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Aging characheristics for polymeric roofing sheets

Norwegian Building Research Institute
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Preface

The Trondheim Division of the Norwegian Building Research Institute has a specialized and trained staff. They act as advisers and consultants for manufacturers as well as users of building materials and components. A special feature of the division is the development of specialized tests methods and laboratory test equipment. Another important point is the collection of practical experience through investigations of damages and systematic field surveys.

The content of this report was presented at the Second International Symposium on Roofing Technology in Gaithersburg, Maryland, USA, September 18. – 20. 1985, arranged by the US National Bureau of Standard.

Because of the general interest in the topic of roof membrane aging the Institute has decided to print the paper as a report. The Royal Norwegian Council for Scientific and Industrial Research (NTNF) has contributed to the printing costs.

Trondheim, april 1986

Einar M. Paulsen

Introduction

The Norwegian Roofing Research Group (TPF) started a project in 1980 aiming at developing design recommendations for roofs using polymeric sheets as water barrier. The Norwegian Building Research Institute (NBI) was asked to carry out a test and evaluation program including a field survey, to establish the state of the art and suggest quality requirements for membrane properties and guidelines for design.

This report presents the overall scope of the project with particular reference to aspects of aging, either by accelerated laboratory tests or by identification of factors which excessively reduce the service life of a polymeric roofing system.

Laboratory testing

Accelerated aging

The following four methods of aging the membrane was used:

- Method I: 48 weeks according to NBI Method 83/83

Test samples of 450 mm x 450 mm were mounted vertically in the apparatus and rotated between four positions, resting one hour in each.

A. Radiation from sun light lamps of the type Osram Ultra Vitalux GUR 53 300 W and simultaneous heating to an elevated temperature. Radiation intensity 1900 W/m^2 (input)

B. Wetting with a spray of demineralized water, 15±2 l/m^{2}h at a temperature of 291±5 K (18±5 °C)

C. Cooling and freezing to a temperature of 253±5 K (−20±5 °C)

D. Thawing at room teperature 296±2 K (23±2 °C) and 40±10 % RH, with possibilities for inspecting and changing the samples without stopping the test apparatus.

- Method II: 4 weeks in air at 353 K (80 °C)

Test samples of 400 mm x 400 mm were placed horizontally in a ventilated oven.

- Method III: 8 weeks in water at 333 K (60 °C).

Test samples of 400 mm x 400 mm were laid in water which was renewed at regular intervals.
After aging, the samples were allowed to rest for four weeks in standard climate (293 K and 50 % RH) before final measurements and testing of properties.

- Method IV: Six hours in air at 353 K (80 °C)

Test for Thermal stability with sample size 100 mm x 100 mm.

- Method II: 4 weeks in air at 353 K (80 °C)

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- Method IV: Six hours in air at 353 K (80 °C)

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Methods of evaluation

In order to observe the changes in the material as a result of the various modes of aging, the following attributes were checked before and after aging:

- Tensile strength/elongation at break

Tensile strength is the maximum force required to elongate a test piece until breakage in the reinforcement or the membrane itself.

The strength is given in N/mm^2 for homogeneous membranes and N/50 mm for reingorced materials.

Elongation at break is the extension of the test piece when the maximum force occurs in reinforcement or membrane. Elongation is given as per cent of original length.
Details regarding sample size, form and test rate are given in *Table 1*.

- Puncture resistance (NBI/81)

One conical and one chisel shaped test body are moved against the membrane with constant speed of 50 mm minute. The membrane is fixed between two metal rings with internal diameter 65 mm. The force at the mement of puncture is recorded.

- Folding at low temperature (DIN 53361)

The test specimen of 10 mm x 50 mm is folded between two pates at a distance of three times the thickness of the membrane. The temperature is lowered in intervals of 5 °C from 0 °C to − 30 °C or to breakage or cracks in the membrane occur.

- Dimensions

The membrane is measured in both directions before and after aging. Changes in dimensions are expressed in % of original size.

- Weight

The membrane is weighed before and after aging. Change in weight is expressed in per cent of original weight.

- Visual inspection of surface

The test samples are inspected visually before and after aging. Spesific aging phenomena are registrered.

Table 1.
Test conditions for strength/elongation

Type of membrane	Test specimen with mm	length mm	form	Test rate mm/min
Homogeneous plastic material (DIN 53455)	15	170	straight edges	200
Homogeneous elasto-meric materials (DIN 53504)	6	115	dogbone	200
Membranes with reinforcements (DIN 53354)	50	300	straight edges	40

Membranes tested

All testing was made on commercially available products sent to NBI by the manufacturers. The list in *Table 2* gives the individual membranes in the same order as they appear in *Tables 4* and *5*.

Changes recorded in membrane

The actual test results have been released for publication by the manufacturers and can be found in reference (1).

The changes recorded in the membrane attributes are given in *Tables 4a, b* and *c*. The changes are given as per cent deviation from figures obtained for fresh material regarding strength, elongation, demension, weight and puncture resistance. Degree Celcius is used for folding at low temperature. For visual inspection, the code as given in Table 3 was used.

In Table 5 is given a summary of all the changes recorded.

\+ indicates increase in figures after aging
− indicates decrase in figures after aging
± indicates that the figures alternate between increase and decrease.
0 means no significant change registered.

In the case of folding at low temperature, and increase in temperture, means that the membrane cracks at a higher temperature after aging.

Discussion of results

- Tensile strength

It is difficult to find any reliable trend. For homogeneous PVC there is an increase for method I as expected, due to the UV light, while for method II and III there is a decrease.

The results of membanes with strong core materials vary. Homogeneous membranes or membranes with relatively weak reinforcement may use tensile strength as an indication of aging.

- Elongation at break

In most cases there is a decrease in the elongation. But again, when the elongation is related to a strong core material, the results are variable.

- Dimensions

With the exception of membranes with core of fibre glass, all the others have shrinkage after aging. Thermal stability test may, however, show an expansion in the cross machine direction if there is shortening in the machine direction.

- Weight

All membranes have a loss of mass after aging. There is a pick up of water with method III, but after drying out, there is reduced weight. Aging according to method I always gives the greatest loss of weight.

- Puncture resistance

There is no clear and overall simple conclusion for the puncture test as an indicator for aging. But there is ± only for membranes with core of fibre glass and methods II and III.

All PVC membranes tested with method I have increased puncture resistance with cone and chisel.

ECB have reduced resistance against chisel. The elastomers have reduced resistance against cone and increased resistance against chisel while in the case of PIB it is opposite.

- Folding at low temperature

Only the products x, y and z cracked at higher temperatures after aging. These products are manufactured today with new formulas.

We have found that folding at low temperature is a good indicator on the aging stability of the composition in the membrane material.

Table 2.
Membranes tested

Type of membrane		Name	Thickness mm	Methode of ageing I	II	III	IV
PVC	Homogeneous	Trocal S	1.0	x			x
		Icopal H	1.2		x	x	x
		Product X	1.2	x	x	x	x
	Core of fibre glass	Icopal G	1.2		x	x	x
		Sarnafil G	1.2		x	x	x
		Product Y	1.2	x	x	x	x
	Core of polyester fabric	Alkorplan (35076)	1.2	x			x
		Rhenofol CV	1.2	x			x
		Sarnafil SE	1.2	x			x
		Delifol P	1.2		x	x	x
		Product Z	1.2	x	x	x	x
PEC	Core of polyester fabric	Alkorflex (35096)	1.2	x			x
PIB	Polyester felt on underside	Rhepanol fk	1.5	x			
ECB	Polyester fibres on underside	Carbofol C 2 K	2.0	x			x
IIR	Homogeneous	Värnamo Butyl	1.5	x			x
		" " NF	1.5	x			x
EPDM	Homogeneous	Värnamo EPDM	1.0	x			x

Table 3.
Codes for visual changes in membrane after aging

Code Nos.	Appearance of membrane surface
1	No significant change
2	Slightly dull surface
3	Slightly dull surface, droplet marks
4	Dull surface, seems greasy
5	Slightly yellow
6	Marked yellow, spotted
7	Dull surface, black stain on finger when touched
8	Dull surface, spotted brown

Table 4 a.
Changes in membrane after aging

Type of membrane		Tensile strength (% change)						Elongation at break (% change)					
		I		II		III		I		II		III	
		l	t	l	t	l	t	l	t	l	t	l	t
PVC	Homogeneous	+ 15	+ 4					+ 7	– 4				
				– 11	– 8	– 6	– 7			– 10	+ 5	– 6	+ 1
		+ 1	+ 3	0	+ 1	– 2	– 2	– 2	– 3	– 3	– 5	– 4	– 8
	Core of fibre glass			– 6	– 8	– 4	– 4			– 10	– 14	– 18	– 17
				+ 5	+ 4	+ 13	+ 15			– 5	– 3	– 10	– 11
		+ 11	+ 8	– 2	0	+ 2	– 4	– 7	– 3	– 5	– 3	+ 2	+ 6
	Core of polyester fabric	+ 2	– 8					– 2	– 15				
		– 11	+ 23					+ 8	+ 15				
		– 17	– 16					– 1	+ 4				
				0	– 10	+ 5	– 8			+ 11	– 14	+ 11	– 5
		+ 3	+ 8	– 12	– 5	– 13	– 4	+ 22	+ 13	+ 19	+ 17	+ 13	+ 7
PEC	Core of polyester fabric	– 5	+ 9					–19	– 5				
PIB	Polyester felt on underside	+ 1	– 10					– 13	– 14				
ECB	Polyester fibres on underside	– 8	– 14					– 56	– 45				
IIR EPDM	Homogeneous	– 17	– 15					– 4	– 3				
		– 18	– 8					– 9	– 11				
		– 7	– 10					– 5	– 17				

Table 4 b.
Changes in membrane after aging

Type of membrane		Dimension (% change)								Weight (% change)			
		I		II		III		IV		I	II	III	
		l	t	l	t	l	t	l	t			After test	After cond.
PVC	Homogeneous	– 2.0						– 1.5		– 3.7			
				– 1.3	– 0.7	– 1.3	– 0.6	– 1.1	– 0.6		– 0.2	+ 3.7	– 0.9
		– 4.5	– 2.9	– 2.9	– 2.2	– 1.6	– 0.5	– 1.3	– 0.3	– 6.9	– 4.0	+ 4.0	– 1.3
	Core of fibre glass										– 1.4	+ 9.3	– 1.4
											– 0.3	+ 3.4	– 0.2
										– 6.5	– 3.3	+ 6.6	– 1.5
	Core of polyester fabric	– 0.1	– 0.1					– 0.1	– 0.1	– 3.7			
		– 0.3	– 0.1					– 0.1	– 0.1	– 4.2			
		– 0.4	– 0.2					– 0.2	– 0.1	– 3.6			
				– 0.9	– 0.1	– 1.7	– 0.1	– 0.5	0.0		– 0.5	+ 6.3	– 0.3
		– 0.8	– 0.1	– 1.2	– 0.0	– 2.2	– 0.1	–0.6		– 3.8	– 1.7	+ 4.5	– 0.4
PEC	Core of polyester fabric	– 0.2	– 0.1					– 0.1	0.0	– 1.2			
PIB	Polyester felt on underside	– 2.8	– 2.1							– 0.4			
ECB	Polyester fibres on underside	– 2.1	– 0.3					– 2.2	+ 0.3	– 0.5			
IIR EPDM	Homogenous	– 0.6	– 0.4							– 0.8			
		– 0.5	– 0.5					– 0.2		– 1.7			
		– 0.4	– 0.6					– 0.2		– 1.8			

Table 4 c.
Changes in membrane after aging

Type of membrane		Puncture resistance (% change)						Folding at low temp. (°C change)			Visual inspection (Code Table 3)		
		Cone			Chisel			I	II	III	I	II	III
		I	II	III	I	II	III						
PVC	Homogeneous	 + 142	+ 4 + 21	+ 4 + 4	 + 51	− 1 + 17	− 1 + 1	0 + 5	0 0	0 0	6 3	1 1	1 1
PVC	Core of fibre glass	 + 4	0 + 20 −20	+ 6 + 27 −20	 + 12	0 + 24 − 5	+ 3 + 39 − 4	 + 10	0 0 + 5	0 0 + 10	 2	2 1 1	1 1 1
PVC	Core of polyester fabriv	+ 79 + 15 + 52 + 47	 0 + 13	 − 24 0	+ 19 + 2 + 2 + 5	 + 4 + 1	 + 5 + 6	0 0 0 + 15	 0 0	 0 + 5	3 1 5 2	 2 2	 4 4
PEC	Core of polyester fabric	+ 13			− 7				0		3		
PIB	Polyester felt on underside	+ 11			− 15				0		2		
ECB	Polyester fibres on underside					− 15				0		7	
IIR EPDM	Homogeneous	− 3 − 7 − 8			+ 3 + 10 + 11				0 0 0		8 2 2		

Table 5.
Summary of changes after aging

Type of membrane		Aging methode	Tensile strength	Elongation at break	Dimensions	Weight: After test	Weight: After conditioning	Puncture resistance: Cone	Puncture resistance: Chisel	Folding at low temp.
PVC	Homogeneous	I	+	−	−	−		+	+	+
		II	−	−	−	−		+	+	0
		III	−	−	−	+	−	+	±	0
	Core of fibre glass	I	+	−	0	−		+	+	+
		II	±	−	0	−		±	±	+
		III	±	±	0	+	−	±	±	+
	Core of polyester fabric	I	±	±	−	−		+	+	+
		II	−	±	−	−		+	+	0
		III	±	±	−	+	−	−	+	+
PEC	Core of polyester fabr.	I	±	−	−	−		+	−	0
PIB	Polyester felt on underside	I	±	−	−	−		+	−	0
ECB	Polyester fibres on underside	I	−	−	−	−		−	0	
IRR EPDM	Homogeneous	I	−	−	−	−		−	+	0

Field survey

The survey was carried out in the summer of 1983. Fourty roofs from all regions of Norway and some from mid Sweden were inspected. From the project report (2) the following points can be noted.

- Uneven membrane was more common than expected.
- Sharp exposed folds had cracked on two roofs with IIR 7 and nine years old.
- Large shrinkage was observed in homogeneous PVC membranes on several roofs.
- Gravel ballasted roofs had very often areas with exposed membrane.
- Pieces of glass from broken bottles were very often found on low rise gravel ballasted roofs.
- The stem of the mechanical fixing device had a tendency to puncture the membrane if the insulation was too soft.

Design recommendation

It would be outside the scope of this report to give all the details of our recommendation given in (1). But here are some of the points of more general interest.

- Membranes under gravel must have good weather resistance because exposed areas are very often found in practice.
- Folds in the membranes are potentially weak points and thus bad practice.
- Membranes must be fixed at parapets and penetrations if the shrinkage is greater than 0,5 % tested for thermal stability or greater than 1,0 % when tested with 48 weeks according to NBI 83/83.

Lose-laid mechanically spot fixed membrane systems should be secured against wind loads on the following premices:

- Wind load requirements must be met. The vacuum effect can be taken into account during reroofing where there is an airtight existing roofing. The minimum capacity of any system should not be less than 1000 Pa.
- The more weather independent installation, the better.
- Even (smooth) membrane without folds and ridges are preferable and required if the fresh membrane does not pass folding at − 30 °C.
- Bulging up or fluttering of the membrane under windloads must be limited.

References

(1) PAULSEN, E. M., BREDER, K.
TPF informerer No. 4. "Polymeric roofing sheets". NBI 1984.

(2) ISAKSEN, T., JUUL, H., PAULSEN, E. M.
Roofs with polymeric sheet membrane.
Project report from field survey (07032), NBI 1984.

(3) BREDER, K., GJELSVIK, T., PAULSEN, E. M.
Accelerated and natural weathering of single layer PVC roofing materials. Third international conference on the durability of building materials and components, ESPOO, Finland 1984.

(4) GJELSVIK, T., PAULSEN, E. M.
PVC roofing membranes.
Report No. 20. NBI 1978.