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PERFORATION RESISTANCE OF POLYMERIC ROOFING SHEETS

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SUMMARY

Polymeric roofing materials have recently become a large portion of the total flat roof market. One major application is with the membrane on a relatively soft insulation material. Very often the membrane is protected with a layer of gravel. But whether the roofing sheet is fully exposed or partly protected with gravel, it is sensitive to perforations in the period of building and afterwards during inspection or occasional traffic. This paper describes a test method for evaluation of perforation resistance of polymeric roofing sheets. (NBI method No. 96/1976). The test equipment contains well defined perforation bodies pushed against the membrane sheet with a constant speed. The load and the movement of the perforation body is registered on an XY-recorder using load cell and inductive displacement transducer.

The membrane is placed on a piece of insulation and held tight either with a metal ring or bent around the edges of the base material. This paper discusses the results from evaluating the perforation resistance of several brands of PVC roof membranes at different temperatures and before and after accelerated aging.

The method has proved to be accurate with good reproduceability and logical spread of test results regarding change in temperature, aging, thickness and composition of material. The equipment is built as a mobile unit which allows testing at temperatures ranging from 243°K to 340°K.

INTRODUCTION

During the last decade various types of polymeric sheets have been introduced to the Norwegian market as roof covering material. In recent years, however, PVC has become a popular material and seems to have increasing application using loose-laid techniques as well as in traditional roofing with fully bonded layers or mechanical fasteners for wind-uplift resistance.

To meet the growing demand for an objective evaluation of membrane properties, NBI invited a number of manufacturers to test their products according to a previously agreed test program where the results would be discussed against recommended performance criteria. The major part of the test program is carried out according to established test methods. The only exception is the perforation test, a new development by NBI. This is the first attempt to discuss the results of tests performed on specimens that underwent 16 weeks of accelerated aging. (Results were submitted in interim reports to each manufacturer.)

Membrane evaluation program.

The complete test program appears in Appendix I. Here it is in outline:

1) Test on fresh material:

Ultimate tensile strength.
Elongation at break.
Water vapour permeability.
Folding at low temperature.
Perforation resistance.
Weight.
Dimensions.
Adhesion of reinforcement (Trennkraft).

2) Accelerated aging in laboratory.

a) With NBI apparatus for accelerated aging which can test four samples of approximately 100 x 100 cm at the same time where there is simultaneous exposure in the following phases lasting 60 minutes. A complete cycle takes four hours.

UV light	343°K
Water spray	296°K
Freezing	253°K
Drying out	296°K

Total time of exposure is 48 weeks for the PVC membranes with interim test after 16 weeks.

b) Xenotest.

3) Tests on membrane after 16 and 48 weeks aging in NBI apparatus.

Ultimate tensile strength.
Elongation at break.
Perforation.
Folding at low temperature.
Loss in weight.
Dimensional changes.

Perforation test method.

The test method (identical with NBI test method No. 96/76) is described in detail in Appendix II. It consists of pushing a well defined perforation body (cone or chisel) against the membrane sheet at constant speed. Load and movement of the perforation body are registered on an XY-recorder using load cell and inductive displacement transducer. (Fig. 1).

The membrane is placed on a piece of insulation and held tight either with a metal ring or bent around the edges of the base material (polystyrene foam). The test specimen is mounted in the apparatus. (Fig. 2).

Perforation resistance of PVC membranes.

Test results on fresh material and after 16 weeks aging appear in Tables 1 and 2 for cone and chisel, respectively. In Table 3 some other membrane properties have been recorded for comparison. Typical load-deformation curves are given in Fig. 3 for chisel and Fig. 4 for cone perforation.

Three main types of PVC membranes are included in the program, (a) homogenous, (b) reinforced with glassfibre felt and (c) reinforced with synthetic fabric.

The first group is most representative with four different manufacturers, A, B, C and D, all having 1.0 mm membrane thickness.

The composite membranes have different thicknesses and the correlation is not so easily seen from the limited number of tests given in Tables 1 and 2.

Discussion of results.

The force required for perforation of a membrane depends on several factors – notably, material composition, membrane thickness, temperature, perforation body, and speed of perforation.

Cone perforation

Because of the cone's sharp point, perforation force is relatively low. The homogenous membranes have results of a similar order. The relative low value for E1 (with glassfibre felt) is not only attributable to the reinforcement. The composition is more likely to have a significant influence. The same material is used in E2 (with synthetic fabric) where the force is lower than for any of the homogenous membranes. The minimum thickness between threads in the fabric is approximately 1.0 mm.

A 30°C lowering in temperature causes a marked increase in perforation resistance.

Weathering stiffens the material, a fact clearly indicated by the perforation force.

Chisel perforation.

For the homogenous membranes the results show somewhat familiar features for cone perforation. Perforation force required to puncture the membrane is, of course, much higher.

Due to the large deformation before perforation, the base material may have a more significant influence on the results.

CONCLUDING REMARKS.

So far only the results from intermediate testing after 16 weeks of aging are available. A complete discussion of results and final conclusions will be given after 48 weeks of accelerated weathering.

However, the method of testing for perforation resistance has proved to be accurate, with good reproduceability and logical spread of results regarding change in temperature, aging, thickness and composition of material.

The equipment was originally designed for testing bond strength of glues. As a mobile unit it can be used in field as well as under controlled laboratory conditions at temperatures ranging from 243°K to 340°K.

Development of this test method has proved worthwhile. It has yielded more information than expected under the performance characteristics of the individual membrane. NBI would like to extend the present evaluation programs – if funds could be made available – taking into account other parameters, e.g., membrane thickness, temperature, perforation rate, base material, and correlation with field performance.

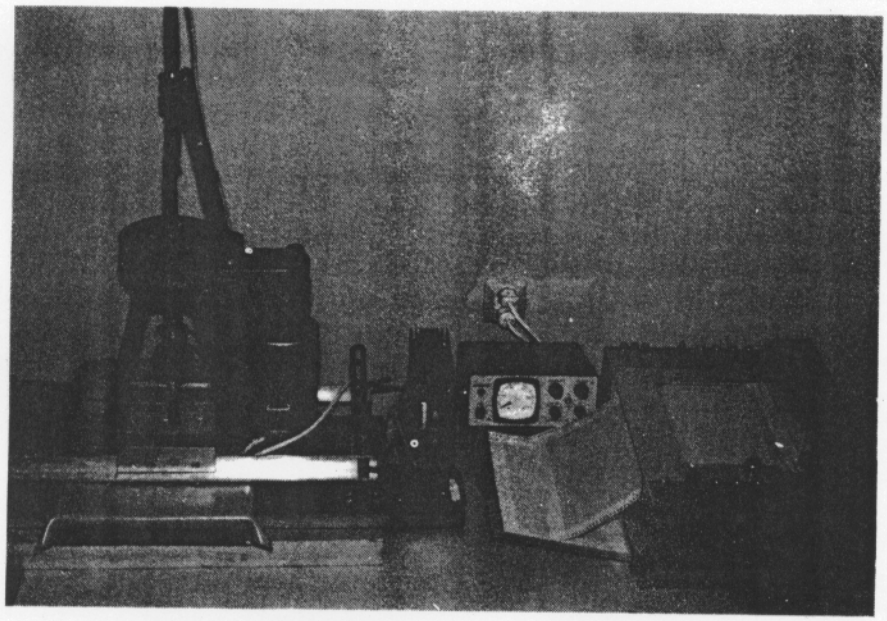

Figure 1 – Perforation test equipment

Figure 2 – Mounting of test specimen.

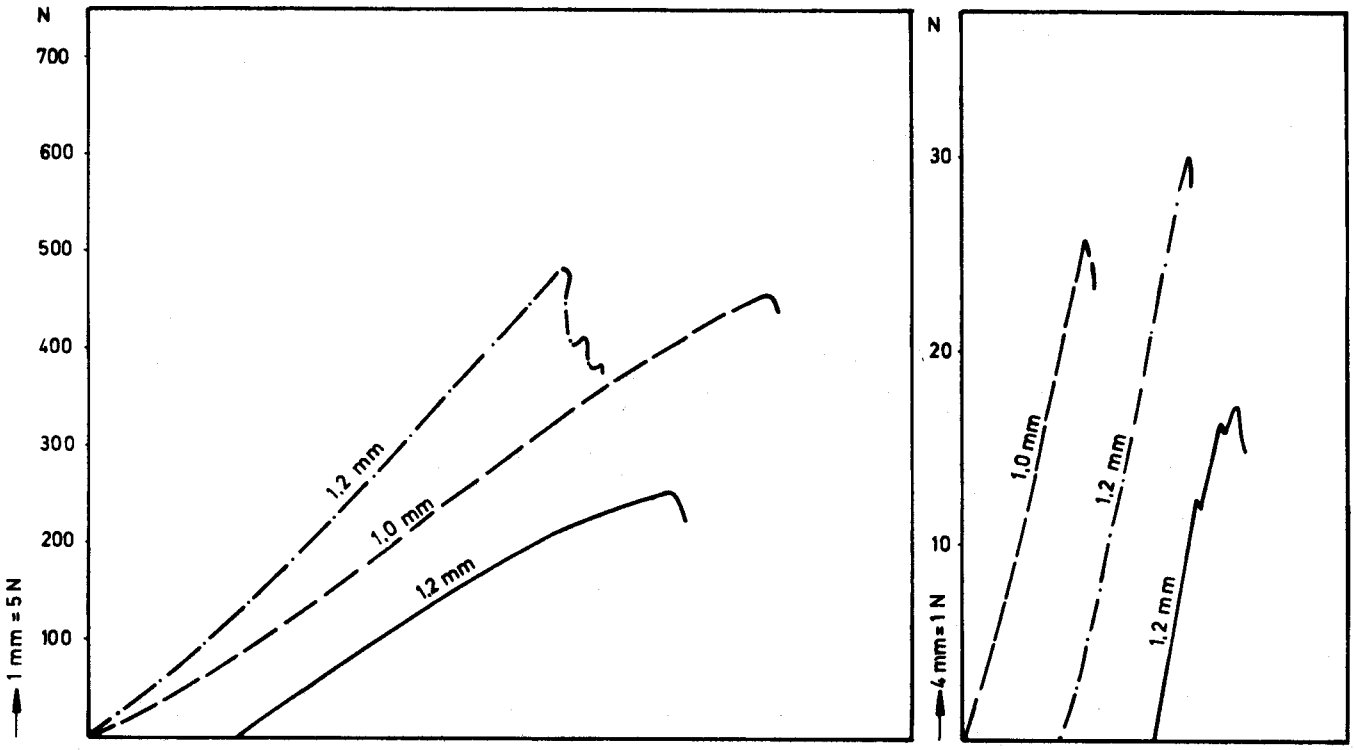

FIG. 3. CHISEL

FIG. 4. CONE

Homogenous — Glassfibre felt — Syntetic fabric

TYPICAL LOAD DEFORMATION CURVES FOR PVC MEMBRANES

TABLE 1 - CONE PERFORATION BODY

PVC MEMBRANE	MANU-FACTURER (A-E)	THICH-NESS mm	FRESH MATERIAL				AGED 16 WEEKS IN NBI-APP.			
			296 K (+23°C)		263 K (-10°C)		296 K (+23°C)		263 K (-10°C)	
			FORCE N	DEFOR. mm	FORCE N	DEFOR. mm	FORCE N	DEFOR. mm	FORCE N	DEFOR. mm
HOMOGENOUS	A1	1.0	26.8	5.0	58.0	5.0	39.1	6.4	70.1	5.6
	B1	1.0	25.8	4.7	50.6	4.5	40.0	5.5	69.5	4.5
	C1	1.0	25.6	3.8	48.0	4.1	29.4	4.4	53.6	4.5
	D1	1.0	28.1	5.3	58.6	4.4	44.5	6.9	71.8	4.7
GLASS-FIBREF	E1	1.2	16.3	3.2	33.4	3.5	24.7	3.6	48.1	3.7
SYNTHETIC FABR.	A2	1.35	47.8	4.6	74.8	5.0				
	C2	1.2	36.2	3.8	70.2	4.5	37.6	4.3	74.4	4.8
	E2	1.2	25.0	3.7	54.0	4.5				

TABLE 2 - CHISEL PERFORATION BODY

PVC MEMBRANE	MANU-FACTURER (A-E)	THICH-NESS mm	FRESH MATERIAL				AGED 16 WEEKS IN NBI-APP.			
			296 K (+23°C)		263 K (-10°C)		296 K (+23°C)		263 K (-10°C)	
			FORCE N	DEFOR. mm	FORCE N	DEFOR. mm	FORCE N	DEFOR. mm	FORCE N	DEFOR. mm
HOMOGENOUS	A1	1.0	436	37	760	31	516	39	839	29
	B1	1.0	451	34	740	27	515	33	820	26
	C1	1.0	473	31	713	28	548	32	720	28
	D1	1.0	427	37	775	28	592	43	826	27
GLASS-FIBREF.	E1	1.2	252	18	508	20	337	21	642	22
SYNTHETIC FABR.	A2	1.35	513	22	840	22				
	C2	1.2	490	22	733	21	510	19	790	22
	E2	1.2	507	20	577	18				

TABLE 3 - MEMBRANE PROPERTIES

PVC membranes	Manu-facturer A-E	Thick-ness mm.	Fresh material				Aged 16 weeks in NBI-app.				Re-duction in weight %	Shrin kage %
			Ultimatetensile STRENGTH N/mm²		Elongation at break %		Strength N/mm²		Elongation at break %			
			Long	Transv	Long	Transv.	Long	Transv.	Long	Transv.		
Homogenous	A1	1,0	19.4	19.4	340	360	20,3	20.6	365	355	1,4	1,1
	B1	1,0	17,3	17.3	270	280	16,7	16,7	255	250	1,3	0.7
	B2	1,0	18.7	18,4	315	310	18,5	18,4	305	315	1,3	1,0
	C1	1.0	19.8	17.7	325	345	20,0	18,0	320	320	1.4	2,9 long 0,3 transv.
	D1	1,0	21,4	19.4	350	370	19.4	19.2	325	350	1.7	0,5
Reinforced with glassfibre felt	E1	1.2	8,9	8,4	280	270	9,5	9,5	250	245	2,1	0.05
Reinforced with syntetic fabric	A2	1,35	14,2	12,4	290	130						
	C2	1.2	13,5	12.8	270	90	13.9	12,3	255	20	1,4	0,3 long 0.2 transv.
	E2	1.2	8,4	7,8	215	25						

APPENDIX I.

Test program for polymer-based roof sealing memebranes

The following characteristics are studied:

On new material:

Tearing strength and tearing Stress, according to DIN 53455, lengthwise and crosswise to course of membrane.

Porosity (Permeability) to water vapor, according to DIN 53122.

Folding when cold, according to DIN 53361, at - 30°C.

Punctures, according to NBI method, with two different testing tools, cone and chisel, at +23°C and - 10°C.

Weight/dimensions, DIN 53377 or NBI method.

Separating (crack) strength, according to DIN 53357. Only materials reinforced with fabric.

On aged material:

a) NBI machine for accelerated aging.

Total time 48 weeks. The following characteristics are tested after 16 and 48 weeks:

- tearing strength/tearing stress
- folding when cold
- punctures
- weight loss/dimension changes

b) Xenotest, according to DIN 53387. Total time 3000 hours, and testing of tearing strength and tearing stress after 1000 and 3000 hours.

Test time:

After materials to be tested are received, some 12 months are required for the complete program with aging in the NBI accelerated aging machines and the Xenotest test. For parts of the test program special appointments must be made.

Test costs:

The price of testing according to the complete program includes tests on new and aged material and testing of certain characteristics before and after aging, and is given as a firm price without any added tax. Prices for parts of the test program are given separately.

APPENDIX II.

Testing method NBI 96/75

Puncture Resistance of Roof Sealing Membranes

Validity:

The method was developed to test the puncture resistance of polymer-based roof sealing membranes lying on a relatively soft underlayer such as polystyrene foam.

Equipment:

The equipment consists of a unit which can apply a puncturing tool against the roofing membrane at a uniform speed independent of the magnitude of the force. The mobile NBI puncturing equipment is composed of:

1) a stand with motor and crossing (bridge) to a coil which provides a constant thrust aginst the piece being tested and which returns after making puncture.
2) a device for strapping the stand firmly to the piece to be tested.
3) puncturing tools.
4) thrust (pressure) measuring apparatus installed between coil and puncturing tools.
5) inductive deformation device installed on the tip of the coil.
6) XY plotter, which registers force and deformation.

Pieces to be tested:

The roof membrane is laid and stretched (clamped) tightly on to the desired underlayer. Small test pieces (15 x 15 cm) are stretched in a metal ring, so that the membrane is not drawn toward the point punctured. Larger test pieces (30 x 50 cm) are laid on a section of the underlayer (polystyrene foam), bent over the edge and secured with tape.

Conditioning:

When testing at a specified temperature, the membrane and the underlayer must be conditioned for the period of time necessary so that the temperature of the membrane as well as the underlayer is the same.

Generally the tests are performed in a room with controlled temperature and humidity of +23°C and RH 50%. Since the equipment is mobile the tests are also performed at other temperatures, e.g. from +70°C to - 30°C.

APPENDIX II (continued)

Tests:

Puncture resistance is determined by applying a well determined and precisely designed puncturing tool against the membrane at a uniform speed, and simultaneously force and thrust are registered on the XY plotter.
The tests are always conducted on new material; but after testing they are also made to best advantage in the NBI accelerated aging machine.
Unless otherwise specified, the tests are carried out as follows:

1) **Puncturing tools:** (see enclosed drawing)
   a) cone
   b) chisel.
2) **Speed:** (50 ± 2.5) mm/min.
3) **Temperature:**
   In conditioned rooms: (23 ± 2°C) RH = (50 ± 5%)
   In cooling chambers: - 10°C.

At least 5 parallel tests are performed with the cone and at least 3 tests with the chisel.

Report:

The test is described in detail with regard to material, testing conditions and results. If the test is performed at several temperatures and on aged material, variations in the results are calculated as percentage deviations from the tests on new material in a conditioned room at 23°C and RH = 50%.

PERFORATION BODIES FOR ROOF MEMBRANES