FULL-SCALE DIMENSIONAL STABILITY TESTING FOR MODIFIED BITUMEN MEMBRANES

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In the past few years, the roofing market has changed dramatically regarding products and membranes, as well as application methods. Concrete decks are slowly giving way to lighter steel decks, and insulation thickness has increased to reach very high thermal resistance values.

The goal of this paper is to present the findings of a study carried out on dimensional stability of waterproofing membranes and to prove the interest of a new test trial on a larger scale.

Several methods can be used in the lab to measure the dimensional stability of membranes. The correlation obtained between the lab results and the membrane performance is not exact. Therefore, the authors developed a new test method that includes more parameters such as size of overlap, scale effect, etc.

The results reflect the relation between the type(s) of membrane reinforcements and its stability. In view of this knowledge, the application method can be improved and optimized so as to ensure the roof's longevity.

KEYWORDS:

Dimensional stability, modified bitumen membranes.

INTRODUCTION

Modified bitumen roofing membranes have been used extensively throughout the world. Their ease of application and proven in-place performance record make them one of the most widely used roofing systems on the market today.[1,2]

The roofing industry has come to know these products and understands the application and performance characteristics of the various systems.

Because of the high temperatures measured on roofs in the last few years,[3] membrane shrinkage occurred causing the end overlap to open. These occurrences have been documented by numerous individuals and groups [3,4,5] who have witnessed actual membrane movement. Basically, the procedure has been to evaluate small samples of the membranes materials in laboratory-based tests.

These tests produced results that often showed the membranes to be within normal manufacturing tolerances and thus performing as intended or in accordance with the specified requirements. Unfortunately, the roof membranes have actually moved on the roof causing the side or end laps to open.

There has been a need for full-scale (complete rolls applied in normal fashion) testing of actual rooftop situations to determine the factors that affect a modified bitumen membrane's ability to withstand movement and perform as intended.

This type of full-scale testing has been developed and the results provide some specific guidelines on application techniques that can reduce or eliminate the shrinkage or sliding found in many situations.

In this paper, the authors will provide background on existing laboratory-based testing techniques designed to measure dimensional stability. The aim of this work is to present the study carried out on dimensional stability of waterproofing membranes and to prove the interest of a new test trial on a larger scale.

The results obtained reinforce the relation between the type(s) of reinforcements composing the membrane and its stability.

DESCRIPTION OF EXISTING DIMENSIONAL STABILITY TEST METHODS

Introduction to the trial methods

Several methods can be used to measure the dimensional stability of a product in the laboratory (free shrinkage).

Three of the standard methods are presented here.

Generally speaking, the principle consists in placing several test samples in an oven at 80°C (176°F). The dimensions of the samples are measured before and after exposure in the oven. Comparison of the dimensions is the basis for determining dimensional stability.

The oven exposure time, size of the test samples, the number of cycles and the conditioning vary with each standard.

First method: ASTM standard D 5147 and D 1204

Standard test methods for sampling and testing modified bituminous sheet material and test method for linear dimensional changes of non-rigid thermoplastic sheeting at elevated temperature.

Five samples sized 25 cm x 25 cm (10 in. x 10 in.) are taken in the length of the roll. The samples are conditioned for 40 hours at 23°C ± 2°C (77°F ± 4°F). The samples are then placed in the oven for 24 hours at 80°C ± 3°C (176°F ± 5°F). After removal from the oven, the samples are conditioned again for 1 hour at 23°C ± 2°C (77°F ± 4°F). Dimensional stability is determined by averaging the five values of length change obtained in each direction.

Second method: UEAtc European union of agreément for bituminous waterproofing membranes—"Essais de stabilité dimensionnelle"

Three samples 10 cm x 10 cm (4 in. x 4 in.) (minimum) are cut in the width of the membrane roll. They are put in the oven at 80°C (176°F) for six hours. The initial dimension measurements are taken without preliminary conditioning;

the intermediary and final measurements are taken after 18 hours of conditioning. The cycle is repeated until the difference between the consecutive measurements does not exceed 0.1 percent of the initial dimensions of the test sample. The results are expressed in a percentage, by an average of the results obtained in the cross and length direction.

Third method: European project norm - prEN 1107-1 — "Détermination de la stabilité, dimensionnelle à température élevé pour feuille bitumineuse." PrEN 1107-1 is a European requirement project currently in development.

Five samples, 25 cm x 5 cm (10 in. x 2 in.) are taken from the membrane roll. The 25 cm (10 in.) dimension is taken in the longitudinal (or machine) direction. The samples are conditioned for 24 hours at 23°C ± 1°C (77°F ± 2°F). The test samples are then placed in an oven at 80°C (176°F) for 24 hours. After removal from the oven, the samples are conditioned again at 23°C ± 1°C (77°F ± 2°F) for a minimum of four hours. Results are obtained by averaging the differences of measurement in the length direction of the samples.

Following is a summary of different test parameters.

Comparison of the results according to the reinforcement used

Imposed Requirements

According to the method and type of reinforcement used in the membrane, the requirements of dimensional stability tests are as follows:

Results achieved

Several products were compared in our laboratory, both on APP and SBS modifed bitumen membranes with the following reinforcements:

- Category A. Single reinforcement products:
  - polyester only
  - complex made of polyester and glass scrim
  - complex made of polyester and glass mat
  - glass mat alone
- Category B. Dual reinforcement products:
  - 1 non-woven polyester and 1 glass mat
  - 1 non-woven and scrim polyester and 1 glass mat
  - 1 non-woven and scrim polyester and glass scrim and 1 glass mat

	UEAtc	ASTM D 5147-D 1204	prEN 1107-1
Size (cm x cm)	≥ 10 x 10	25 x 25	25 x 5
Conditioning before initial measurement 23°C +/- 1°C (H)	no specification	40	24
Oven exposure 80°C +/- 3°C(H)	2 x 6	24	24
Conditioning after oven at 23°C +/- 1°C(H)	18	1	4 at least

Table 1: Test conditions according to the different standards.

Product or combination	UEAtc	prEN 1107-1	ASTM D 5142-D 1204
Polyester	≤ 0.5	≤ 0.6	(1)
Polyester + glass scrim	≤ 0.5	≤ 0.6	(1)
Polyester + glass mat	≤ 0.5	≤ 0.6	(1)

(1) Standards are still in development. Based on draft specifications from a wide range of products, the range is between 0.1 and 1 percent
Note: For single layer application, according to the European country, requirements can be below or equal 0.3 percent.

Table 2: Imposed requirements for standards.

The different products were tested in accordance with the UEAtc standards and ASTM D 5147 and D 1204 standards.

The results presented in Table 3 are margins obtained on the basis of an analysis on six to eight different products for each category.

This analysis provided the following conclusions:

- The UEAtc and ASTM methods give similar results.
- The best results are given by fiberglass-only reinforced membrane material. (Note: The given values come in the measurement errors.)
- Glass addition enables an important increase of the dimensional stability proportional to its weight.
- The different products can be clearly differentiated by this method.

Nevertheless, in view of the roll length conversion values, it seems that the method cannot accurately predict the behavior of the product on the roof. The extrapolated values are to high.

The reasons for this are as follows:

- The first reason is the size of the test samples, only 10 cm (4 in.), whereas membranes have a length varying between 7 m and 15 m (23 ft. and 49 ft.).
- The second reason is that other parameters are not evaluated in the trials, such as overlap width and strength and application method.

Therefore, in the lab, a test has been developed by the authors on a large-scale dimension to simulate shrinkage phenomena on roofs.

FULL-SCALE TEST METHODS DEVELOPED

Description of the test method

A test chamber was developed utilizing a large shipping container that had been conditioned to maintain consistent temperatures while providing a temperature range of 0°C to 80°C (32°F to 176°F) (tolerance deviation: ± 3 °C [± 5°F]). The deck is made of 50 mm (2 in.) glass wool insulation board. The membrane roll is unrolled to a length of 10 m (33 ft.). Two kinds of tests were made; a free shrinkage test and a shrinkage test with overlap.

Test A: Free shrinkage test

The membrane is secured by means of clips on one end. The other end is free to move and its end-position is reported on the deck. After 48 hours at 80°C (176°F), the distance between the end of the membrane and the reference position on the deck is reported in millimeters.

Test B: Shrinkage test with overlap

In the middle of the membrane, an end overlap of 10 cm (4 in.) is carried out over the whole width of the roll. The end overlap type is torched over the whole width and compressed

Bitumen-APP	UEAtc method (%)	Length conversion roll 10 m (mm)	D 5147-D 1204 ASTM method (%)	Length conversion roll 10 m (mm)
A. Single reinforcement products Polyester	0.4 0.6	40 60	0.4 0.6	40 60
Complex polyester + glass scrim	0.2 0.25	20 25	0.18 0.23	18 23
Complex polyester + glass mat	0.15 0.20	15 20	0.13 0.21	13 21
Fibreglass	0.02 0.02	2 2	0.02 0.02	2 2
B. Dual reinforcement products 1 Non-woven polyester+ 1 glass mat	0.05 0.15	5 15	0.07 0.16	7 16
1 non-woven + scrim polyester + 1 glass mat	0.08 0.11	8 11	0.08 0.12	8 12
1 non-woven +scrimglass+ scrim polyester+1 glass mat	0.04 0.10	4 10	0.04 0.10	4 10
SBS - Bitumen				
A. Single reinforcement products Polyester	0.35 0.62	35 62	0.4 0.56	40 56
Complex Polyester + glass scrim	0.2 0.3	20 30	0.18 0.3	18 30
Complex Polyester +glass mat	0.17 0.21	17 21	0.15 0.2	15 20
Fiberglass	0.02	2	0.02	2

Table 3. *Results on dimensional stability obtained in our lab, Note: The average mass of the polyester mats used as the main reinforcement is 180 grams (0.4 lbs.). The average weight of the polyesters used in combination with fibreglass varies between 100-200 grams (0.2 and 0.4 lbs.). The weight of the glass varies between 8 and 60 grams for the scrims and between 50 and 100 grams (0.11 and 0.22 lbs.) for the glass mat.*

by means of a 15 kg of pressing roll. The two ends of the membrane are secured by means of clips. The system is exposed to a temperature of 80°C (176°F) for 48 hours. The shrinkage at the overlap is measured on both sides of the membrane in three points and the values are averaged and expressed in millimeters. This test procedure was developed following a series of comparative analyses that considered several parameters, such as temperature and cycles.

The following two graphs summarize the results obtained.

- *Influence of the temperature:* Trials were made at three different temperatures (50, 65 and 80°C [122, 149 and 176°F]) on one product (Category A. Complex polyester+ glass mat) (80°C [176°F] being generally accepted as the maximum temperature encountered on a roof).[6]

After 40 hours, no more changes were observed.

Shrinkage was observed at 65°C (149°F) and 80°C (176°F), but at 50°C (122°F) shrinkage was not observed at all.

- *Influence of the thermal cycles:* The following cycle was applied on the preceding product:
  1° 10 H at 80°C (176°F)
  24 H at room temperature (25°C ± 3°C [77°F ± 5°F])

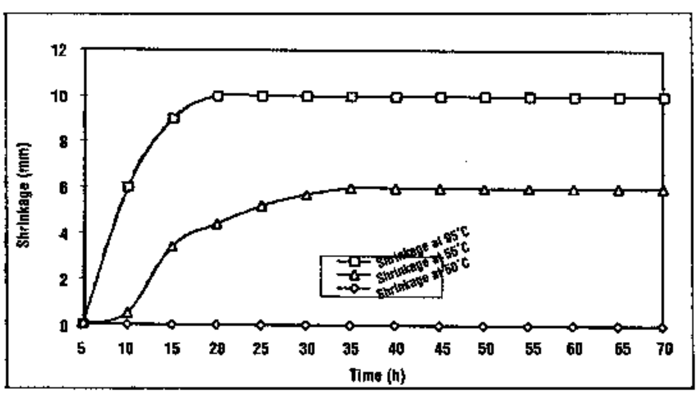

Figure 1. *Evolution of shrinkage with time.*

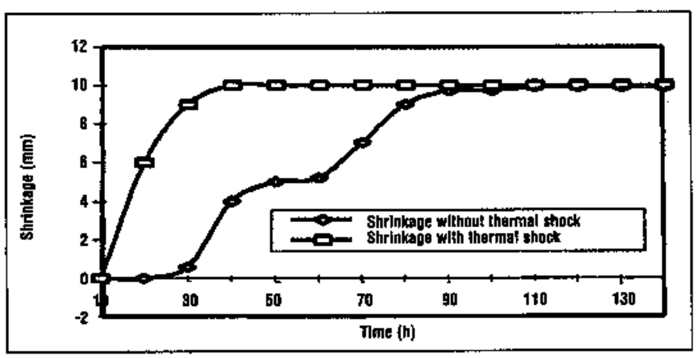

Figure 2. *Evolution of shrinkage with time and thermal shocks.*

From what is observed when the product was subject to constant 80°C (176°F) exposure, the addition of a cycle just postpones the phenomenon of shrinkage but does not change it. Based on the results of this study, a test lasting for 48 hours is considered sufficient for the polyester to reach its maximum and total shrinkage 80°C (176°F).

Results
The results obtained in the chamber are shown in Table 4.

CONCLUSIONS

This full-scale analysis enables the authors to make the following conclusions:

- Regarding free shrinkage, the results obtained in this full-scale dimensional stability test were similar to the results obtained in the lab.
- The products composed of fiberglass only reinforcements exhibit excellent dimensional stability. This was observed both in the lab and on the full scale test.
- The full-scale dimensional stability test with a torched overlap of 10 cm (4 in.) provides different results. According to the authors' roof experience with some of these products, it can be said that the full-scale dimensional stability test provides a more precise correlation with real life situations on the roof.
- The difference between free shrinkage and shrinkage with an overlap indicates that some others parameters have to be taken into account, such as size of the overlap, quality of the blend, quality of the polyester and the glass mat, and quality of the overlap itself.

All these parameters have to be handled by the producer of the roofing membranes. In this way, the application method can be optimized on the basis of the product's behavior.

In the future, the full-scale analysis can be improved by introduction of additional parameters such as trials with total or partial adhesion and with mechanical fixation.

It is clear that these findings, in combination with the application method and the built-up system, contribute to the durability and watertightness of the roof itself.

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Bitumen-APP	UEAtc-Length conversion roll 10 m (mm)	ASTM-Length conversion roll 10 m (mm)	Large-scale test free shrinkage (mm)	Large-scale test shrinkage with welded overlap (mm)
A. Single reinforcement products Polyester	40 60	40 60	30 35	7 20
Complex polyester + glass scrim	20 25	18 23	13 17	2 11
Complex polyester + glass mat	12 20	13 21	12 25	0 10
Fiberglass	2 1.7	2 1.8	0 0	0 0
B. Dual reinforcement products 1 Non-woven polyester+ 1 glass mat	5 15	7 16	6 11	0 4
1 non-woven +scrim polyester+ 1 glass mat	8 11	8 12	7 10	0 4
1 non-woven + scrim glass and polyester	4 10	4 10	6 12	0 3.5
SBS - Bitumen				
A. Single reinforcement products Polyester	35 62	40 56	32 37	9 22
Complex Polyester+glass scrim	20 30	18 30	9 24	2 7
Complex Polyester+glass mat	17 21	15 20	12 19	1 4.5
Fiberglass	2	2	0	0

Table 4.