

TEST METHODS USED IN PRODUCT DEVELOPMENT

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The new plasticized PVC membrane for unballasted use is the subject of this paper. This membrane is a direct outgrowth of the lessons learned from the many negative experiences with older types of ballasted and unballasted plasticized PVC roofing membranes in the early '70s.

Chemical composition and membrane thickness determine the application suitability of any roofing membrane, including plasticized PVC membrane for unballasted use.

A roofing membrane should satisfy the following basic prerequisites:

- it should be age-resistant
- it should be stable and flexible in the entire temperature operative range
- it should be perforation-resistant, including resistance to impact from hail storms
- it should meet the requirements for fire resistance
- it should have easy and lasting weldability (adhesion); it should be easy to handle and easy to affix to the roof area, as well as to flashings.

By employing appropriate test methods, initial and valid indications about the application suitability of a roofing membrane can be determined in the laboratory. The most important tests conducted in the development stages of a plasticized PVC membrane for unballasted utilization will be outlined briefly in Part 1 of this paper.

PART 1

Testing of Weathering Resistance

Figure 1 shows the preferred Xenotest 1200 used, whereby the test objects were exposed for up to 10,000 hours to this artificial weathering (radiation, heat, water). After this long

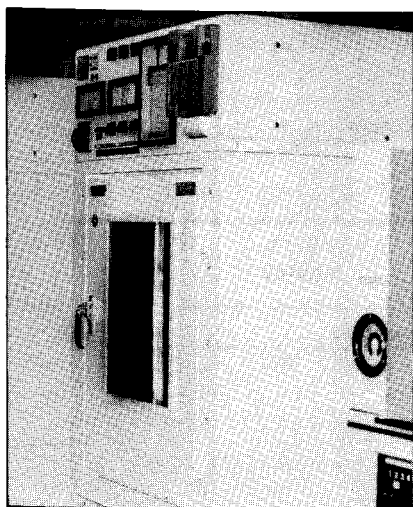


Figure 1 Xenotest 1200

weathering exposure, neither discolorations, nor signs of surface crazing could be observed. While these laboratory tests were being conducted, plasticized PVC material (see Figure 2) was also subjected to actual outdoor exposure, thereby testing the entire roof package, together with the perimeter fastening. From these models, supplemented by additional test projects, samples were taken on an annual basis. These samples were tested for relevant aging properties and then compared with the Xenotest results.

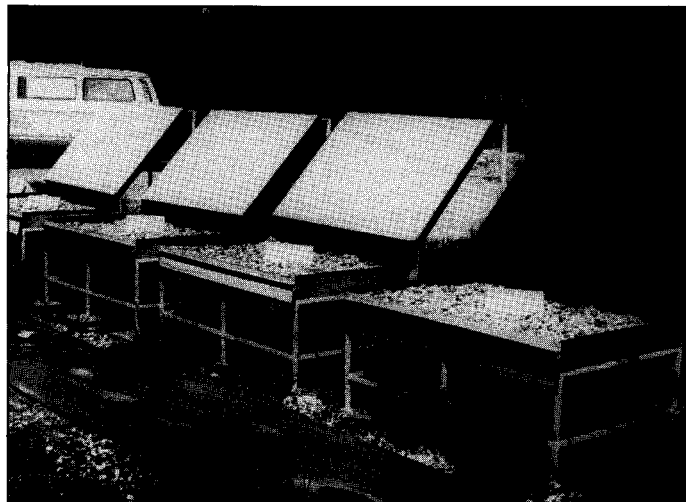


Figure 2 Outdoor weathering at test facility - Troisdorf, W. Germany

Ultimate Tensile Strength and Elongation Stability Test/ Temperature Dependent

As shown in Figure 3, stress-strain-diagrams on plasticized PVC membranes were measured in relevant application-climate-zones with temperatures between -40°C and 80°C .

physical property	standard	unit	(new)	after 10 years outdoor exposure
thickness	DIN 53370	mm	ca.145	ca.145
tensile strength (L)	DIN 53455/5 /VII	N/mm ²	ca.19	ca.20
elongation(L)	..	%	ca.330	ca.330
1/2%modul of elasticity (L)	—	N/mm ²	ca.18	ca.18
brittleness temperature (at low temperature)	DIN 53361	°C	ca.-35/-40	ca.-35/-40
dimensional stability 6 h, -80°C L/C	DIN 16730	%	ca.-1,5/±0	ca.-1,4/±0,1

Figure 3 Stress-strain behavior of a 1.5mm thick plasticized PVC membrane, in dependency on the test temperature

Looking at these results, important properties of plasticized PVC come to light. The results derived from stress and strain are of the same magnitude at all application-relevant temperatures. However, since the stress reflects nothing else but the force per material cross section, and the results obtained from force and way (elongation) can be viewed as the determining energy at the tear point, it can be assumed that this material, independent of temperatures which occur during outdoor exposure, will always withstand any damage with the same high resistance. With these properties, plasticized PVC roofing membranes are by far superior to many roofing membranes of other material types.

Figure 4 shows the tensile testing machine with environmental temperature test chamber which is used in these tests.



Figure 4 Tensile testing machine with environmental temperature test chamber

Testing of Perforation Resistance

The test apparatus is shown in Figure 5. The measuring principle already was tested in 1974, during a research project conducted by the Federal Ministry for Planning, Civil Engineering and Urban Construction, at the South-German Plastic Center, Wuerzburg, West Germany. The apparatus shown in the illustration was constructed by Dynamit Nobel. The measuring principle can be described as follows.

Nine cone-shaped penetration objects are screwed to a metal plate which is electrically connected to a second metal plate. When the plates are placed on top of each other—separated by the membrane to be tested—the elapsed time counter will run during the penetration test until the tested roofing membrane is penetrated and the metal plates make contact via the penetration objects which, in turn, brings the time counter to a halt. The test arrangement is operated by a pushbutton switch located on the upper plate which is automatically released upon contact with the load. The relatively wide range of dispersion in the measured values makes this test method rather time consuming, as only the average, i.e. mean value, derived from several measurements, reflects an accurate picture of the perforation behavior.

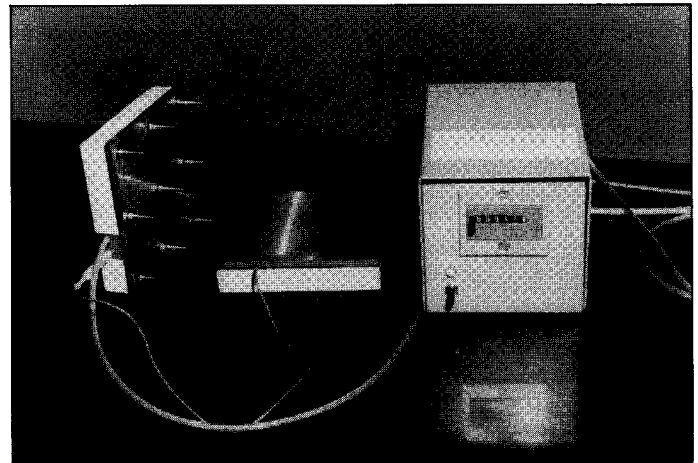


Figure 5 Nine cone apparatus, opened, without test object and without load. The test results are shown in Figure 6.

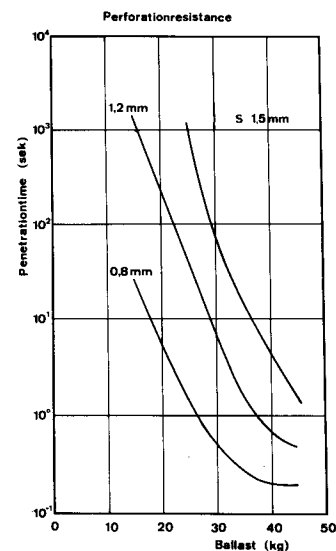


Figure 6 Dependency of the perforation behavior of a plasticized PVC membrane upon the material thickness

On the horizontal axis (abscisses), the load during the test is indicated in kilograms; on the vertical axis (ordinates), the endurance up to the actual perforation is logarithmically indicated in seconds. Materials, which for high load also require high endurance, are more perforation resistant than materials with lower endurance at relatively low load.

The high stress properties of 1.5 millimeter plasticized PVC sheet becomes apparent when observing the three material thicknesses and their related curves. Regarding their perforation resistance, membranes with a thickness of 1.5 millimeter can be classified as "highly suitable" for the building construction industry. As long years of experience have proven, there is no danger that these products will be perforated, and consequently leak, due to small stones or items placed above or below the membrane or by roof traffic. The noticeable low perforation resistance of the 0.8 millimeter thick roofing membrane may lead to a restricted use of this material in building construction, especially considering the average poor quality of the gravel with its relatively high percentage of fractured particles.

Based on these results, it can be established that the thickness of a membrane is of special importance. For long-term good performance of a roof area covered with a plasticized PVC sheet, it is of utmost importance.

Testing of Hailstorm Resistance

Figure 7 shows the hailstorm test equipment of the EMPA-Duebendorf (Switzerland).

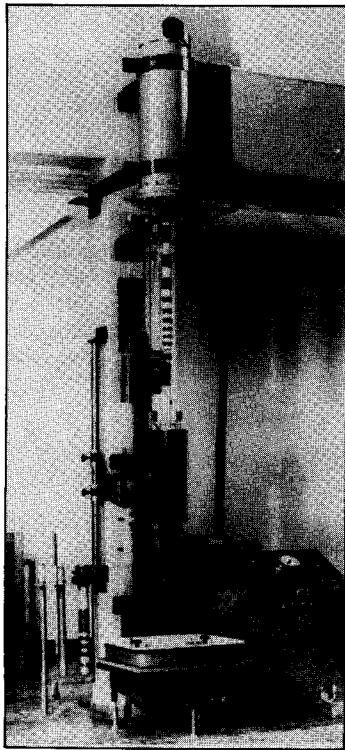


Figure 7 Hailstorm test apparatus of the EMPA/Switzerland

The testing equipment consists of a firing device with a vertical firing direction, a horizontal sample holding device, and measuring instruments to determine the exact speed of the pellets. The pellet accelerator is operated pneumatically, with the load pressure controlled by a manometer. The accelerated Polyamid pellet is 40 millimeters in diameter and weighs 38.5 grams, ± 0.5 percent. The pellet speed is controlled by the load pressure. Photo cells with an accuracy of 0.5 percent measure the speed of the pellets. The sample holder allows for three different positions of the test objects:

- on a rigid base
- on a flexible base
- on a hollow base

With this device, plasticized PVC membranes were tested, both new and after 7½ years of unballasted installation. The test certificate issued confirms that no reduction in the impact stability during hailstorms is measurable, even after 7½ years of outdoor weathering.

Flammability Test

The flammability of plasticized PVC membranes is evaluated in accordance with the DIN Standard 4102. The membrane satisfies the requirement "B2" (normal flammability) according to DIN 4102, Part one, as well as the requirements for fire resistant roof installations and roofing membranes exposed to rapidly spreading fire and radiant heat, according to DIN Standard 4102, Part seven.

Testing of Weldability, Application and Fastening System

Plasticized PVC roofing membranes are easy to install and their service life is excellent and has proven itself for many years. The membranes may be solvent-welded in a wide range of temperatures, and because of their excellent forming stability, they are easy to handle. The stability of the welding seams in new material, as well as in installed, aged material, is constantly tested in peel and shear tests.

The plasticized PVC membrane on the roof area is fastened, especially against wind uplift. As shown in Figure 8, the application suitability of the anchorage points are tested in the system. With a load of 40 kilograms, the fastener is stressed at variable frequencies up to 20,000 times and, subsequently, tested in a tensile testing machine for the remaining tear stability.

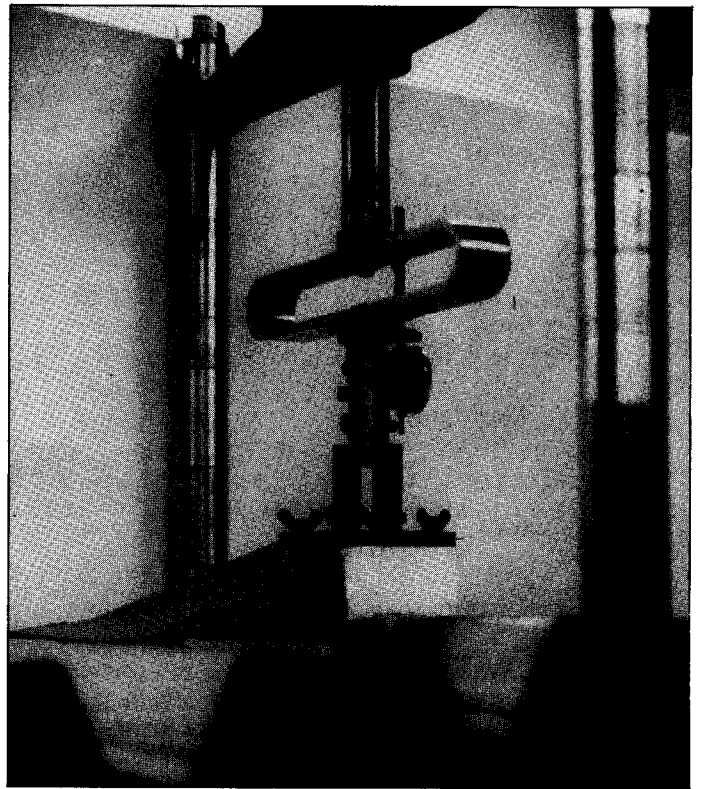


Figure 8 Arrangement for testing of fastener systems (system: corrugated sheet metal - insulation - separation sheet - plasticized PVC membrane)

Especially for the perimeter connections, sheet metal is available which, at the same time, presents a proven and aesthetically pleasing solution for a flat roof. Adhesion stability of sheet and metal, as well as the weatherability of these systems are constantly checked by Quality Control.

Testing of General Physical Properties

In addition to the briefly described installed material properties and systems characteristics, overall material characteristics are tested during continuous external and internal quality control procedures. Among other tests, this includes the measuring of cold brittleness, tear resistance, water vapor transmission, dimensional stability, anchor stability, chemical resistance, biological stability, compatibility with surrounding substances, as well as the elasticity (1-2 percent modulus).

PART 2

The Success of Plasticized PVC 1.5mm Roofing Membrane Installations in the Field

In three roof examples, that vary greatly in size, the excellent aging behavior of a plasticized PVC roofing membrane will be described.

Exhibition Halls at Nuremburg, West Germany

Project size: approximately 60,000 square meters

Installed: 1977, plasticized PVC (1.5 millimeters thick) installed over insulation (Polystyrene foam) with separation sheet



Figure 9 Exhibition halls at Nuremburg

To ensure a definitive evaluation of the aging behavior of the plasticized PVC roofing membrane utilized, the Technological Institute of Nuremburg has removed material samples every two years since its installation in Spring of 1977. These samples are cut in half, and each half is tested at the Technological Institute in Nuremburg and at Dynamit Nobel in Troisdorf. The last sample cut was taken 6½ years after installation. The physical property values established on the plasticized PVC membrane samples, as compared to new plasticized PVC membranes, are summarized in the table below.

physical property	standard	unit	(new)	half G after 78 months outdoor exposure)
thickness	DIN 53370	mm	1,52	1.52
tensile strength (L)	DIN 53455/5/VII	N/mm	18,5	19,0
elongation (L)	..	%	360	350
1/2%moduls of elasticity (L)	—	N/mm	ca. 18	ca. 17
brittleness temperature (at low temperature)	DIN 53361	°C	-35/-45	-30/-40
dimensional stability 6 h, +80°C L/C	DIN 16730	%	-1.1/+0,2	-0.7/+0.1

Table 1 Unballasted plasticized PVC, installed 1977, exhibition halls/Nuremberg

Within the scope of measuring accuracy, no changes in the aging-relevant property values, after outdoor exposure, are visible which could be judged negatively.

Warehouse - Troisdorf, West Germany

Project size: approximately 700 square meters

Installed: 1974, plasticized PVC 1.5 millimeters installed over insulation (Polystyrene foam) with separation sheet

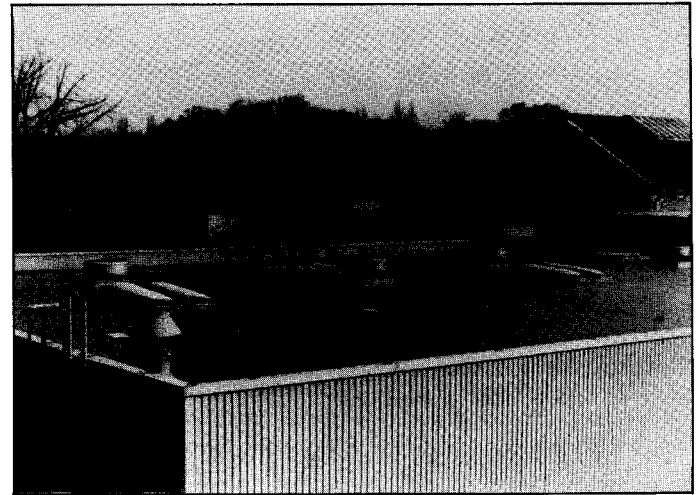


Figure 10 Warehouse, Troisdorf

A sample was removed from this project on an annual basis, with subsequent testing for relevant aging property values. Table 2 indicates the test results after 50, 74 and 100 months in comparison to new material.

physical property	standard	unit	(new)	after 50 months	after 74 months	after 100 months
thickness	DIN 53370	mm	1,45	1,44	1,46	1,46
tensile strength (L)	DIN 534 55/5/VII	N/mm ²	ca.18	ca.18	ca.19	ca.19
elongation (L)	..	%	ca.325	ca.300	ca.325	ca.335
1/2%moduls of elasticity(L)	—	N/mm ²	ca.18	ca.15	ca.15	ca.16
brittleness temperature (at low temperature)	DIN 53361	°C	-35/-40	-35/-40	-35/-40	-35/-40
dimensional stability 6 h, +80°C L/C	DIN 16730	%	-1,1/-0,3	-1,0/-0,5	-0,6/-0,1	-1,1/-0,2

Table 2 Unballasted plasticized PVC, installed 1976, storage shed/Troisdorf

On this project as well, no aging was noticeable in the plasticized PVC roofing membrane after approximately 8½ years of exposure.

Public School - Baesweiler, West Germany

Project size: approximately 1,500 square meters

Installed: 1974, plasticized PVC 1.5 millimeters installed over insulation (Polystyrene foam) with separation sheet

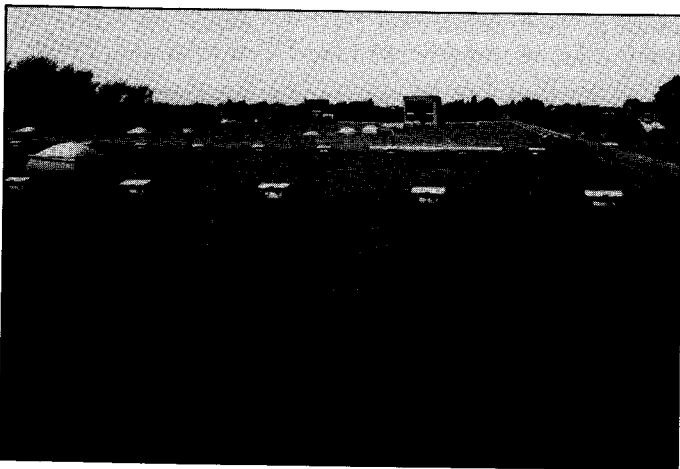


Figure 11 Public school, Baesweiler

The physical properties recorded in Table 3 indicate that the plasticized PVC roofing membrane, after 10 years of exposure, is not only fully functional but, compared to new material, has remained practically unchanged in its application-relevant properties.

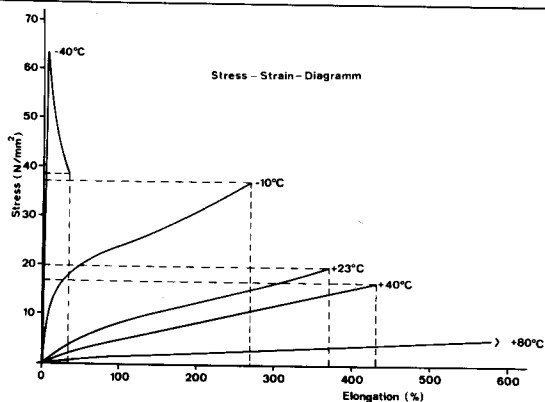


Table 3 Unballasted plasticized PVC, installed 1974, public school/Baesweiler

In summary, the aging behavior of the tested plasticized PVC roofing system membrane can be evaluated as follows:

- no reduction in strength
- no reduction in elongation capability
- no reduction in thickness
- no increase in rigidity
- no increase in shrinkage values
- constant cold brittleness stability
- no visible change in the weather exposed surface
- stress-strain free coverage over the entire roof area

In addition to the typical flat roof projects introduced in this paper, Figures 12 and 13 will show that plasticized PVC roofing membranes are excellently suited for installation on buildings with more modern and unusually shaped roofs.

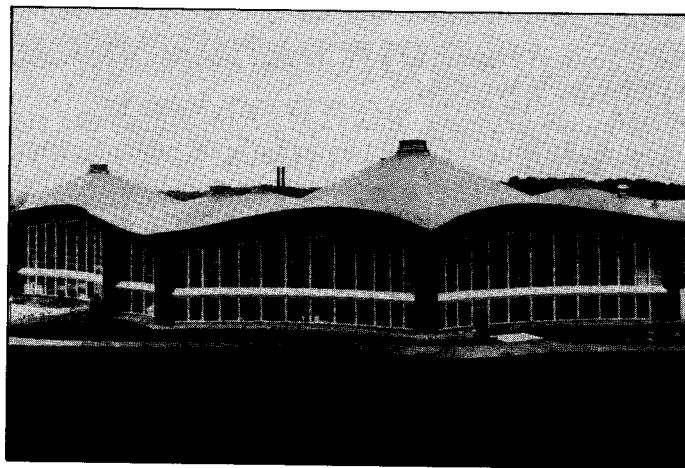


Figure 12 Garden indoor swimming pool, Rebstock Park, Frankfurt, W.G.



Figure 13 Auditorium, Nazareth College, Rochester, New York

PUBLICATIONS ON THE SUBJECT OF "ROOFING MEMBRANES"

1. "Temperature dependency of dimensional changes of plasticized PVC roofing membranes in "Plastics in the Construction Industry" 1979/4.
2. "Measuring of the cold shrinkage forces in plasticized PVC roofing membranes," "Rubber, Asbestos & Plastics" 1981/2 and 4 (in two parts).
3. "The behavior of reinforced and non-reinforced plasticized PVC membranes, in the tensile test, dependent upon the test speed," "Plastics in the Construction Industry," 1983/8.
4. "The long-term behavior of plasticized PVC roofing membranes," "Building with Plastics," 1983/8.
5. "Aging of plasticized PVC roofing membranes under gravel ballast," "Plastics in the Construction Industry" 1984/2.