ADVANTAGES, LIMITATIONS AND SELECTION OF MODIFIED BITUMEN

JOEL P. PORCHER, JR.

Rettew Engineering Co.
Greenville, S.C.

During the 1960s, modified bitumens were developed in Europe for roofing applications. Publications of pacesetting technology and development of these products came primarily from Italy, which specialized in blends modified by atactic polypropylene (APP), and from France, which specialized in blends modified by styrene butadiene styrene copolymer (SBS).

Modified bitumens entered the roofing market of the United States as imports during the 1970s. These products are now widely promoted throughout the United States by American companies that manufacture their own products. Present products include APP blends, SBS blends, blends with APP and SBS, and ethylene copolymer bitumen (ECB). A wealth of technical information for these new membrane products has been published during the past two decades, and a synthesis of this information is offered here with the objective of aiding those responsible for the selection of waterproofing roof membranes. A selection procedure has been proposed to assist the licensed professional, i.e., the architect or engineer, who serves as a roofing consultant or specifier for the building owner.

ADVANTAGES OF MODIFIED BITUMENS

Modified bitumen roofing provides a useful combination of traditional roofing practice and modern, single-ply roofing technology. The familiar roofing components of asphalt and fabric reinforcement are processed with state-of-the-art polymers to produce a prefabricated waterproofing sheet suitable for single-layer installation. Various advantages of these prefabricated products have been widely reported by other authors, and are summarized subsequently by topic.

Improved quality assurance

Factory prefabrication of the membrane sheets enables tight quality control, resulting in product uniformity. Waterproofing binder, fabric reinforcement, weather-resistant surfacing, and torch-preparation linings are assembled into a single-ply membrane sheet having uniform thickness and physical properties that are consistent for the entire set of sheet rolls.

Improved physical properties

Modified bitumens are suitable for a broader range of service temperatures than built-up roofing membranes, because polymer modification improves the flow resistance of the blend at high temperatures and its ductility at low temperatures. Moreover, because of the improved flexibility at cold temperatures, some modified bitumen manufacturers allow, under certain weather conditions, installation at temperatures below 32°F. Polymer modification imparts a greater degree of elasticity to the blend, in the sense that some deformation can be recovered upon removal of an applied load. The thermoplastic-rubber blends (e.g. SBS) have greater elasticity than the APP blends. Properties of ultimate elongation and endurance during cyclic straining are greater for modified bitumens than for built-up roofing. A comparison of some of these properties is made in Table 1.

Modified bitumen membranes are the thickest of the single-ply class of roofing materials, yet are still lighter in weight than built-up roofing. Chaize[1] noted that total thickness is related to dynamic puncture resistance and to rate of aging. Modified bitumens are more resistant to weathering than built-up roofing.

Successful performance experience

Modified bitumen products were developed in Europe, and European countries continue to use them. Gorgati[2] reported successful service of APP modified bitumens in Italy. Medlock[3] reported excellent service of SBS modified bitumens in France. Hendriks[4] reported good performance of both APP and SBS modified bitumen in the Netherlands. Haushofer[5] reported growing use of SBS modified bitumens in West Germany to replace more rigid roofing materials that are susceptible to damage by hail. The CIB/RILEM SLR Joint Committee[6] reported recently that the low-slope roofing market in Italy, Norway, France, West Germany, England, and the United States consists of 89 percent, 65 percent, 60 percent, 35 percent, 30 to 35 percent, and 10 to 15 percent modified bitumen, respectively; excellent or good performance ratings were reported by each of these countries for APP and for SBS modified bitumen, except for Norway, which reported a fair performance rating for APP modified bitumen.

Similarities with traditional low-slope roofing

Modified bitumen roofing materials more closely resemble the built-up roof than any other of the single-ply products. The producers have developed blends that have viscosities similar to those of oxidized roofing asphalt, so that manufacturing technology and equipment for modified membranes closely parallel that used to produce built-up roofing felts. The membrane products are marketed in rolls that resemble rolls of built-up roofing products. Moreover, built-up roofing crews are familiar with solid-mopping installation and are easily adaptable to the torching installation techniques appropriate for many of the modified bitumen products. The modified products are compatible with built-up roofing; some manufacturers produce both modified bitumens and built-up roofing, and allow use of their modified products as flashing in their built-up roofing systems.

Cost advantages

Construction cost data are given in Table 2 for several single-ply membrane types relative to a typical built-up roofing membrane. Data are based on unit prices for materials and labor that were compiled and averaged by the R.S. Means Co., Inc. in 1985 for 30 major U.S. cities. These data are provided for illustrative purposes only and should not be misconstrued as authentic price ratios for the present market. The tabulated ratios indicate that modified bitumen roofing was one of the least expensive of the single-ply categories in 1985, and that modified bitumen roof-

ing was approximately 3 to 18 percent more expensive than built-up roofing, depending on the method of attachment. The greater materials cost for modified products was offset by a reduced labor cost.

Greater versatility in substrate configuration
Some manufacturers indicate that their products are unaffected by ponded water. Nevertheless, the Handbook of Accepted Roofing Knowledge guideline[16] regarding provision of drainage to prevent ponding should be followed for all modified bitumen products. In addition to applications on low-slope roofs, some manufacturers of modified bitumens allow use of their products to waterproof steep roof configurations such as spires, domes, and hyperbolic paraboloid shells.

LIMITATIONS OF MODIFIED BITUMENS

Limitations regarding the use of modified bitumens may be classified as production precautions, installation precautions, usage restrictions, and performance uncertainties. Understanding of these limitations can aid the roofing specifier qualitatively in the selection and specification of a suitable product. Some of the more prominent limitations are discussed by topic.

Lack of composition standards
The degree of variation among modified blends seems inexhaustible. The polymer loading, the type and amount of fillers, and the degree of compatibility between the polymer and bitumen influence the properties of the blend. Consensus standards have not been established by the industry to define acceptable limits for these variables.

Necessity for quality control
Compatibility between the bitumen and polymer is a widely recognized production precaution. Halasz[7] demonstrated that incompatible blends have inferior mechanical properties, particularly after artificial weathering, although incompatibility is not necessarily detectable by routine properties of unaged specimens. Kraus[8] indicated that compatibility of new bitumen sources is best determined empirically, by performing selected physical tests on sample blends such as inclined plane flow at 100°C and low temperature flexibility. Consistent quality control by the manufacturer is essential in the production of a durable modified bitumen. Hendriks[4] attributed a case of premature membrane deterioration to inadequate quality control by the manufacturer.

Application precautions
Laaly[9] reported that use of oxidized roofing asphalt to adhere modified bitumen membrane sheets has sometimes led to failure at the sheet laps due to embrittlement of the asphalt (at cold temperatures) or incompatibility of the asphalt. In one of his case histories, Hendriks[4] attributed membrane shrinkage and wrinkling to damage of the reinforcement mat caused by installation of the membrane with oxidized bitumen at an improper application temperature. Hendriks[4] noted also that another membrane failure was caused by use of an incompatible cold mastic containing a solvent that softened the modified bitumen.

Special safety precautions are required when hot bitumen is used to mop the membrane or when an open flame is used to torch the membrane. Haushofer[5] reported that caution is especially necessary to prevent fire when the membrane is installed or repaired around roof openings such as expansion joints or skylights.

Usage restrictions
Modified bitumens, particularly the SBS blends, are susceptible to degradation by exposure to sunlight, and, therefore, require some form of protective surface or coating. Dupuis[10] has reported that modified bitumens are also susceptible to degradation by exposure to certain chemicals, such as compressor oil and mortar sealer. Modified bitumens are flammable, and special fire-resistant coatings have been developed to deter spreading of flames along the roof surface.[5]

Lack of established performance criteria
The lag of performance standards behind product production and marketing is exemplified by the statement of Medlock[3] that official French standards for SBS blends were established in 1978, whereas French installations of SBS blends dated from the early 1970s. A comparison by Chaize[1] indicated that universal standardization has not yet been attained, and that the American guidelines (from the Midwest Roofing Contractors Association) are less stringent than the European guidelines for minimun thickness of torch-applied membranes and for cold flexibility. The absence of requirements for low-temperature flexibility and ultimate elongation after artificial weathering is particularly disconcerting because Halasz[7] has demonstrated that incompatible blends are easily identified by measurement of these properties.

Limited service experience
Although Meynard[11] and Chaize[1] have reported correlations between artificial and natural aging for SBS blends, estimates of durability beyond[10] years are based upon extrapolation. Furthermore, observations by Halasz,[7] that European compatibility rules are not necessarily applicable to the variable asphalt supplies in North America, imply that European experience with long-term durability should be confirmed, not merely assumed, for North American installation. Effects of freeze/thaw cycling and natural aging on protective surfacings have not yet been established and correlated with laboratory tests.

SELECTION OF MODIFIED BITUMENS

Helpful discussions regarding the selection of single-ply roofing are given elsewhere by Rossiter and Mathey,[12] by Mertz,[13] and by Laaly.[14] The guidelines offered subsequently may be classified as development of a general data base for roof design, definition of distinctives for individual projects, tabulation of product distinctives, and tabulation of manufacturer distinctives. The first step was discussed by Busching and Porcher,[15] and the last two steps are greatly facilitated by use of the current edition of the NRCA *Guide*.[16] The guidelines enumerated below are intended to give the specifier a rational procedure for the selection of the most appropriate modified bitumen membrane for a particular roofing project.

Development of a general data base
The primary source for roofing design information is the roofing manufacturer. The specifier should accumulate a library of specificaton manuals from a broad range of modified bitumen manufacturers (e.g., APP products, SBS products, ECB products, and APP/SBS products). The specifier should also acquire several general reference publicatons such as the NRCA *Manual*[17] and the NRCA *Guide*,[16] which give overviews of accepted roofing practice and of available membrane products, respectively. State-of-the-art roofing knowledge may be maintained by collecting technical publications available in trade magazines, reports of government agencies (e.g., NBS or DOE), papers from roofing symposia, and other sources.[15] The technical publications amassed into the database could also be indexed by key words and topics in order to facilitate development of computer software for retrieval and cross-reference of information needed by the specifier.

Determination of project distinctives
The specifier should compile a comprehensive description of the building to be roofed. The list should address at least the following questions.

- Will any aspects of the interior building usage affect the roofing?
- What is the dead-load capacity of the roof structure?
- What kind of roof deck is/was used (type, size, slope)?
- Can the roof deck move relative to the roof perimeter?
- Will the deleterious substances be exhausted onto the roofing membrane?
- What building code requirements apply to the roofing (i.e., fire resistance, wind-uplift resistance, thermal insulation requirements)?
- What are the extreme environmental conditions for the site (high and low temperatures, maximum wind speed)?
- What amount has been budgeted for the roofing contract?

Tabulation of product distinctives
To make a rational selection of the most suitable modified bitumen product for a particular building, the specifier must discover the distinctives between the numerous products presently marketed. Comparisons may be grouped into technical, financial, and practical distinctives for individual products. Although an exhaustive comparison of the entire industry is unwarranted, the specifier should select several manufacturers, according to the guidelines in the subsequent section, and then tabulate comparisons of their products. The NRCA *Guide*[16] gives tabulated comparisons of descriptive, technical, and warranty information in a uniform format that would aid the specifier in making product comparisons.

A summary comparison of selected product data was made for all modified bitumen products listed in the NRCA *Guide*[16]. This summary is shown in Table 3. The list of characteristics selected for Table 3 is not exhaustive, but was compiled to illustrate a manner for determining product distinctives. Several characteristics were chosen from those which were reported quantitatively in the NRCA *Guide*[16] by the majority of the participating manufacturers of modified bitumen. Properties reported on a "Pass/Fail" basis were excluded from Table 3, because these characteristics are irrelevant in distinguishing between products that "Pass" the recommended values.

Technical distinctives
Technical distinctives are herein defined as key material properties where a broad range of magnitudes have been reported for the various products available on the market. In this sense, based on the summary of Table 3, ultimate elongation (varying from 4 to 215 percent) is a better technical distinctive than maximum workable temperature (varying from 100 to 150°F), because the available products offer a broader spectrum of values for the former property than for the latter one. As a minimum requirement, modified bitumen membrane properties should conform to a standard accessible to the U.S. roofing industry, such as the Midwest Roofing Contractors Association (MRCA) *Technical Document MB-30* or the Canadian General Standards Board (CGSB) *Standard 37-GP-56M*. In addition, however, technical distinctives should be determined for the various products.

Use of technical data, such as material properties, is primarily qualitative. A specifier may conclude that a "stronger" material is required, or that a "more flexible" material is needed, depending upon the particular project, but present state-of-the-art roofing technology has no procedure for computing material requirements as a function of project parameters. Inasmuch as movement of the structural substrate is inevitable, and the roofing membrane, not being a structural member, is unable to resist such movement, the membrane must be capable of straining without rupture to accommodate any possible substrate movement. Thus, resistance to cyclic fatigue (or crack-bridging ability), especially at the colder service temperatures and after exposure to weathering, is an important material property. Laaly[14] provides guidelines for the selection of other important properties.

Financial distinctives
The specifier should also compare membrane products on the basis of relative costs. Accumulation of these data may require discussion with manufacturers, with contractors, and with building owners or their representatives, although some published data are also available.[16,18]

The comparison should provide information for at least the following questions.

- What is the cost for materials ($/ft²)?
- What is the estimated cost for materials and installation ($/ft²)?
- What is the cost for the desired warranty (include cost for additional coatings, etc., if required) ($/ft²)?
- What is the warranty term of coverage (years)?
- What is the cost for warranty extension beyond the initial term of coverage ($/ft²)?
- What is the estimated cost for maintenance ($/ft²)?
- Does the warranty cover workmanship of an approved contractor (yes/no)?

Practical distinctives
Membrane products should be compared on the basis of relative performance in service. The information required for this comparison is difficult to obtain. Moreover, this analysis is the most subjective of the product comparisons, yet it is necessary for the assessment of product durability and practical performance.

Determination of the first year of product use, as shown in Table 3, is an indicator of relative experience among manufacturers. Products may be in a continuous state of development, however, so it is possible that some of the "oldest" formulations are no longer being used. Additional information may be obtained by talking with contractors, building owners or maintenance supervisors, and competing manufacturers. The specifier should seek answers for the following questions.

To contractors and to building owners or supervisors:

- What product(s) do you prefer to use?
- What problems have you had with the products that you have installed?
- How difficult has it been to locate and to repair roof defects?
- How helpful is the manufacturer in assisting with roof repairs?

To competing manufacturers:

- How is your product superior to the others?
- What problems are the other suppliers having?
- The following problems have been alleged for your product; what is your refutation of these claims?

The answers to these and similar questions will be subjective conclusions; it is important that the specifier seek the basis for each answer so that a judgment can be made regarding the validity of each conclusion.

Manufacturer distinctives

Several manufacturers should be selected, from the long list of available manufacturers, that best satisfy the expectations of the specifier with regard to availability, service, and competence. The following considerations are important in the selection of a suitable manufacturer.

- Does the manufacturer offer prompt response to requests for sales and technical assistance?
- How thorough are the guidelines furnished by the manufacturer for the specification, detailing, and installation of the product?
- Will a representative visit the site prior to the bid process?
- Can the manufacturer dispatch a technical representative to the jobsite, upon request of the specifier?
- Does a representative inspect the job during installation?
- Does a representative make a final inspection?
- Does the manufacturer use only approved roofing contractors?
- Does the manufacturer have a list of approved contractors that are in business in the vicinity of the jobsite?
- Is the contractor required to submit a roof survey drawing to the manufacturer prior to job approval?
- Is the manufacturer solvent financially?
- Does the manufacturer have a list of product installations for the vicinity of the job locality?

These considerations should enable a specifier to develop a manageable list of roofing manufacturers for which the product distinctives may be studied.

The selection process

Modified bitumen manufacturers set forth general requirements and specifications regarding the installation of their products. While examining the product distinctives and manufacturer distinctives, the specifier must study carefully the individual specifications of each manufacturer in order to ensure that products being considered are appropriate for the particular project.

SUMMARY

Selection of a modified bitumen membrane is based on the experience and judgment of the specifier. The selection process is based primarily on subjective conclusions, such as the opinions of manufacturers, contractors, and the specifier, rather than on computational design principles involving material properties and job parameters. A rational procedure has been proposed to aid the specifier in the selection of the most suitable product for a particular job. The specifier should first accumulate a general data base, which involves the development of a library of roofing information. A list should then be formulated of the roofing manufacturers that best meet the criteria of the specifier. The roofing products of those firms should then be tabulated in a uniform format to discover product distinctives. Finally, for a particular roofing job, the specifier must develop a comprehensive description of the roofing requirements, noting particularly any project distinctives. The product selection may then be made by choosing the membrane whose distinctives best match the project distinctives.

REFERENCES

[1] Chaize, A., *Second International Symposium on Roofing Technology*, NBS, 116 (1985).

[2] Gorgati, R., *Symposium on Roofing Technology*, NBS, 93 (1977).

[3] Medlock, J., *Second International Symposium on Roofing Technology*, NBS, 134 (1985).

[4] Hendriks, N. A., *Second International Symposium on Roofing Technology*, NBS, 129, (1985).

[5] Haushofer, B., *Second International Symposium on Roofing Technology*, NBS, 265 (1985).

[6] "Elastomeric, Thermoplastic, and Modified Bitumen Roofing," *Technical Report*, CIB W.83 & RILEM 75-SLR JOINT COMMITTEE, October 1986.

[7] Halasz, A., *Second International Symposium on Roofing Technology*, NBS, 123 (1985).

[8] Kraus, G., *Second International Symposium on Roofs and Roofing*, Brighton, 17 (1981).

[9] Laaly, H. O. and Ashton, H. E., *Second International Symposium on Roofs and Roofing*, Brighton, (1981).

[10] Dupuis, R. M., *Roofing Spec*, November 1983, p. 32.

[11] Meynard, J. Y., *Roofing Spec*, June 1982, p. 22.

[12] Rossiter, W. J., Jr. and Mathey, R. G., "Elastomeric Roofing: A Survey," *NBS Technical Note 972*, 1978.

[13] Mertz, E. C., *Plant Services*, April 1984, p. 38.

[14] Laaly, H. O., *Second International Symposium on Roofing Technology*, NBS, 42 (1985).

[15] Busching, H. W. and Porcher, J. P., Jr., "Roofing Industry Perspective and Research Capability," *ORNL/SUB/82-22293/2*, 1985.

[16] *NRCA Roofing Materials Guide*, August 1986.

[17] *The NRCA Roofing & Waterproofing Manual*, January 1983.

[18] Mahoney, W. D. (Editor-in-Chief), *Building Construction Cost Data 1986*, R. S. Means Co., Inc., 1985.

[19] Blanken, T. C. and Gooswilligen, G. van, "Bitumen/Polymer Blends for Premium-Quality Roofing Products and Systems," Shell Research B. V.

Material	Elongation (percent)[1]		Fatigue endurance (cycles)[3]	Temperature of cold bend rupture (°C)[4]
	Ultimate	Permanent set[2]		
Oxidized bitumen	140	>100	1	− 5
Blend with 14% SBS	2200	9	>10000	−40
Blend with 30% APP	400	>300	700	−10

[1]Based on ASTM D2523-66T/D412 for specimens conforming to ASTM D1708-70.
[2]Deformation remaining after 24 hours relaxation of a specimen extended to 1500% elongation, or to rupture.
[3]Specimens cycled at 1 cycle/minute by steel plates with a gap separation varying from 1 to 2 mm.
[4]Specimens bent over 30 mm mandrel in 5 seconds (modified DIN 52123).

Table 1 *Comparison of selected physical properties (after Table 1 of Blanken and Gooswilligen[19])*

Single-ply category	Method of attachment	Relative installation rate[1]	Relative cost[2]		
			Materials only	Installation only	Total, with overhead and profit
Chlorinated polyethylene (CPE), 40 mils	Partially adhered	2.32	3.68	0.30	1.53
Chlorosulfonated polyethylene, (CSPE), 45 mils	Ballasted	3.18	3.60	0.22	1.46
	partially adhered	2.32	4.03	0.30	1.67
Ethylene propylene diene monomer (EPDM), 45 mils	Ballasted	3.18	1.45	0.22	0.67
	Partially adhered	2.32	5.00	0.30	2.03
	Fully adhered	1.59	2.00	0.46	1.01
Modified bitumen, 150 mils	Ballasted	1.45	2.00	0.50	1.03
	Partially adhered	1.14	1.75	0.64	1.03
	Fully adhered (torch)	0.91	1.75	0.78	1.13
	Fully adhered (asphalt)	0.91	1.88	0.78	1.18
Neoprene, 60 mils	Partially adhered	2.32	4.38	0.30	1.79
	Fully adhered	1.59	3.68	0.46	1.63
Polyisobutylene, 100 mils	Ballasted	3.18	3.50	0.22	1.43
	Partially adhered	2.32	3.25	0.30	1.38
	Fully adhered	1.59	3.50	0.46	1.56
Polyvinyl Chloride (PVC), 48 mils	Ballasted	3.18	1.75	0.22	0.78
	Partially adhered	2.32	2.65	0.30	1.16
	Fully adhered	1.59	2.95	0.46	1.36

[1]This ratio gives installation rate relative to that for a 3-ply Type IV glass fiber felt built-up roofing membrane, reported as 2200 ft^2/day.[18]

[2]This ratio gives costs relative to those for a 3-ply glass fiber felt built-up roofing membrane, reported as \$0.40/ft^2, \$0.50/ft^2, and \$1.20/ft^2 for materials only, for installation only, and for total cost, respectively.[18]

Table 2 *Illustrative comparison of selected single-ply membranes relative to a built-up roofing membrane (three plies of Type IV glass fiber felt, mopped) [after* Building Construction Cost Data 1986,[18] *a 1985 publication by R. S. Means Company, Inc. of average material and labor costs for 30 major U.S. cities, for use in engineering estimates of building costs. Caveat: The reader is cautioned that these data are not current.]*

Characteristic reported (units)	Category of bitumen modifier[1]	Number of products reporting	Minimum value reported	Average of reported values	Maximum value reported
Thickness (mils)	SBS	58	40	128	200
	APP	56	118	160	200
	Others	7	70	170	320
	ALL	121	40	145	320
Weight (psf)	SBS	52	0.30	0.88	1.65
	APP	55	0.60	0.93	1.25
	Others	7	0.50	1.16	1.75
	ALL	114	0.30	0.92	1.75
Minimum workable temperature (°F)	SBS	45	0	23	50
	APP	57	0	24	45
	Others	7	−30	0.7	35
	ALL	109	−30	22	50
Maximum workable temperature (°F)	SBS	43	100	120	150
	APP	55	100	121	140
	Others	7	120	131	150
	ALL	105	100	121	150
First year of foreign use	SBS	30	1966	1974	1984
	APP	45	1960	1967	1983
	Others	6	1965	1968	1970
	ALL	81	1960	1970	1984
First year used in USA	SBS	44	1972	1982	1985
	APP	47	1976	1981	1986
	Others	6	1965	1977	1982
	ALL	97	1965	1981	1986
Breaking strength, MD (lb/in)	SBS	35	51	246	677
	APP	35	67.2	226	392
	Others	0	–	–	–
	ALL	70	51	236	677
Ultimate Elongation, MD (%)	SBS	35	7	67.4	215
	APP	35	4	49	87
	Others	1	–	57	–
	ALL	71	4	58.2	215

[1]Others (APP and SBS, Nitrile, ECB)

Table 3 *Summary comparison of selected characteristics for modified bitumen products listed in the NRCA* Guide[16]