" and "multi-ply" but "single-layer" materials. These materials included neoprene (chloroprene), polyisobutylene (PIB), butyl (IIR), polyvinylchloride (PVC), Hypalon (chlorosulfonated polyethylene), and chlorinated polyethylene (CPE). The materials marketed in the 1960s were basically used in fully adhered systems that emulated the application techniques and performance characteristics of the bituminous roof membranes they sought to replace.

Early applications of these materials were unsuccessful for a variety of reasons, including lack of competitiveness, poor specifications, inadequate training, and poor performance of the systems themselves.

In the 1970s, a new generation of synthetic polymer roofing systems was introduced. These included most of the materials mentioned above, plus EPDM (ethylene propylene diene monomer). The most significant change in this generation of materials was that they no longer clung to the practices of built-up roofing, such as having all elements fully adhered together. Instead, they introduced concepts such as loose-laying of these elastomeric materials with just the edges sealed. This allowed the materials to stretch to accommodate the stresses induced in the roof membrane without these forces being concentrated at insulation joints or other substrate discontinuities. The loose gravel ballast also afforded excellent fire protection to the relatively thin and sometimes combustible membranes.

The introduction of loose-laid, ballasted roof systems also led to the widespread use of expanded polystyrene roof insulation. While expanded polystyrene has good thermal properties and acceptable physical characteristics, it was not widely accepted as a substrate for hot built-up roofing because of its vulnerability to hot spilled bitumen. Expanded polystyrene can also be attacked by the solvents commonly used in asphalt mastics for setting drains or flashing built-up roofing systems. The combination of loose-laid expanded polystyrene, followed by a loose-laid elastomeric roof membrane, avoids melting and minimizes solvent problems. This combination is extremely competitive with traditional

hot-applied built-up roofing systems.

Neoprene, a good weathering and oil-resistant compound, has gradually been displaced by EPDM, which is less expensive. EPDM also has superior resistance to ozone and ultraviolet attack. Butyl, which has properties similar to the other elastomers, has also yielded to EPDM or to EPDM/butyl blends.

The family of chlorinated hydrocarbon sheets includes plasticized polyvinylchloride, chlorinated polyethylene and Hypalon. These products are greatly improved over the products of the 1960s. The plasticizers now used in PVC are less volatile, and the use of divorcing slip sheets helps avoid plasticizer migration into the substrate. The ballasted systems gain UV protection, while other systems have been compounded for direct exposure to sunlight. Many of these thermoplastic sheets are also backed, or internally reinforced, for better mechanical performance. It is very common in PVC systems to incorporate PVC-clad metal as part of the system. In the field, it is only necessary to fuse the PVC membrane to the PVC-cladding on the metal, rather than trying to develop an adhesive system that can bond PVC to wood, metal, masonry and the like. The anchored clad metal acts to restrain the PVC against shrinkage.

Because PVC has a high halogen content, PVC membranes have relatively good flame-spread ratings even when unballasted.

Other membranes based upon polyisobutylene and polymer-pitch blend have been introduced in the United States but have had relatively little impact to date.

Another group of high technology materials now undergoing considerable growth include the polymer-modified bitumens. Currently two polymer-modifiers are widely used. The first is a thermoplastic material called atactic polypropylene (APP), a byproduct of the petroleum and plastics industries. APP is thermoplastic, which means that it is relatively simple to blend into hot bitumen. The blend produces improved toughness and flow resistance. The other modifier is a novel thermoplastic elastomer best known as "sequenced butadiene styrene" (SBS) although other thermoplastic "block" co-polymers are also available. The thermoplastic portions of the SBS polymer allow the polymer to disperse in hot bitumen, but elastic properties develop upon cooling even though the polymer is less than 15 percent of the mixture.

The modified bituminous sheets are almost always combined with reinforcing material. Fiber glass mat reinforcements provide good strength and dimensional stability and reasonable fire performance, but do not permit elastic behavior. Polyester mat reinforcements permit considerably more deformation before failure. It is not uncommon to find glass reinforcements designated for "normal service" and the polyester mats for "high performance". Other forms of modified bitumen systems include plastic core materials usually of polyolefin, surfacing sheets of plastic or metal foil, and sheets surfaced with mineral granules. Some products are available with two or three of the above reinforcements and surfacings.

Special "tacky" modified bituminous compounds allow application by simply removing a "release" paper. These may be plastic film-surfaced or UV-resistant, non-woven mats.

Other modified bituminous sheets carry extra coating on

the bottom side. This allows remelting and lamination by torch or hot-air welding. To a large extent, the modified bitumen systems require protection from sunlight. This is accomplished by the use of metal foils such as aluminum, copper or stainless steel; by the use of roofing granules; or by the subsequent application of a reflective coating.

SPECIFICATIONS

Roofing specifications are generally organized into systems that are: 1) directly applied to combustible or non-combustible roof decks, 2) applied to decks that are either nailable or non-nailable, or 3) applied over roof insulation. These distinctions have tended to blur lately because mechanical fasteners have recently been introduced which make even such substrates as hard concrete "nailable".

The roof decks that are selected also depend somewhat upon regional preferences. For example, on the Pacific Coast of North America, it is quite common to use plywood roof decks. The very gentle Pacific weather allows for roof membranes to be applied directly to uninsulated plywood. Thermal insulation such as fibrous glass batts can be installed underneath the roof deck without much concern for deck movement or condensation. The most common built-up roof membrane used over plywood decks consists of a mechanically fastened base sheet, followed by mopped ply felts and a light-colored, mineral-surfaced cap sheet. Typically, all of these roofing materials are based on asphalt-treated glass fiber. There has been only slight acceptance of the new single-ply systems. The reasons include: 1) the glass systems perform very well, 2) they are extremely cost effective, 3) they are very light in weight, 4) they are available in reflective light colors, and 5) they provide good fire ratings over combustible plywood decks.

In other parts of the United States roof decks are predominantly ribbed steel. Exceptions include poured or pre-cast concrete and, on older buildings, heavy timber. Other deck types are of minor significance. On ribbed steel decks, spanning for continuity of the substrate is accomplished by rigid fire-resistant mineral fiber boards, gypsum wallboard, or special fire-resistant foamed plastics such as isocyanurate or phenolic. The fire resistance is important because steel decks conduct heat very readily. Without fire retardancy, interior fires could result in serious fire loss to unprotected steel deck structures.

Because of the recent emphasis on energy efficiency, fire-resistant perlite and fiber glass boards have been displaced to some extent by combination boards which combine plastic foam with a fire-resistant underlayment, and more recently by highly fire-resistant polyisocyanurate or phenol formaldehyde (phenolic) foams.

In the case of non-combustible roof decks such as concrete or gypsum, it is permissible to use wood fiber boards, polyurethane foam, and even thermoplastic foam boards such as expanded polystyrene (EPS), as well as the previously discussed materials. For loose-laid single-ply roofing systems, EPS is most common on non-combustible decks. Where the insulation is to be mechanically fastened, a layer of rigid wood fiber may overlay the EPS to provide compressive strength and a bondable surface. The single-ply membrane may then be adhered or mechanically fixed to the fiber board layer.

The application techniques for the single-ply system include: 1) fully adhered systems which typically have roof insulation mechanically fastened to the roof deck, followed by full adhesion between the membrane and the insulation layer; 2) partially fixed systems in which the mechanical fasteners not only hold the insulation down but also restrain the roof membrane through disc or bar anchors; and 3) loose-laid and ballasted systems. The modified bituminous systems usually require a heat-resistant insulation, adhered with bitumen or mechanically fastened in place, followed by a bituminous base ply and a modified bituminous top layer.

APPLICATION

We have already touched on some of the common application techniques. Because roof areas are frequently large, attention is paid to labor-efficient roofing techniques. For built-up roofing, this includes the use of hot tankers to deliver bitumen, pumps to deliver bitumen to the roof, mechanical bitumen spreaders, felt layers and other devices. Also included are pneumatic devices, stand-up screw guns and stapling machines to aid in the rapid deployment of roofing fasteners. Mineral aggregate surfacings such as "pea gravel" meeting ASTM D-1863 and coarse, river-washed ballast are both delivered in bulk to the jobsite, mechanically conveyed or hoisted to the roof level, and machine-spread. Since the ballasted roof requires a half-ton of ballast per roofing square (48.8 Kg/m²) this is a significant labor factor.

For the thermoplastic systems, self-propelled hot-air welding devices are used to improve the efficiency and quality of heat-welded seams. Stand-up solvent "jet" welding systems are also useful for those systems that are solvent-weldable.

For elastomeric sheets, it is common practice to factory-fabricate the sheets into very large units so that field-seaming is minimized.

Large sheets are not used in adhered systems. They would be difficult to handle, adversely affecting productivity. Instead, the sheets are typically no more than about 10 feet in width.

Ganged, open-flame torch heads allow fairly rapid torching and laying of "torch-grade" modified bitumen sheets. Application is still slower than mopped systems, however.

In all of these single-ply systems, inspection and hand-rewelding is required to achieve perfection.

LABOR CUSTOMS AND INDUSTRY PRACTICES

In North America, roofing contractors are usually independent contractors in complete control of their businesses. Many become "licensed applicators" approved to apply roofing systems from many competing manufacturers. Some contractors are "approved" to apply at least one BUR and one of the several single-ply categories. However a roof is specified, these contractors are able to bid and install these systems. Within their companies, some contractors have found that their "hot" crews show some reluctance to install single-plys. Conversely, many single-ply installers are convinced that these systems are safer and easier to work with and prefer not to handle hot bitumen.

Manufacturers of the membrane materials provide complete specification manuals that describe the use of their materials for each type of roof deck and for each flashing

detail. They also arrange for the necessary fire and wind tests to meet building codes.

In the case of single-ply systems, many manufacturers provide training schools where the applicators are trained in the special techniques needed for successful application of their systems. The manufacturers also provide field service, inspection and field training as necessary to maintain installation quality. Manufacturers also provide warranties on the materials, the system and in most cases even the workmanship of the licensed contractors.

The rapid growth of a new generation of roofing systems has led to some problems in training and control. There is a definite lack of qualified inspectors to check the installation of these systems. Most manufacturers have not reached out to train consultants or inspectors on the builder's payroll. This leads to a lack of sufficient supervision in the busy summer season when most roofing application takes place.

Another emerging problem is that of record-keeping and maintenance of the new systems. With conventional bituminous roofing, it is fairly simple for owners to maintain their buildings using their own semi-skilled maintenance crews and to make minor repairs or modifications as needed. However, the chemically divergent elasto/plastic systems require special materials as well as special skills which are not readily available to the unsophisticated building owner. While the availability of roofing warranties helps delay the day where the owner has to provide this skill, ultimately it will be his responsibility to keep track of exactly what is installed on each roof area and what materials are necessary for its maintenance. Single-ply manufacturers should give comprehensive instructions to the building owner on his rights and obligations, especially for inspection and routine maintenance.

TRENDS

We have already mentioned the rapid growth of single-ply systems throughout the last decade. It is estimated that in many parts of the United States, these systems now constitute more than 50 percent of new roofing being specified and installed. This growth is being countered by proponents of built-up roofing, who argue that built-up multi-ply roofing systems are performing better than ever before. The advanced technology of glass fiber-ply felts, research on the quality of bitumen, and the introduction of equiviscous temperature (EVT) control for mopping temperatures all add credibility to this claim.

On the other hand, the withdrawal of asbestos fiber-based flashings, mastics and coatings will cause further dislocation of BUR systems. In some cases, modified bituminous flashings are now combined with conventional BUR to bridge this gap. Built-up cap sheet systems continue to dominate the West Coast market because of their lower cost, acceptable performance, and good fire ratings over plywood. These attributes will be difficult to meet with the current generation of single-ply materials.

In the northern part of the United States, where roof decks are designed to withstand appreciable snow loads, the growth of loose-laid, ballasted roof systems has been significant. These buildings usually will accept an additional 10-13 psf of ballast and still retain adequate environmental load capacity. Because northern buildings also require a great deal of thermal insulation, the EPS/ballasted single-ply

system is having good success. Throughout the United States, with the exception of the Pacific Coast, elastomeric membranes, various thermoplastic sheets and modified bituminous systems all compete for market share.

Within the last year or so, non-woven synthetic fiber reinforcements have also been introduced into this market. Many are designed for construction of membrane systems by a cold process, while others may be applied in hot bitumen. While these systems will probably be multi-ply, the ultimate or optimum construction of these new materials is not yet clear.

Another relatively new development is the introduction of corrosion-resistant, standing seam metal roofing systems for relatively low slopes. These metal panel systems can be produced in rather long spans, up to 40 feet, for good productivity. Raised seams permit use on relatively low slopes. Thermal contraction and expansion is accommodated by concealed clips. These systems have recently been promoted as alternatives to membrane roofing systems and as reroofing systems where increased slope is also achieved.

Another distinctly different roof system is the sprayed-in-place polyurethane foam system. These systems were actively promoted in the 1960s, and, for many of the same reasons as the single-ply systems of that generation, were not very successful. However, better equipment, better coatings and better foam has led to renewed market strength. Excellent and rigorous specifications and application guidelines have been issued by the Naval Civil Engineering Command and Urethane Foam Contractors Association (UFCA). These new guidelines should help to eliminate many of the difficulties of the early sprayed-in-place foam systems.

Protected membrane roofs (PMRs), in which a water-resistant insulation is placed above the roof membrane, continue to gain acceptance. These systems are offered with both BUR and single-ply membranes. Recent innovations include the use of a porous, non-woven mat on top of the insulation to "raft" insulation boards together and to serve as a filter-course. Another product recently introduced consists of a 3/8-inch layer of latex-reinforced mortar, bonded to extruded polystyrene. The boards are tongue-and-groove shaped, to provide mechanical interlocking for wind and flotation resistance. Continued research on PMRs is available from the National Research Council of Canada and the U.S. Army's Cold Regions Research & Engineering Laboratories.

The National Roofing Contractors Association (NRCA) has published an award-winning and widely recognized publication called *The NRCA Roofing and Waterproofing Manual*. This manual provides specifiers with comprehensive information on roofing systems and has helped resolve many of the conflicts that existed prior to its publication. A similar manual has been produced for Canada by the Canadian Roofing Contractors Association.

In the single-ply area, an organization called the Single-Ply Roofing Institute (SPRI) has begun functioning. It is expected that SPRI will supply similar information to this fledgling industry. The American Society for Testing Materials (ASTM) and the Rubber Manufacturers Association are also developing standards for single-ply systems.

Bituminous built-up roofing is guided by the technical committees of the Asphalt Roofing Manufacturers Association (ARMA) and by the Roofing Systems Technical Committee, a joint committee of NRCA, ARMA and the ASTM.

Significant research on all types of roofing is conducted by the National Bureau of Standards, the National Research Council of Canada, the Cold Regions Research and Engineering Laboratories, the Army Civil Engineering Research Laboratories, the Naval Civil Engineering Laboratory and others.

Another item of significance is the creation of a non-profit educational institute called The Roofing Industry Educational Institute (RIEI). This institute is managed by a Board of Regents which include four roofing materials manufacturers, four roofing contractors and four "users" such as building owners and design professionals. RIEI has gathered a faculty of more than 60 industry experts to write and conduct its various public seminars on roofing technology. RIEI provides rapid transferral of information and technology to the roofing community.

CONCLUSIONS

Roofing technology in North America is certainly in a state of flux. Many diverse roofing systems are competing for essentially the same market. The improvements in technology and information will gradually coalesce into clearer guidelines as to which systems are best for certain roofing conditions.

At the present time, these distinctions are blurred and obscured by aggressive promotion and fierce competition. Certainly, at this point, there is no clear indication as to which of these systems will succeed and which might be driven from the marketplace.