DURABILITY OF THE SBS-MODIFIED BITUMINOUS DOUBLE-LAYER SYSTEM: CORRELATION BETWEEN PERFORMANCES AFTER ARTIFICIAL AND NATURAL AGING

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The first styrene-butadiene-styrene (SBS) modified bitumen membranes were applied in France in 1969 and are now over 20 years old. The first assessment of these membranes was made at the end of 10 years by taking samples from work sites located in the mountains, the plains and on the seashore. The results were then published. It has already been possible to make a correlation between artificial aging in ventilated ageing chambers, and natural aging on-site after 10 years.

A second assessment was necessary after 20 years, by taking samples on the same sites, one on a mountain and one on the seashore.

This paper will report on the results of the comparisons of the 10 and 20-year samples, and add an assessment made of two other sites after 10 years; one site in Africa and one in Florida. Also, an assessment of a gravel-protected, double-layer system.

The author gives his conclusions on the durability of this type of complex, on the correlation with artificial aging allowed by international standards and on the prospects for development of the technology in the area of building waterproofing.

KEYWORDS

Cold bending, creep testing, elasticity, GPC—gel permeability chromatography, polymer content, ring/ball temperature, SBS—styrene-butadiene-styrene.

INTRODUCTION

When the first applications of the SBS-modified bituminous, double-layer system were made in France, Siplast engaged in a major industrial gamble—to transform the public's image of the traditional multilayer membrane made with oxidized bitumen materials for the waterproofing of flat roofs and terraces. This image had been tarnished by a series of problems due to the unsuitability of these multilayer membranes for light building structures and increased thermal insulation. These applications confirm the laboratory studies made since 1966, based on the true behavior of the coating material during its elastic phase, and on the behavior of the binder during artificial aging.

Considerable literature has been written in France, Europe and throughout the world since then on the subject, allowing an improved insight into SBS-modified bituminous mixtures and also mixtures that are plastic or elastic.

However, the assumed durability, based on artificial aging in a ventilated chamber at 70°C for six months, remained to be proven on-site.

This test estimated that the working life of the system could be 30 years, considering changes in the binder performances. This paper will not expand on the reason for selecting any particular type of aging-reduction agent because many papers have already been written on the subject.

However, it was necessary to prove that the theoretical study was confirmed in practice over time. This was the reason only a few sites were selected and monitored.

This paper is devoted to an assessment of the self-protected, SBS-modified bituminous, double-layer system after 20 years on exposed sites.

For the purpose of this paper, two sites in different climates in France were chosen; one on the seashore at Biarritz, near the Atlantic Ocean, close to the Spanish border, and the other in the mountains at Vougy, in the Haute-Savoie, near Geneva, Switzerland.

The paper will integrate the assessment made after 10 years on the same sites, which was published in Siplast's review "Les Cahiers de l'Etancheur," October 1983.

It will also discuss, to complete and widen this assessment, the results obtained after 10 years on two sites outside France; a site in Jacksonville, Florida, USA, and a site in Brazzaville, Republic of Congo, Africa. These sites are interesting because of their different climates, the presence of thermal insulation and the work of construction by a different type of worker, e.g., hot asphalt poured in France, hot asphalt mopped in the USA, and hot asphalt poured, cooled and the second layer torched on coated asphalt in Africa.

This paper is divided into a description of the work and of the materials, and a comparison of the performances of the binder extracted from the systems, with the minimum figures required by the UEAtc Directive, "Bitumens—SBS Elastomers," January 1984.

Samples were taken from the two French sites, after 10 years and also 20 years, to be analyzed by both the Centre Scientifique et Technique du Bâtiment at Grenoble and by Siplast's research laboratory, for better correlation of results.

Visual examinations made on-site by the persons in charge of sampling gave rise to no particular remarks on the condition after 10 and 20 years—very good aspect, no crazing, no cracks and good adhesion of the factory-applied protective granules. (See Table 1 for a description of the work and the materials.)

ASSESSMENT OF BINDERS EXTRACTED FROM SAMPLES

The assessment was based on the binders and not on the reinforced sheets. Therefore, the analyses were based on the SBS-modified bitumen separated from its mineral fillers with all traces of the reinforcement removed by preliminary filtration.

Tests were made carried out using gel permeability chromatography (GPC) to separate the polymer from the bitumen. The CSTB employed a Waters ALC/GPC 201, and Siplast's lab used a Waters ALC/GPC 150. The position of the polymer peak after aging is marked on every chromatogram. The molecular weight of the polymer is expressed in equivalent weight of polystyrene compared to the outlet position of samples of standard polystyrene of known mass. Further, measurement of the surface area of the polymer peak allows quantification of the polymer present in the bituminous binder. It was possible to base calibration on the nature of the SBS polymer used at the time of site work.

Creep Testing to Measure the Binder Elasticity

This method stems from that detailed in the CSTB instructions of March 1983. It consists of submitting a test piece of binder, 40mm x 50mm x 2mm, to creep for 24 hours under a load of 0.014 MPa. The load is removed after noting elongation (Ef), and then, after 24 hours at rest, the residual elongation (Er) is measured.

The rate of elastic return is then:

$$\text{Elastic ratio Te } (\%) = 100\left(1 - \frac{Er}{Ef}\right)$$

The Te of a binder that is not elastic is 0 percent and the Te of a fully elastic binder is 100 percent.

Method of Elastic Elongation Described in the UEAtc Directive, "Bitumens—SBS Elastomers," for the Measuring of Binder Elasticity

Materials needed for the test include a traction machine, glass plate, test tube (100mm x 20mm x 2mm), and two test pieces, conditioned in a standard climate chamber.

Draw at a traction speed of 300 mm/min. and maintain the sample at the predetermined elongation for 24 hours. Release tension for 24 hours and again measure the sample to calculate the residual deformation.

Repeat the test by increasing the elongation by 25 percent up to maximum elongation, allowing the sample to return to within five percent of its initial length.

Method Described in AFNOR Standard T 66-008 and in AFNOR Standard T 66-004

The method described in AFNOR Standard T 66-008 is for the measuring of softening points and in AFNOR Standard T 66-004 is for measuring penetration at +25°C.

Method of the UEAtc Directive, "Bitumens-SBS Elastomers" for Cold Bending

The method described is for cold bending on a test piece 2mm thick, and on a mandrel 20mm in diameter.

Interpretation of Results

Table 2 summarizes the results of the analysis and compares the results on the basis of three major factors:

- Minimum performance characteristics of the binder in SBS-modified bitumen determined by the UEAtc Directive applicable to all such materials employed in Europe.
- Characteristics and performances of the binder were sampled on an in-plant line before manufacturing into sheets, and after six months aging at 70°C in conformance with the UEAtc Directive.
- Characteristics and performances of the binder extracted from samples taken on-site of prefabricated sheets after 10 and 20 years of natural exposure.

The advantage of this comparison is that it is possible to correlate two types of aging and thus estimate the durability of the mixture.

Polymer Content

Results are only given for information. This percentage is not imposed by the European Directive in order to avoid delaying the normal progress of SBS polymers in the chemical industry. Only the performance of the binder resulting from the mixture of bitumen and polymer is to be adopted. Nevertheless, it is interesting to note that this percentage, after 20 years, reflects the performance capabilities of modified bitumen.

Molecular Weight of Polymer

The molecular weight of the polymer depends on its nature and is only given to complete the information on its percentage in the mixture.

The weight is calculated only from the upper layer after 10 years, and from the two layers after 20 years, given the molecular weight of the polymer employed on these sites was 170,000.

Elasticity

This is one of the most important characteristics required of the binder since it governs the reaction of the system to cyclic movements of the roof (notably in the case of joints between thermal insulation panels).

This is why the European Directive has determined minimum figures applicable before and after aging. Details of the two measuring methods have been given, stemming from the directive, and the other from the CSTB laboratory, of which the latter is the easiest and most reliable.

The results confirm that the blend is reliable and stable after 10 and 20 years.

Ring/Ball Temperature or Temperature Bille Anneau (TBA)

This characteristic before and after aging is specified in the UEAtc Directive. Though it may not be decisive for the durability of the mixture, sudden deterioration of results after aging may be one of the indicators of damage to the mixture's polymer chains.

Penetration of the Blend at 25°C

This characteristic was not adopted in the UEAtc Directive, but the author believes it can complete the criteria used to assess the mixture by giving information on the hardness of the binder and on any changes of hardness.

Cold Bending

This performance can be obtained on the binder and also on the sheet, and can complete the information given on elasticity for the following reasons:

- Tests of the blend's homogeneousness.
- Tests of the polymer content to gauge the working life of the blend and its quality over time.
- Practical handling on-site; in relation to unrolling the sheet without cracking or adherence to the sheet, and in operation to the reaction of the system to cyclic movements due to temperature deviations.

The results of examining sheets after 20 years (lower and upper sheet) show there is an excellent correlation between natural and artificial aging. The results also reveal that the safety factor is good when the requirements of the directive are compared with the performance of the samples.

Puncture Resistance, Tensile Tear and Cyclic Fatigue

These performances cannot be tested on sheets on systems. This was not the subject of the study which was limited to the durability of blend after natural aging. This investigation will be pursued in a second study in which performances will be tested in accordance with UEAtc Guideline and Recommendations of RILEM 75-SLR/CIB W83—Joint Committee on Elastomeric, Thermoplastic and Modified Bitumen Roofing, November 1988.

CONCLUSION

This investigation and subsequent publication of the SBS-modified bitumen test results was essential.

When the first French approval was made by the CSTB in 1973, the experts, who were members of the commission, based their opinion on a laboratory study and on experiments done at 300 sites in France which were fairly new. When the approval was renewed in 1975, it was based on a wide range of factors including different types of slopes and substrates, and the assessment of durability allowed for this. The approval has been renewed every three years, since no particular problems have been mentioned by contractors, engineers and architects and owners.

A more complete response was therefore needed to the questions that remained pending:

- What were the changes of the characteristics of the first generation of binders after 20 years of natural exposure.
- What final correlation can be made between artificial and natural aging.

The results listed after 10 and 20 years in France, and after 10 years in a hot and humid atmosphere, show that they conform in every way to laboratory results. These results are stipulated in the UEAtc Directives, adding a certain safety margin. The initial published results have been confirmed, i.e., the artificial aging for six months at 70°C is equivalent to natural aging over 25 years on-site.

Results from Table 2 indicate that when the lower sheet is protected by hot asphalt the aging of the upper sheet is slowed, enhancing its durability. Therefore, in cases of extreme stress, a stronger reinforcement in this lower sheet of a two-ply system would further increase the durability of the system.

However, the author would like to make a few additional observations stemming from the system based on manufactured sheets. The study was based on the durability of the SBS-modified bitumen binder alone, which ensures good waterproofing, and not on the system. Yet, it is common knowledge that every waterproofing system must be studied in relation to several parameters:

- Nature of the substrate.
- Nature and thermal resistance of the insulation.
- Final use of the system.
- Accessibility to traffic.
- Climatic data such as sun, stagnant water, snow and ice.
- Possible upkeep and maintenance.

Therefore, selection of the basic binder must include selection of the additional reinforcement, of the protective surface, of the link with the substrate and of the method of applying the system making, full allowance for local habits and regulations imposed in the country, such as fire regulations.

This contribution should allow the roofing profession to gain a better insight into the SBS-modified bitumen mixture. This is, however, only one stage. The technology of mixing, and the natures of the polymer and of the bitumen are likely to change. Thus, conclusions cannot be final since this assessment will have to be repeated during the coming years on new formulas.

Hopefully, the same assessments can be made for other categories of membranes, whether they are based on modified bitumen, thermoplastic resins or elastomers. A certain number of standards, guides and codes to practice are in fact being implemented in and outside Europe, which are increasingly based on notions of performance and should relate to the behavior of membranes before and after aging. It may be possible and relatively easy to indicate performances after artificial aging, but it is much harder to correlate such aging with natural aging because of the time required. However, such a correlation is essential even if it leads to changes of certain criteria used for assessment, when considering the results.

Therefore, such a system of correlation should be systematically conducted after 10 years on-site, with an intermediate stage after five years, as on the blend, the sheets and the systems.

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REFERENCES

J.C. Marechal, CSTB Grenoble, "Etude de la degradation thermique des liants en Bitume-Elastomere SBS," CSTB France, September 1984.

A. Noordam, Shell International London, "Polymer-modified bituminous roofing system."

J.Y. Meynard, Siplast, "European developments in rubber/bitumen," New Orleans Symposium, April 19-23, 1983.

ACRONYMS

AFNOR—Association Francaise de Normalisation (French Standards Association), CIB—International Council for Building Research Studies and Documentation, CSTB—Centre Scientifique et Technique du Batiment de Paris, France (Scientific and Technical Building Center), RILEM—International Union of Testing and Research Laboratories for Material and Structures, TBA—Témperature Bille Anneau (Ring-Ball Temperature), UEAtc —Union Européenne pour l'Agrément Technique de la Construction (European Union of Agrement).

	FRANCE	FRANCE	UNITED STATES	AFRICA
	Residence Sunset at BIARRITZ, 64	The Martin plant at VOUGY, 74	Carroll-Tire warehouse JACKSONVILLE, Florida	The Meridien Hotel BRAZZAVILLE, Congo
UTILIZATION	Apartment building	Industrial plant	Storage	Hotel
Surface area	1,000 m2	400 m2	1,000 m2	500 m2
Gradient	0%	3%	0%	1%
Year of laying	1970	1970	1979	1980
Bearing surface	Concrete	Concrete	Concrete	Concrete
Heat insulation	—	—	FESCO-BOARD	FESCO-BOARD
Waterproofing system	Double layer, SBS modified, in half-adherence to the concrete by cold glue. Two sheets torched together	Double layer, SBS modified, in half-adherence to the concrete by cold glue. Two sheets together by hot-oxidized bitumen.	Double layer, SBS modified, in adherence to the insulation by hot-oxidized bitumen. Two sheets together by hot-oxidized bitumen.	Double layer, SBS modified, in adherence to the insulation by hot-oxidized bitumen. Two sheets together by hot-oxidized bitumen.
Description of system	1st layer: 2mm thick, sanded both sides and reinforced with one layer of non-woven glass fabric. 2nd layer: 2mm thick, sanded one side and protected on one side, reinforced with one layer of non-woven glass fabric.	1st layer: 2mm thick, sanded both sides and reinforced with one layer of non-woven glass fabric. 2nd layer: 2mm thick, sanded one side and protected on one side, reinforced with one layer of non-woven glass fabric.	1st layer: 2mm thick, sanded both sides and reinforced with one layer of non-woven glass fabric. 2mm thick, sanded one side and protected on one side, reinforced with one layer of non-woven glass fabric.	1st layer: 2mm thick, sanded both sides and reinforced with one layer of non-woven glass fabric. 2nd layer: 2mm thick, sanded one side and protected on one side, reinforced with one layer of non-woven glass fabric.

Table 1 Description of the work and the materials.

Characteristics of binder in SBS modified bitumen	Characteristics given by the UEAtc Directive. "SBS modified bitumens", January 1984	Characteristics of the binder after articicial ageing at 70°C				Characteristics of the binder extracted from samples after 10 and 20 years						
		0 day	1 month	3 months	6 months	Position of sheets	SUNSET BIARRITZ		MARTIN VOUGY		JACKSONVILLE USA	BRAZZAVILLE CONGO
							After 10 years	After 20 years	After 10 years	After 20 years	After 10 years	After 20 years
Polymer content (%)	not required	15	13	11,5	10	Lower	N.M.(1)	11	N.M.	10,3	N.M.	N.M.
						Upper	12	10	12	11	N.M.	N.M.
Molecular weight (%)	not required	—	—	—	—	Lower	N.M.	185000	N.M.	185000	N.M.	N.M.
						Upper	170000	185000	200000	185000	N.M.	N.M.
Elasticity ratio TE (%)	new: ≥100 aged: ≥25	200	150	125	25	Lower	N.M.	78	N.M.	84	60	58
						Upper	75	72	80	73	58	55
T.B.A. (°C)	new: ≥110 aged: ≥100	130	125	120	110	Lower	118	110	110	102	105	102
						Upper	112	107	108	103	102	100
Penetration at 25°C	not required	35	25	22	20	Lower	35	36	38	40	42	40
						Upper	33	30	36	37	40	38
Cold bend (°C)	new: ≤ −20 aged: ≤ −5	−30	−25	−25	−20	Lower	−25	−25	−23	−20	−20	−25
						Upper	−22	−20	−20	−20	−20	−20

(1) N.M.: not measured

Table 2 Expression of the results.