ELASTOMER SBS MODIFIED BITUMENS: A COMPARATIVE STUDY OF THREE SPECIFIC DOCUMENTS

MRCA RECOMMENDED STUDY PERFORMANCE CRITERIA (USA)
UEAT GUIDELINES (WESTERN EUROPE)
DIN STANDARD PROJECT (FEDERAL REPUBLIC OF W. GERMANY)

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The CIB W 83-RILEM SLR 75 Committee organized a project to study performance criteria standardization of waterproofing materials for roofing use. The present work is a contribution to the project. It compares three documents that define the elastomer SBS modified bitumens. These are: a DIN standard project of a prescriptive nature and of conventional standardization, a recommendation by the MRCA, an association of entrepreneurs (builders, contractors) in the Midwestern region of the United States, of a performance criteria nature; and the UEAT Guidelines established by the cooperation of several European institutes.

The comparison relates to these materials' performances, and their occasional dangers when product quality and durability are not sufficiently taken into consideration.

The conclusion is that the CIB-RILEM project will probably produce a recommendation that includes a combination or synthesis of these documents. The general performance criteria approach appeared entirely possible, providing that it leads to classifications of materials in terms of their performances and to classifications of usage in terms of climate or other fixed requirements of workmanship, such as accessibility.

The principles for these classifications are reviewed in this paper. In addition, durability is examined as a factor in performance. A method of evaluation is suggested for the elastomer SBS modified bitumens that has proven to be well-founded.

At a time when an international standard for waterproofing materials is needed, it seemed useful to compare three documents on this subject which are recent yet address different levels. The UEAT Guidelines pertain to general performance requirements whether the waterproofing materials are known or not. The MRCA recommendations and the DIN Standard project specifically aim at materials that have been known for many years. It follows that the comparison only will involve essential performance levels, the impact that have been known for many years. It follows that the comparison will only involve essential performance levels, the impact that each of these documents can have on the quality of the product, and the risks and advantages they afford to the user.

The conclusion will be critical for each of these three documents. Using a modern performance criteria approach, the specifically prescribing character of the DIN standard project obviously appears too rigid and apparently falls short where durability is concerned. The MRCA recommendation and UEAT Guidelines follow similar approaches on the performance level but differ on methods and sometimes in spirit, probably because the history and pathology of waterproofing has followed different paths in Europe and the United States.

A synthesis of the two approaches probably would be of value in ensuring the success of an international performance standard, and it will no doubt be the honor of the CIB W 83-RILEM SLR 75 Committee on Monoliner Waterproofing to achieve this, under the direction of William Cullen.

The plan is the one used by the CIB RILEM committee to study monoliner waterproofing membranes. It takes into account three types of general characteristics for the membranes.

- mechanical resistance
- hot/cold performance
- durability

MECHANICAL RESISTANCE

The following functions are grouped under this heading:

- resistance to movement of the supports
- resistance to punctures
- resistance to stress induced by temperature variations
- resistance to wind effects

RESISTANCE TO MOVEMENT OF THE SUPPORTS

One can note three different approaches to this essential problem:

- The MRCA proposes a material classification into three categories using the formula stretch factor x rupture tension at low temperature (−18C, 0F) that represents the strain energy at low, medium, and high levels. However, the MRCA does not propose any directions for the use of this classification, in terms of admissable movement for each energy level. Also, it requires a resistance level of 10 back-and-forth cycles under cold conditions.
- The UEAT proposes a resistance requirement of 500 back-and-forth movements of the supports under normal testing conditions. The test will graduate in severity by varying the temperature and amplitude conditions. This

appears as the start of an unfinished classification.

- The DIN project chooses two reinforcements: JUTE 300g/m² (1 ounce per square foot), and fiber glass 200 g/m² (⅔ ounce per square foot) which could belong to a "high stretch x high resistance" class that the MRCA recommendation does not seem to question for its usefulness. The DIN project points to the similar characteristics criteria in the three directions (length, width and diagonal), yet only applies it to polyester.

To judge these three approaches, one must keep in mind that the resistance of liners to the movements of their supports (reinforcements) has been the object of several mathematical models and that work is continuing in this area. It obviously is out of the question to use such models in the normalization of waterproofing materials, but one cannot ignore them when taking a performance approach. What does this teach us?

a) In certain models, it is assumed that the membrane has elastic qualities, and the allowable movements are controlled in a way whereby the efforts and induced deformations do not exceed the elastic limit of the waterproofing materials. This leads to a life duration theoretically infinite. Of course, this approach is incomplete and slightly conventional, yet relatively simple to manage. The French code of practice has been inspired by these principles for the past five years.

b) In other models, one takes into consideration the "real" visco-elastic behavior and one attempts to establish a relationship between amplitude, frequency of movement, and the lifespan of the waterproofing materials in use. The model is rigorous yet the management is more complicated.

c) All of the models prescribe that the movements of the supports take place in two ways: opening of a joint and closing of a joint. The opening of a joint leads to tension strain in the membrane sheets, and the closing leads to compression strain.

Thus, it can be seen that the allowable amplitude for the movement is, according to the following performance approach, the limit of the break (rupture) in traction or compression (one single movement during lifespan), the limit of elasticity in traction or compression (undefined repeatable movements), or the limit of fatigue (certain number of movements during the lifespan).

One is able to imagine somewhat simple tests for measuring the limits retained in traction; however, a method for measuring the limits in compression in unknown. Moreover, the movement of compression is limited by the collapse of the reinforcement, which we cannot measure either. Now, the authors generally agree that the performance of the membranes is less in compression than in traction, notably because of collapse. This is shown by the numerous examples of folds in the sheets adjoining the support joints. It is worth noting that systems of several reinforcements (multiple liners) are, in this case, preferable to a single reinforcement since the resistance to collapse is improved.

Thus, creating a simple but realistic method of evaluation is difficult. Membranes must be classified as well as reinforcements and assemblies. These classifications must correspond to obtain the optimum roofing design at the lowest cost. Such a classification method has yet to be established, but can be with a synthesis of both MRCA and UEAT approaches. The organization would consist of the following:

Classification By (of) Endurance	Classification of Strain Energy (MRCA)	Classification of (by) Systems Support & Assembly
(test) E1	ExS weak/low	Risk (hazard) #1 weak
(test) E2	ExS average/medium	Risk (hazard) #2 average
(test) E3	ExS strong/high	Risk (hazard) #3 strong

The classification of liners ought certainly to take into consideration the movements in compression.

For example, risk number one considers the independent systems, or those glued to the mineral insulators of approximately one meter, risk number two, the gluing of the wood boards, and risk number three, the gluing of plastic rubber wood insulators.

RESISTANCE TO PUNCTURES

The UEAT has been unique in its attempt to deal with puncture resistance which leads to a classification of waterproofing systems and supports (reinforcements) on the one hand, and a classification of roofs according to the accessibility and the constraints of the work site on the other hand. Combining the two classifications leads to an accurate design of roofing at the lowest possible cost. MRCA proposes using the UEAT test without resuming the principle of classification or determining requirements.

The DIN project suggests nothing in this area, aside from the selection of three reinforcements which should, in principle, present adequate resistance to static puncturing, at least for fiber glass and polyester.

A mathematical model does not exist for the problem of punctures. The practice of testing demonstrates that, for systems of reinforced bitumic polymers, the reinforcements provide resistance to static punctures and the total thickness provides resistance to dynamic punctures.

The logic of performance standardization would seem to lead to classification. It also would be satisfying to recall the classification principle of the UEAT group:

Resistance to Static Punctures	Resistance to Dynamic Punctures	Classification of Roofs
L1	I1	P1 weak risk (hazard)
L2	I2	P2 moderate risk (hazard)
L3	I3	P3 normal risk (hazard)
L4	I4	P4 strong risk (hazard)

As an example of risk P1, one may cite architectural roof designs of the arched dome type. The P2 risk may be represented by the roofs of single family dwellings; risk P3 by inaccessible terraces of joint dwellings (collectives), and P4 by circulables of private or public use.

RESISTANCE TO STRESS INDUCED BY VARIATION IN TEMPERATURE

The MRCA proposes a testing method including the possible effects of aging, yet does not propose requirements. One ought to be able to expect an allowable ratio between induced stress and the limit of rupture, or recommendations of use according to the measured value. The DIN project does not discuss this problem. The UEAT suggests (without great conviction) a global test upon models, with visual observation of eventual disorders. This method applied to several polymeric bitumen membranes did not produce useful results.

The mathematical models mentioned in reference to movement of reinforcements include those created by variations in temperature of the membranes, which add to those generated by the support in traction and compression. However, the calculations seem to indicate that the constraints and strains induced are weak before those generated by the supports, notably by cold temperature upon materials made rigid by low temperatures. Even if these constraints are weak, they are not to be ignored in the evaluation of our systems.

One may also suggest that the supporters of this test, most of whom are in the United States, try to associate the notions of induced strain and strain energy to produce a comprehensive requirement expressed in the same terms.

RESISTANCE TO EFFECTS OF WIND

MRCA and UEAT formulate regular requirements, and the DIN project does not. In effect, polymeric bitumens have adherence qualities equivalent to those of traditional bituminous systems, and one may use the regular supports with precautions against the wind.

UEAT advocates a general test method especially applicable to non-conventional assemblies and supports.

BEHAVIOR DURING SHORT-TERM EXPOSURE TO HEAT/COLD

Several problems may be listed under this general heading:

- manageability for implementation when hot and cold
- behavior when hot
- behavior when cold: flexibility and resistance in traction
- dimensional stability

MANAGEABILITY

MRCA and UEAT treat the problem by formulating general and qualitative requirements and a requirement for cold unrolling. The DIN project does not deal with this directly.

The qualities of flexibility and rigidity necessary for an accurate and simple implementation depend upon the binder and the reinforcement. For delicate torch application, where the flame partially melts the binder, the reinforcement ensures the rigidity and the thickness ensures thermal inertia. It thus is sound to require thick sheets adapted to torching, with no less than three millimeters according to MRCA and no less than four millimeters according to DIN guidelines. It would prove useless to consider heavier thicknesses, which become awkward and difficult to handle in upright positions. The ease of torching also depends upon the content of the filler and the anti-gluing product prevalent under the sheet. None of the documents give limitations for the fillers and the anti-gluing. The DIN prohibits calcereous fillers based upon very old reasons, considered debatable today.

BEHAVIOR IN EXTREME TEMPERATURES

The three documents have requirements for cold flexibility:

- MRCA −10C (14F)
- DIN −25C (14F)
- UEAT −15C (5F) for sheets and −20C (−4F) for a binder

DIN and UEAT have a requirement for hot non-drainage (outflow): 100C (215F)

Thus one may notice a difference in choice in the base limit. The characteristics of flexibility at low temperature and of outflow at high temperature are two criteria which should not be separated, for they provide what J.Y. Meynard called, the "Parameters of Temperatures of Utilization." Low and high temperatures and the gaps which separate them provide for the behavior of the roofing sheets being used, rather than for the conditions of application.

It appears, then, both expedient and economical to adapt the conditions of utilization to the conditions of use, while keeping in mind that the choice of limits will make the choice of raw materials more or less structured. These choices are not neutral from a cost, or a commercial point of view, nor are they neutral concerning the subject of durability for reasons which Meynard and A. Bruder, both directors of the Research Center for French Companies and Products of SBS Bitumens, have made evident (*Figures 1 and 2*).

RESISTANCE TO SLIPPING

Resistance to slipping is a question of reducing the risk of sliding upon slanted roofs and upright columns.

The UEAT and the MRCA have attempted the same test of verification over the course of seven days at 70C (160F). The DIN project does not propose additional data about the requirement of holding in heat in vertical suspension at 100C, without outflow.

The technique of implementation may influence the behavior.

DIMENSIONAL STABILITY

Dimensional stability deals with the question of shrinkage. Shrinkage appears progressively when the material is reheated. In different terms, both the MRCA and the UEAT require that shrinkage stabilizing at 80C, not exceed 0.5 percent. DIN sets forth but one requirement, that being the choice of G200 among reinforcements which offers the only guarantee of dimensional stability at 0.5 percent. Above all, it is the conditions of workmanship which dictate shrinkage.

DURABILITY

Under this heading, we find the provision for behavior of exposed waterproofing when coming in contact with aggressive agents. In reference to behavioral aspects, the intent is to become familiar with the speed (pace) of the variation of functional characteristics over the course of time. It is essential that apparently simple technical steps of a normalized procedure may be warranted, whenever possible, by a basic step which shows that it is well founded.

In Europe, where dealing with bitumic polymers is important, and in France, where the SBS bitumens are preponderant, it is considered useful to follow a basic approach justifying the choices of UEAT for evaluation of the durability of the SBS bitumens.

FUNDAMENTAL ASPECTS

The aging process of SBS elastomeric bitumens, its speed, and the correlation between natural aging and a conventional method of aging have been studied by several researchers. J.C. Marechal, CSTB, characterizes the SBS bitumens and their evolution by distribution of molecular masses on the one hand (*Figure 3*), and by the physical property of elastic recovery on the other hand (*Figures 3 and 4*).

His conclusions are summarized below:

> *"It has appeared that the initial rate of weak SBS (approximately seven percent) does not allow enough in reserve for the binder in order to sufficiently maintain the polymeric network progressively affected by the cutting of the bonds (sequences)."*

However, this is not the only parameter to consider, for resistance to aging also assumes that the bitumen is and stays compatible with the SBS and that blending is done correctly, while avoiding degradation of the polymer as much as possible during manufacturing.

The conventional ventilation oven treatment at 70C (160F) induces a deterioration of the SBS bitumic binder exactly comparable to that of natural aging. The correlation has been established among products aging naturally on roofs for four to 10 years. The durability of certain formulations may thus be extrapolated to 25 years.

Correctly blending bitumen with SBS is the most important consideration in resisting the aging process of the membranes. It also is difficult to apply in practice to current proposed tests, to factory quality control, and to verification of quality in a commercial setting.

TECHNOLOGICAL ASPECTS—ESSENTIAL CHARACTERISTICS AND TECHNOLOGY OF MEASUREMENT

The logical approach which allows for the transition of basic testing to industry is the following: from the conclusions of Marechal it may be said that the bitumen SBS blend offers a polymeric network combining elastic properties. The following conditions must exist in order for this to form and maintain itself:

- the bitumen and the SBS polymer should be as compatible as possible
- the dispersion should be as minimal as possible
- the rate of non-gradual SBS should be sufficient, yet more than 7 percent in any case

The artificial aging was done in an oven at 70C using test pieces of two-millimeter-thick bindings or sheet products of normal commercial thickness. The thick sheets displayed a much slower rate of aging.

A six-month exposure in an oven at 70C obviously is a heavy subjection. An extension of the study was done during 1984 which demonstrated that three months at 80C (176F) appreciably lends the same results. For reasons of obvious convenience, tests upon binders are preferred; their response to effects of aging is clearer and makes the influence of parameters of bituminous and polymeric composition more legible. This appeared evident in the graphs (*Figure 5*) drawn from publications from Ste SIPLAST where it can be seen that two types of bitumens of different aromaticity, two types of SBS polymers, or two rates of SBS lead to different aging evolutions.

The sheets of polymeric bitumen also may present an incompatibility among themselves or with bitumens oxidized in sheets or melted for glue treatment (soldering), if the asphaltic residual bitumens of different materials are incompatible when coming in contact with one another. UEAT has proposed a practical method for examining compatibility.

CONCLUSION

Several significant conclusions may be drawn from the above:

- An international standardization based upon performance criteria standardization is very possible.
- It should allow for flexibility to adapt basic functional characteristics to the geographic zones in which they are used and to the conditions of use in roofing. The standardization should result in a classification of resistance of waterproofing systems and a classification relative to the severity of usage.
- Becoming evident from such classifications is the resistance to the effects of wind, either already available such as in terms of resistance to punctures, or possibly being constructed as in terms of resistance to the movements of supports and stress induced by temperature. On the other hand, dimensional stability appeared to be an absolute requirement.
- Finally, the requirements for durability should be specifically formulated and inspected by a follow-up of the evolution of significant characteristics. Those that were able to characterize the SBS bitumens already were indicated.

Presently the UEAT regroups the Common Market members by excluding Greece, while including Spain, Austria, and Portugal. Also, it may be noted that C.S.T.B. is a French member of the UEAT.

These works are put into concrete form by the establishment and the publication of the following guidelines:

"General Guidelines for the Approval of Waterproofing Materials for Roofing," a document of a general nature based upon a performance approach which concerns itself with new types of waterproofing materials, either monoliners or biliners.

"Particular Guidelines":

- for monoliner materials of base width made of plasticized PVC without reinforcement
- for APP polymeric bitumen materials (essentially suggested to be monoliner)
- for materials of asphaltic residual bitumen modified by SBS. This guideline, essentially conceived for homogeneous biliner systems, is capable of being equally applied to monoliner systems.

TECHNOLOGICAL ASPECTS				
Base Requirements	Basic Char's and Methods of measure	Significant Properties	Possible Technological Tests Upon Binders	Possible Technological Tests Upon Sheets
Compatibility between the Bitumen and Polymer	Aromaticity of Bitumen (analysis by chromatography UV detection, refractometry)	No Separation	Exudation Development of char during aging	Exudation Development of char during aging
Quality of Dispersion	Continual Polymer Phase (fluorescent microscopy)	Elastic Recovery Preservation of properties in cold and heat	Conventional elasticity Cold bending and its development during aging	Resistance to support movements (fatigue) Cold bending & its development during aging
Rate of Polymer	Dosage & identification (by chromatography)	Extent of graph/gaps between temps of utilization	Cone penetration cold bending Its development during aging	Behavior in heat and cold bending Its development during aging

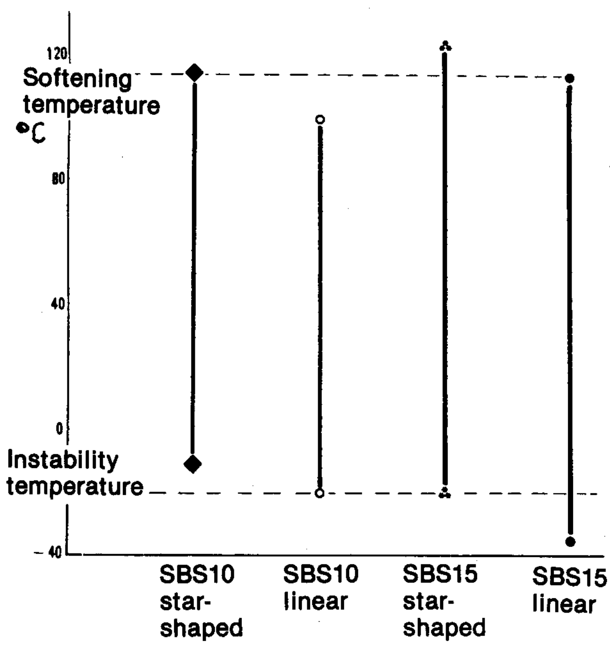

Figure 1 Graph of utilization temperatures (source: Siplast Corp. J.Y. Meynard)

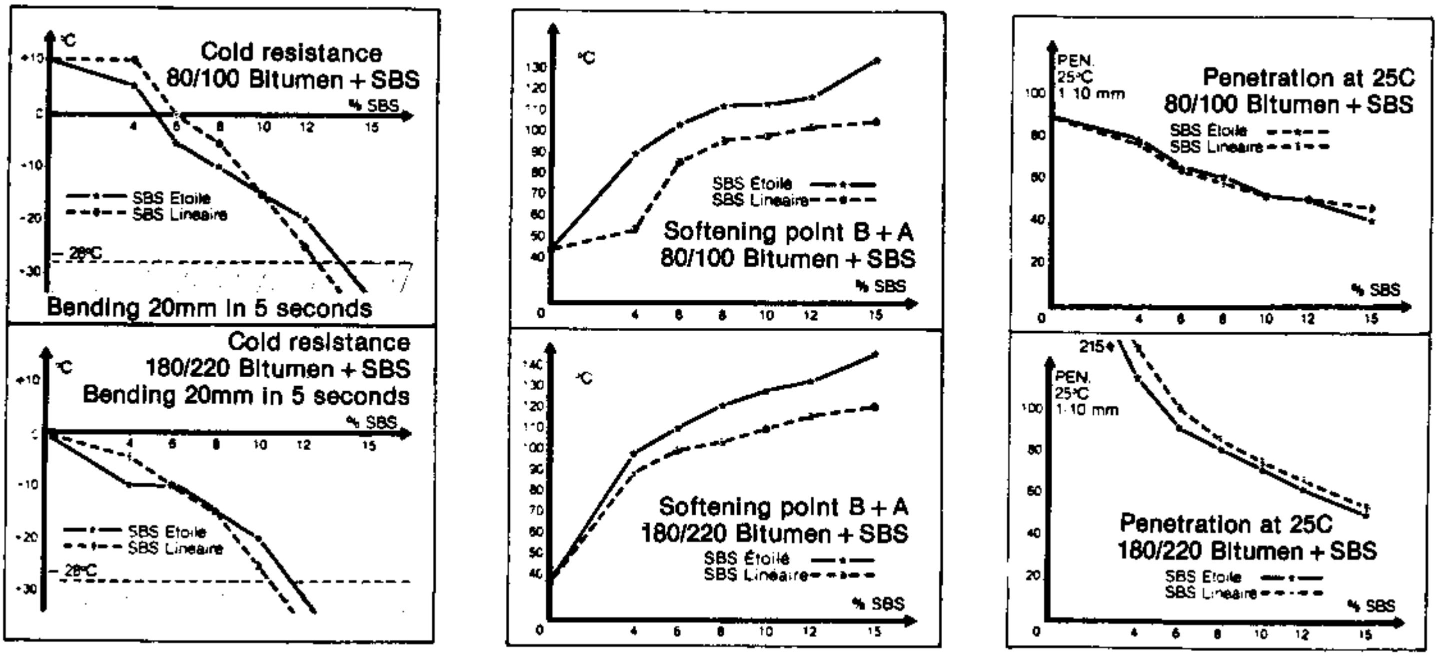

Figure 2 *Characteristics of SBS bitumens in terms of the parameters of manufacture: asphaltic residual bitumen, elastomer SBS type, rate of SBS (source: Soprema Corp., A. Bruder)*

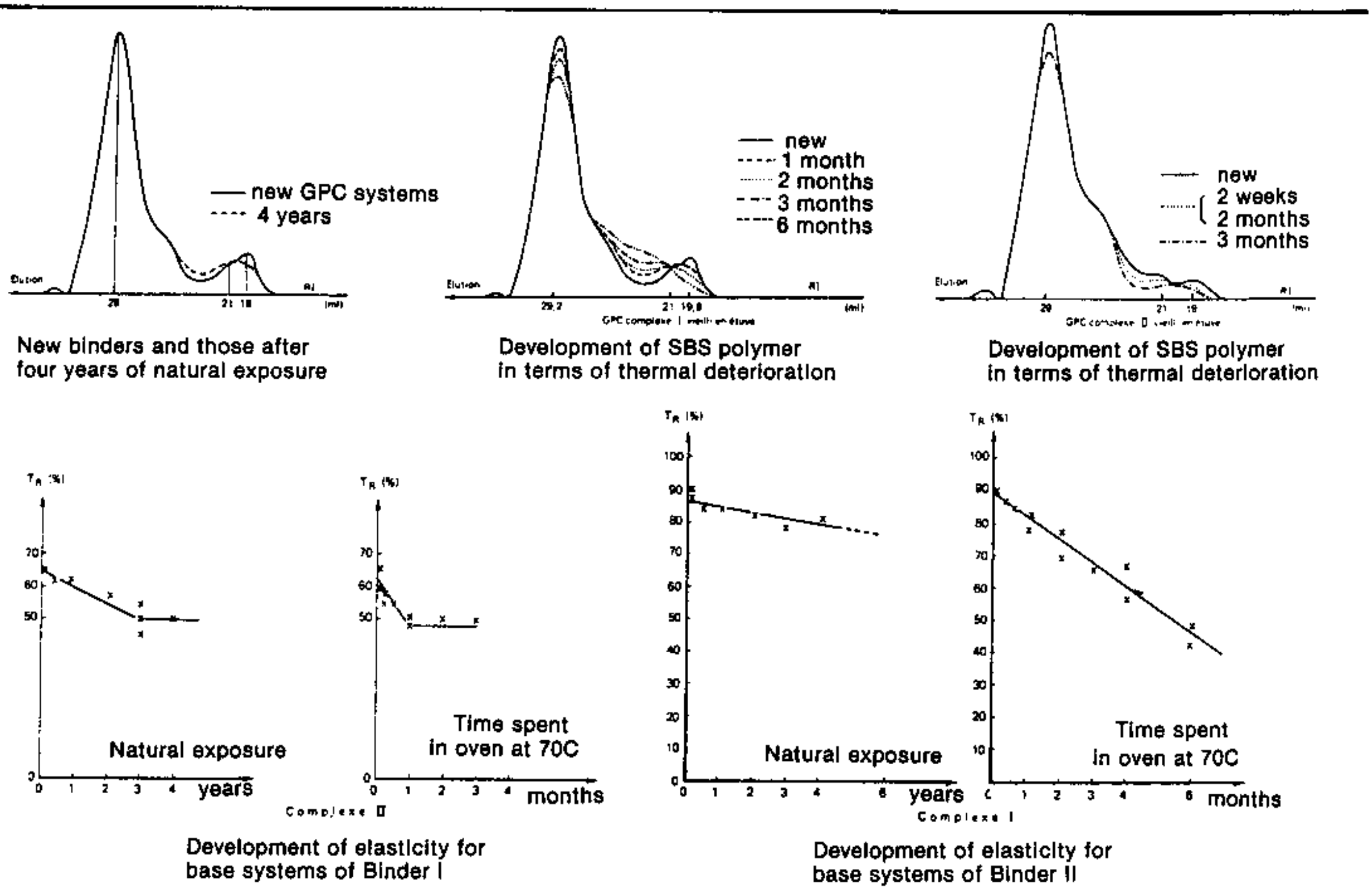

Figure 3 *Effects of natural and artificial aging upon the distribution of molecular masses and upon the elastic recovery of (the) binders SBS modified bitumen binders*

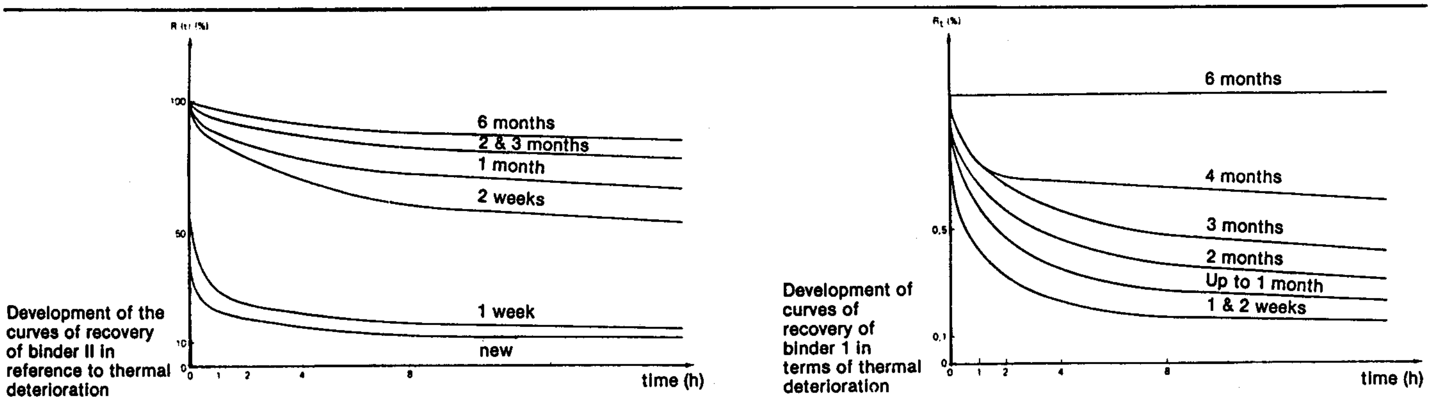

Figure 4 *Effects of artificial aging upon the elastic recovery of SBS bitumen binders (source: CSTB Marechal)*

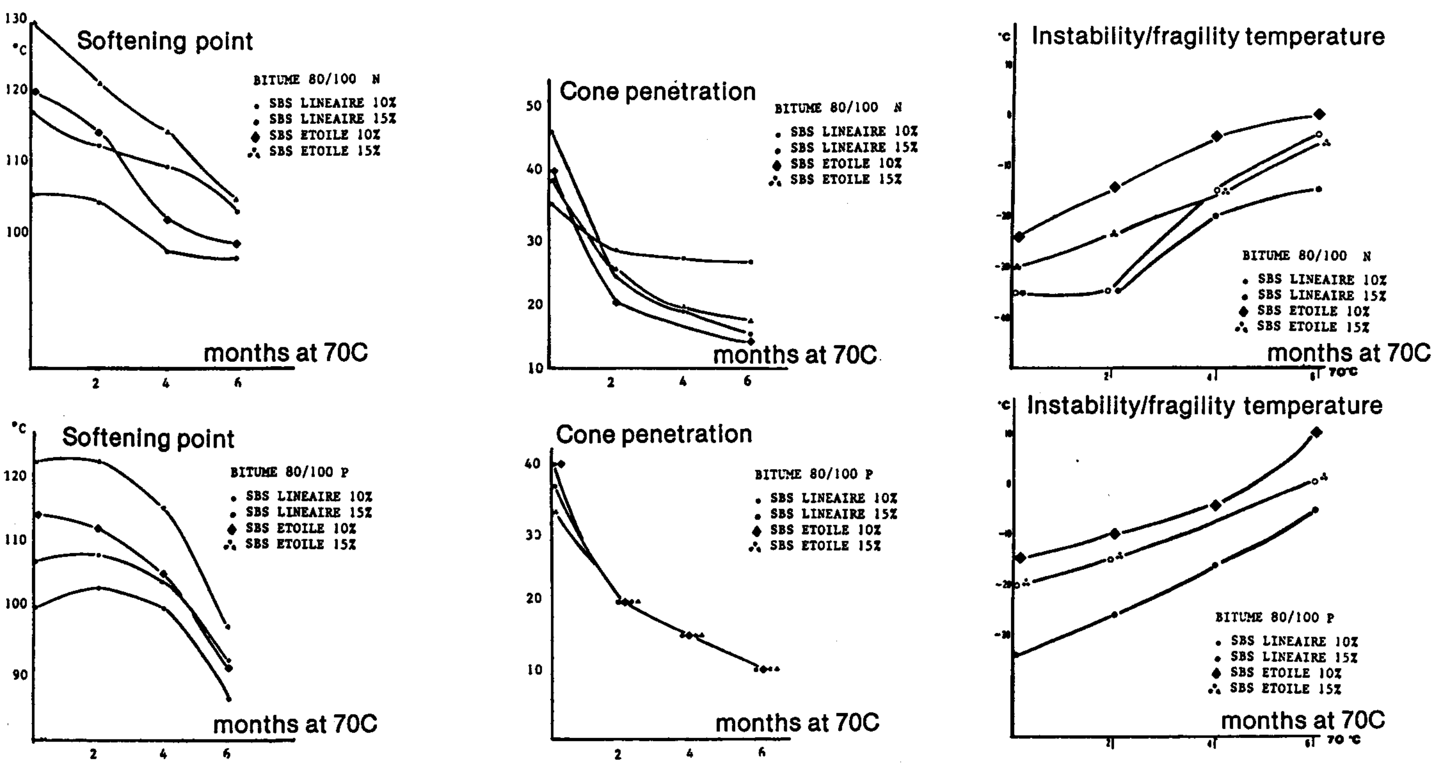

Figure 5 *Effects of artificial aging upon the characteristics of SBS bitumen binders, in terms of their composition: type of asphaltic residual bitumen, type of SBS, rate of SBS (source: Siplast Corp. J.Y. Meynard)*