Long Term Behaviour of Synthetic Roofing Membranes

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1 Introduction

A large number of thermoplastic and elastomeric roofing waterproofing membranes are used for the waterproofing of flat roofs. According to a report published in 1983 (1), more than 130 different roofing membranes from approximately 30 manufacturers were being offered on the German market. For most of these membranes, material standards were issued in the mid-nineteen eighties, in which the minimum specific requirements were established for each material (2). These standards are primarily meant to allow comparisons to be made between products as well as for quality control purposes in order to ensure consistent production-quality.

There have been surprisingly few publications that compare the ageing behaviour of waterproofing membranes (3 to 8). Up to now there are no generally recognised and standardised criteria to evaluate the ageing behaviour of waterproofing membranes.

An investigation program was carried out at the SKZ (South German Plastic Centre), sponsored by the Federal Minister for Area planning, Building Industry and Town Construction, in which different roofing membranes, present on the market, were submitted to 10 years natural ageing as well as to ageing in artificial weathering devices. The study was undertaken to examine the influence of:

- the type of weathering
- mechanical preloading
- bitumen contact with the membrane.

Samples were taken and analysed at different stages over a 10 year period.

The major factors that impact on products during weathering are radiation, temperature and humidity. Under external conditions, these factors are not mutually exclusive and act synergistically in combination with mechanical, chemical and biological influences.

2 Test materials

The tests were carried out using, thermoplastic as well as elastomeric industrial roofing membranes (Table I). The membranes were assigned, as far as possible, to the material standards that appeared in 1984 and 1986.

Table 1: Roofing membranes tested and standards

Test No. :	Base of Material	Abbreviation	Material Standard	Thickness (mm)
1	Ethylene-copolymer-bitumen	ECB-T2	DIN 16729	2.0
2	Ethylene-copolymer-bitumen	ECB-T1	DIN 16729	2.0
3	Ethylene-Vinyl acetate	EVA	-	1.2
4	Chlorinated polyethylene	PE-C	-	1.5
5	Chlorinated Polyethylene	PE-C-E-PW	DIN 16737	1.5
6	Polyisobutylene	PIB	DIN 16935	1.5
7	Polyisobutylene	PIB-K-PV	DIN 16731	2.5
8	Soft Polyvinyl chloride	PVC-P-BV	DIN 16937	1.5
9	Soft Polyvinyl chloride	PVC-P-NB	DIN 16730	1.5
10	Soft Polyvinyl chloride	PVC-P-NB	DIN 16730	1.5
11	Soft Polyvinyl chloride	PVC-P-NB-V-PW	DIN 16734	1.2
12	Chloro-sulphonated polyethylene	CSM-K-AV	-	1.2
13	Ethylene-propylene-diene-rubber	EPDM	DIN 7864 T1	1.3
14	Ethylene-propylene-diene-rubber	EPDM	DIN 7864 T1	1.3
15	Ethylene-propylene-diene-rubber	EPDM	DIN 7864 T1	1.1
16	Isobutene-Isoprene-rubber (butyl rubber)	IIR	DIN 7864 T1	1.3

Description of abbreviations:

K: fleece-backed

V: reinforced

E: internal layer

BV: bitumen-compatible

PV: polyester fleece

PW: polyester fabric

AV: asbestos fleece

NB: not bitumen-compatible

Compilation of the test material

The quality of the products is not only influenced by the composition of the material or formulation, but also by the method of manufacture. The results apply therefore only to the examined roofing membranes, and cannot be generalised nor be transferred to membranes of other manufacturers.

In order to gauge the material-specific ageing behaviour more accurately, unbacked ECB, PE-C and PIB roofing membranes were integrated into the research project, although in practice, these membranes are normally only used as fleece-backed products and/or with reinforcement layers.

3 Weathering-conditions

3.1 Natural ("free") weathering

For the natural weathering tests, samples measuring 250 mm long x 80 mm wide were taken from the different roofing membranes, and exposed to natural weathering conditions on the roof of the institute at Würzburg at an angle of 45° facing south.

The bitumen-compatible membranes were tested in contact with industrial bitumen 85/25. The bitumen was heated to 160° C, and applied approximately 2 mm thick on silicone paper and after cooling, was then applied to polystyrene plates. The roof sheet samples were laid loosely on the plates. The unbacked and non-reinforced samples were subjected to an additional extension of 5 %. The non-bitumen compatible membranes were laid on chip-board V 100 G according to DIN 68.763.

Open-air weathering began on June 1, 1981. Samples were taken out and examined after one, three, five and ten years. Climatic conditions prevailing during the test period at Würzburg are summarized in Table 2.

Table 2: Climatic conditions during natural weathering

Period	Duration (Years)	Global radiation (GJ/m^2) [1]	Sunshine hours (h)	Precipitation (l/m^2)
6.81 - 5.82	1	3.8	1552	705
6.81 - 5.84	3	11.6	4633	1824
6.81 - 5.86	5	19.3	7670	2916
6.81 - 5.91	10	38.8	15190	5947

[1] Composed of both direct and diffuse spread solar radiation.

3.2 Artificial weathering devices

Samples were submitted to artificial weathering in Xenotest 450 and Suntest equipment (manufacturer: W.C.Heraeus GmbH Hanau), according to DIN 53.387. The artificial weathering tests were designed to accelerate the ageing process in a reproducible manner and to simulate climatic conditions. Global radiation was simulated by filtered xenon arc radiation and periodic water-sprinkling was carried out to mimic natural rainfall.

The samples were arranged perpendicularly in the Xenotest 450 test unit, subjected to a Xenon emitter and sprayed with water periodically. Samples were laid horizontally in the Suntest unit, and were periodically flooded to simulate heavy rainfall.

A cycle of 17 minutes dry time: 3 minutes of wetting was maintained throughout the test cycle. A black board temperature range of +45 to - 2 ° C was also maintained during the drying phase in both test units. Samples were subjected a total of 20.000 hrs and 10.000 hrs of radiation in the Xenotest 450 and Suntest units respectively. This equated to an equivalent total irradiation level approximately 40 GJ/m^2 in both units.

4 Ageing criteria

"Ageing" is understood to mean an irreversible change in membrane characteristics and is the principal determining factor that limits the ultimate use of a membrane. The following mechanical properties were determined at various weathering intervals to assess the effect on ageing. They included:

- Modulus of elasticity (E-1-2 module) according to section 5.6.2. of DIN 16.726 (secant modulus between 1 and 2 % extension according to DIN 53.457)
- Break resistance according to section 5.6.1 of DIN 16.726
- Elongation at break according to section 5.6.1 of DIN 16.726
- Seam behaviour shear test according section 5.7.1 of DIN 16.726

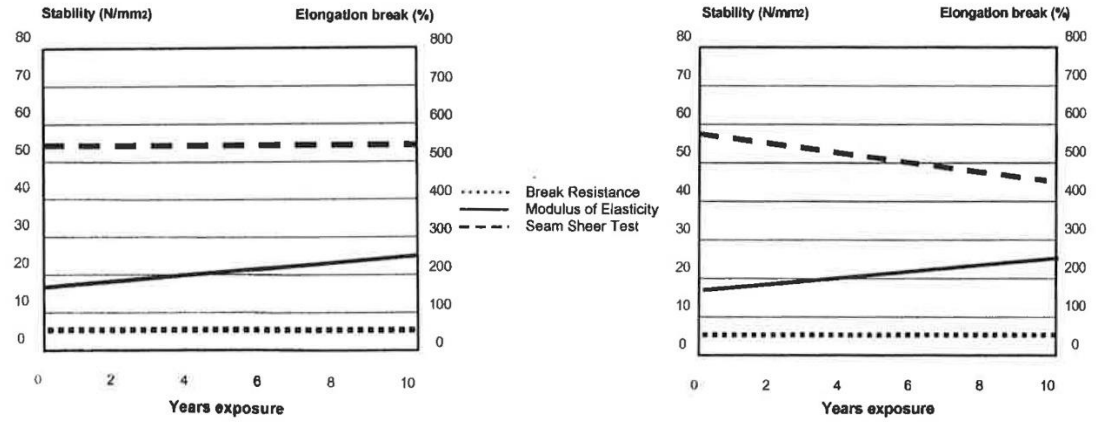
5 Test results

Mechanical preloading of the membranes, caused by a 5% pre-stretch, did not affect the ageing behaviour of the non-strengthened membranes. It would appear that the induced tension is rapidly diminished due to 'relaxation' phenomena, even with elastomeric membranes, causing no lasting effect to the membrane. This result tends to reinforce the fact that often over emphasis is attached to production-conditioned internal tensioning (10).

No deviating ageing behaviour was observed in the seams compared to the base or non-welded/joined material. This means that with professional installation, neither the operation of seaming/joining, nor the resulting increase in thickness of the seam, as a consequence of overlapping, would represent a problem in practice. However on building sites, climatic conditions can play a crucial role in operator efficiency.

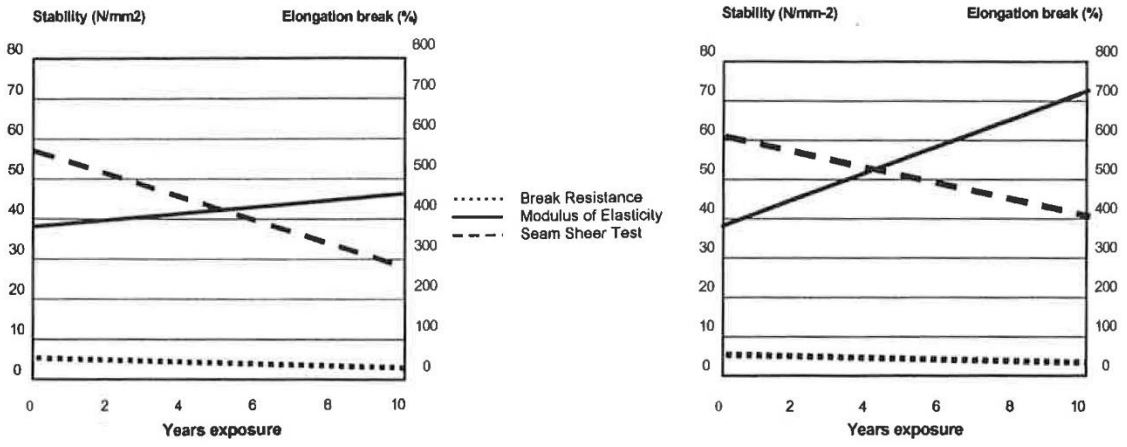
ECB membranes

There was no observed influence of open-air weathering on the mechanical characteristics of unmodified ECB (Type 1).



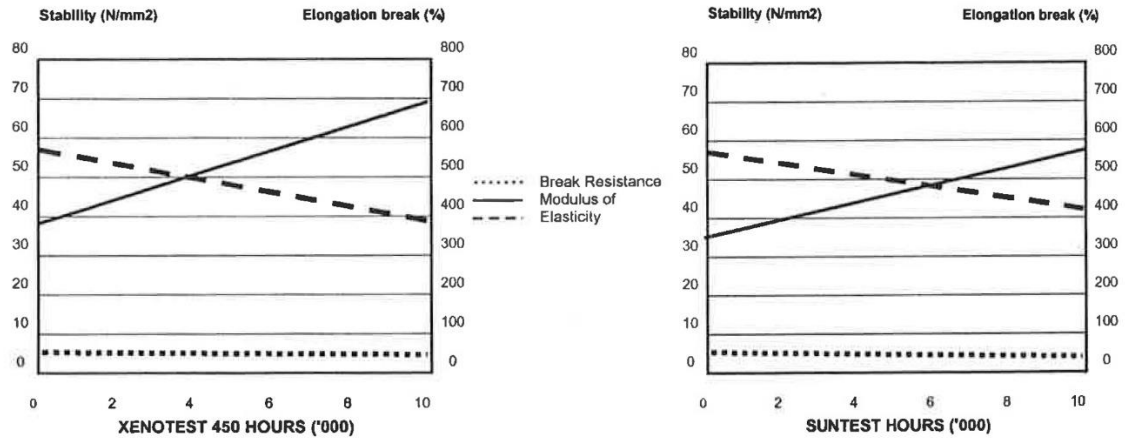
Graph 1: Influence of free weathering in contact with bitumen on the mechanical characteristics of ECB-T1 2.0 mm (left: without, right: with a pre-tension of 5 %)

Modified ECB (Type 2) applied over bitumen. Showed a fall in elongation break after 5 years of open-air weathering. Membranes that were not laid directly on bitumen exhibited higher elongation of break levels and increased modulus of elasticity readings.



Graph 2: Influence of the open-air weathering on the mechanical characteristics of ECB -T 2 2.0 mm (left: directly on bitumen, right: without contact with bitumen)

Artificial weathering leads to similar results to those obtained with open weathering; the modulus of elasticity increases and the elongation of break drops over time. (Graph 3).



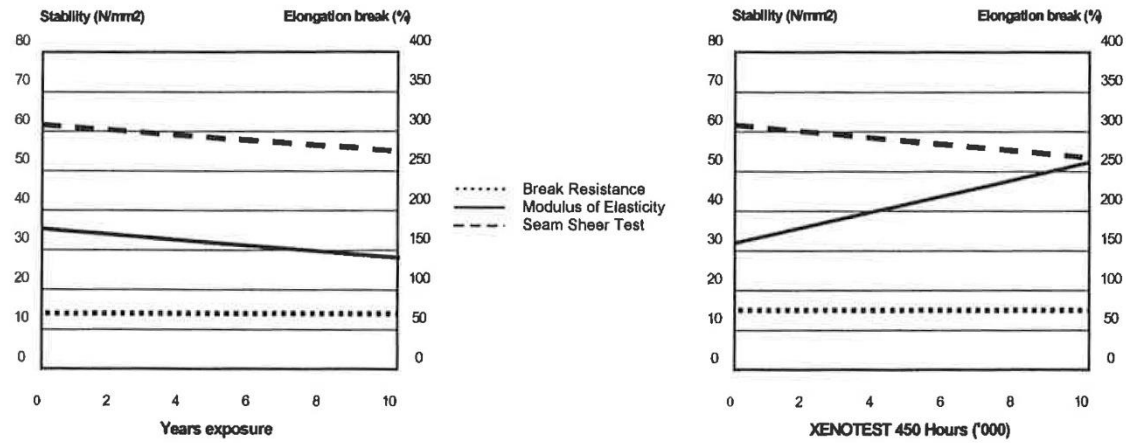
Graph 3: Influence of the artificial ageing on the mechanical characteristics ofECB-T2 2.0 mm (left: in Xenotest 450, right: in Suntest)

EVA membranes

EVA membranes showed no significant changes over the 10 year period. Contact with bitumen did not affect mechanical properties.

PE-C membranes

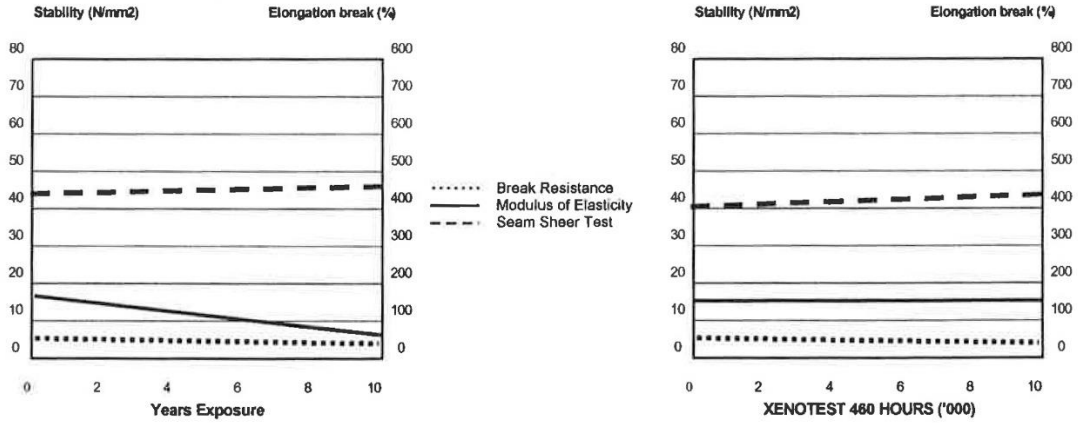
10 years of free weathering and artificial ageing caused a small decrease in the elongation of break reading. An increase of the modulus of elongation occurred after artificial weathering.



Graph 4: Influence of the weathering on the mechanical properties of PE-C 1.5 mm (left: free weathering on bitumen, right: artificial weathering in the Xenotest 450)

PIB membranes

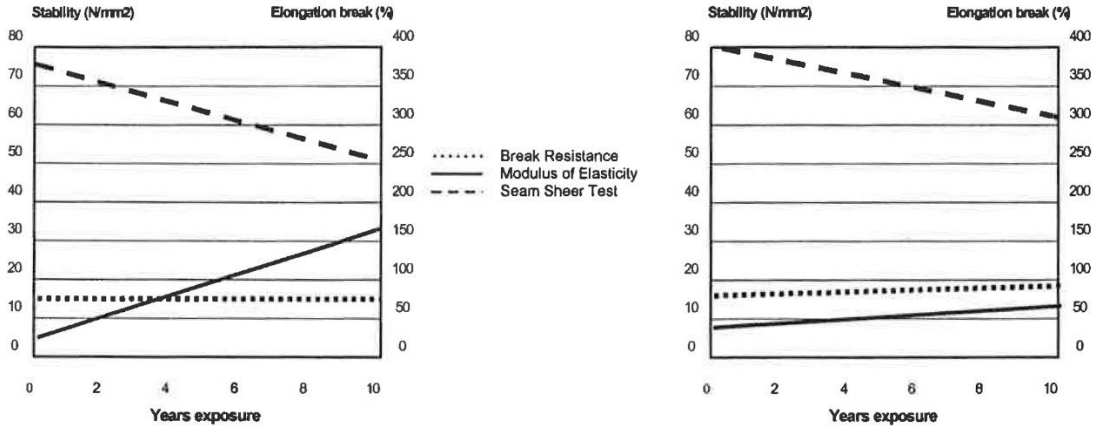
PIB membranes did not show any ageing and the material properties remained almost unchanged over the duration of the 10 year test period.



Graph 5: Influence of weathering on the mechanical characteristics of PIB 1.5 mm
(left: free weathering on bitumen, right: artificial weathering in the Xenotest 450)

PVC-P-BV (soft PVC, bitumen-compatible) membranes

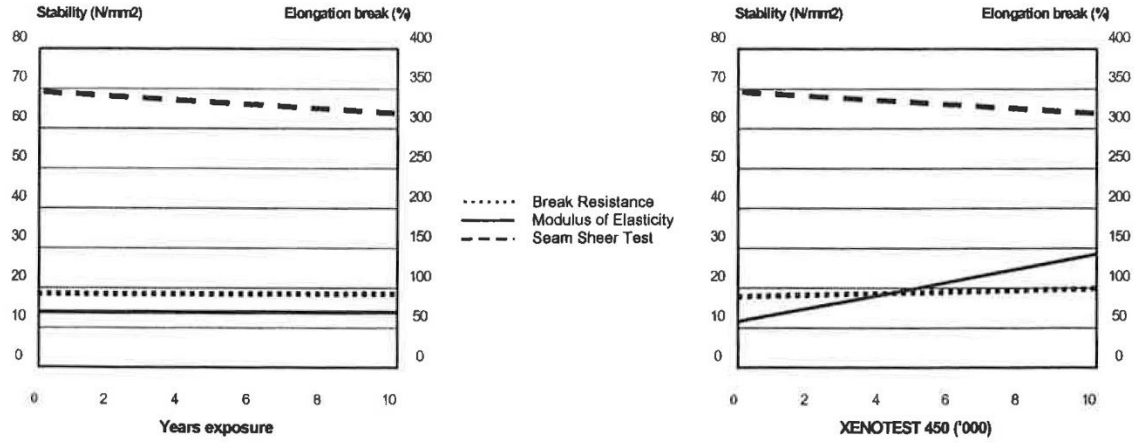
These membranes exhibited a continuous decrease of the elongation at break as well as a continuous increase of the modulus of elasticity both in open-air weathering and when in direct contact with bitumen. These results are explained by plasticiser loss and migration into the bitumen, which are mitigated if there is no contact with bitumen. Artificial weathering manifested similar results.



Graph 6: Influence of the weathering on the mechanical characteristics of PVC-P-BV 1.5 mm
(left: open-air weathering on bitumen, right: without contact with bitumen)

PVC-P-NB (soft PVC. non-compatible with bitumen) membrane

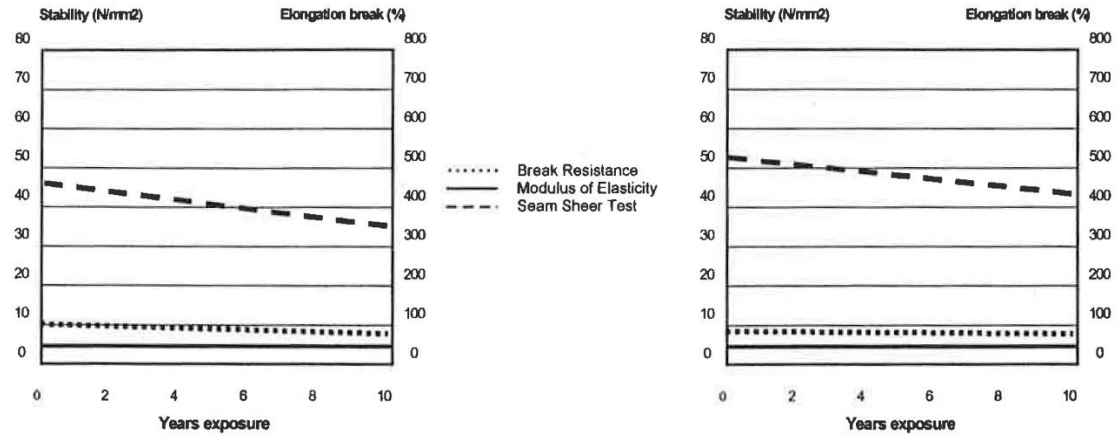
A small ageing influence was evident which was expressed as a small decrease in the elongation at break. An increase of the modulus of elongation was observed under artificial weathering. This phenomenon was not evident in open-air weathering conditions.



Graph 7: Influence of weathering on the mechanical characteristics of PVC-P-NB 1.5 mm
(left: open-air weathering, right: weathering in the Xenotest 450)

Elastomeric membranes

A decrease of the elongation at break arises after 10 years open-air weathering for both EPDM and IIR membrane types (Graph 8). This decrease was accentuated in the absence of bitumen contact. The modulus of elasticity and the strength remain almost unchanged when subjected to weathering.



Graph 8: Influence of the weathering on the mechanical characteristics of Elastomers
(left: EPDM 1.3 mm, right: IIR 1.3 mm)

Summary

In practice, synthetic roofing and waterproofing sheets can remain fully functional over several decades when properly installed.

A number of examined commercial roofing sheets exhibited changes in their mechanical characteristics, defined as ageing, after 10 years of free weathering or alter artificial ageing up to a total irradiation level of 40 GJ/m^2.

The effect on performance under both open-air and artificial weathering conditions did not always correlate. Material dependent ageing behaviour was considered under both conditions during the evaluation.

Product development and quality testing will in future necessitate that manufacturers carry out accelerated ageing tests. In order to obtain meaningful long-term behaviour results, very high irradiation needs to be applied, which clearly exceeds the requirements described in specific material standards.

The results were obtained for sheets that were loosely laid and exposed to UV radiation and subjected to temperature changes. The results obtained are not transferable to gravel/stone ballasted sheet membrane systems.

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