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LABORATORY ANALYSIS OF PROTECTIVE WATERPROOF MEMBRANES ACCORDING TO THEIR DEGREE OF WATERTIGHTNESS

ABSTRACT

Attention is paid to the problems of the protective waterproof membranes of sloping roofs. The article presents a laboratory analysis of protective waterproof membranes according to their deree of watertightness. The laboratory analysis consists of 3 kinds of laboratory measurements: watertightness by a method of constant loading by a water column, watertightness by the method of a maximal water column up to 1500 mm, and watertightness by a dynamic method through rain simulation.

KEY WORDS

- *protective waterproof membrane,*
- *watertightness,*
- *laboratory analysis,*
- *sloping roof,*
- *roof deck of attic.*

1. INTRODUCTION

The laboratory measurements are aimed at the most important function of protective waterproof membranes, i.e., the drainage of water that has penetrated through the main waterproofing system. Laboratory measurements aimed at ascertaining watertightness are performed using three methods. The three methods all include loads by rainwater. Below are the following laboratory methods:

- Constant loading by a water column
- Loading by a maximal water column up to 1500 mm
- Loading by the dynamic method through rain simulation.

The laboratory measurements aimed at ascertaining watertightness were realized in the development laboratories of the Dörken Company in Herdecke, Germany.

2. SAMPLES SELECTION

The samples were extracted according to STN EN 13 416 “Waterproofing strips and foils – Asphalt, plastic and rubber strips and foils for waterproofing roofs – Sampling regulations. The samples were extracted from all the materials that are available in Slovakia so that they would represent the whole range of the material composition and mechanical properties of protective waterproof membranes. An overview of the samples used for the laboratory measurements is presented in Table 1.

3.1 Laboratory measurements of watertightness by the method of constant loading by a water column

Methodology of laboratory measurement
The methodology of the laboratory measurement is in line

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Tab. 1 *Overview of samples used for the laboratory measurements of watertightness.*

Sample identification	Type of protective waterproof membranes		Basis weight (g/m^2)
1	Microperforated	Microperforated	140
2	Microporous	Based on non-woven fabrics	115
3		Based on non-woven fabrics	150
4		Based on non-woven fabrics	120
5		Based on non-woven fabrics	140
6		Based on non-woven fabrics + dispersed coat	220
7		Based on non-woven fabrics + microporous coat	190
8		Microfibre	60
9		Microfibre	80
10		Microfibre	127
11		Asphalted strip type A	610
12		Asphalted with glass fabric bearing insert	250
13		Asphalted with glass fabric bearing insert	610
14		Asphalted with polyester mat bearing insert	630
15	PE foil	Polyethylene foil with non-woven fabrics	150
16		PE Foil	140
17	Monolithic	Monolithic	127

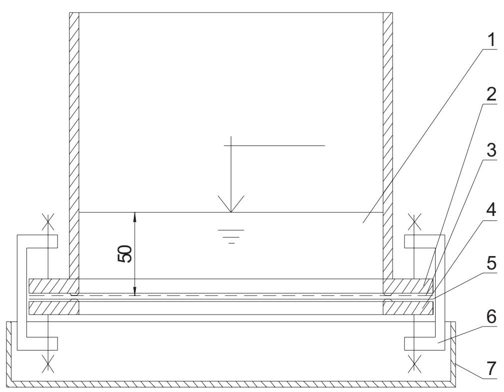

Fig. 1 *Principal picture of the laboratory unit section for measuring watertightness by the method of constant loading by a water column of 50 mm.*

1 – Distilled water, water column 50 mm, 2 – Structure of tu tub's upper part, 3 – Tested protective waterproof sample membrane 300 x 200 mm, 4 - Structure of tub's lower part, 5 – Supporting sheet under a protective waterproof membrane with Ø 8 mm lugs, 6 – Tub switch aggregate, 7 - Collection tub for water seeping through protective waterproof membrane

with STN EN 1928 [72]. The aim of the measurement was to determine which volume of water will flow or leak through a protective waterproof membrane if the protective waterproof membrane is in a horizontal position, and if loaded by a 50 mm distilled water column for 4 hours. The inspection unit is made of plexiglass and consists of a small tub, switch aggregates and a catching tub. The tub is the place where the distilled water with a constant height of 50 mm is put; it consists of the upper part of the tub, a supporting sheet under a protective waterproof membrane and the lower part of the tub. The sample was placed over the supporting sheet, and it was enclosed in the testing tub from the upper and lower parts. After pouring the distilled water up to a height of 50 mm, the watertightness of the protective waterproof membrane was monitored for 4 hours. An evaluation of the individual samples specified the volume of water that flowed through during the 4 hours. The testing unit is presented in Figures 6.1 and 6.2.

Limiting conditions during the measurement process

The measurement was done under laboratory conditions with a temperature of 20°C and 50% relative humidity.

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Tab. 2 *Overview of the results of the laboratory watertightness measurement by the method of constant loading by a water column.*

	Type of protective waterproof membrane		Basis weight (g/m^2)	Test results / Number of sample			Note
				1	2	3	
1	Micro perforated	Microperforated	140	Leaked through (1780ml)	Leaked through (720ml)	Not leaked through	
2	Microporous	Based on non-woven fabrics	115	Not leaked through	Not leaked through	Not leaked through	Water toadheres on letters on foil
3		Based on non-woven fabrics	150	Not leaked t.	Not leaked t.	Not leaked t.	- ll -
4		Based on non-woven fabrics	120	Not leaked t.	Not leaked t.	Not leaked t.	
5		Based on non-woven fabrics	140	Not leaked t.	Not leaked t.	Not leaked t.	
6		Based on non-woven fabrics + microporous coat	220	Not leaked t.	Not leaked t.	Not leaked t.	
7		Based on non-woven fabrics + microporous spray	190	Not leaked t.	Not leaked t.	Not leaked t.	
8		Microfibre	60	Not leaked t.	Not leaked t.	Not leaked t.	Water toadheres on letters on foil
9		Microfibre	80	Not leaked t..	Not leaked t.	Not leaked t.	- ll -
10		Microfibre	127	Not leaked t.	Not leaked t.	Not leaked t.	- ll -
11		Asphalted strip Type A	610	Not leaked t.	Not leaked t.	Not leaked t.	From lower part dry, from water side saturated
12		Asphalted with glass fibre bearing insert	250	Leaked through (100ml)	Leaked through (180ml)	Leaked through (340ml)	
13		Asphalted with glass fibre bearing insert	610	Not leaked t.	Not leaked t.	Not leaked t.	
14		Asphalted with polyester mat bearing insert	630	Not leaked t.	Not leaked t.	Not leaked t.	
15	PE foil	Polyethylene foil with non-woven fabrics	150	Not leaked t.	Not leaked t.	Not leaked t.	
16		PE Foil	140	Not leaked t.	Not leaked t.	Not leaked t.	
17	Monolithic	Monolithic	127	Not leaked t.	Not leaked t.	Not leaked t..	

Note: Not leaked t. = Not leaked through

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Evaluation of the laboratory measurements for the method of constant loading by a water column

During the testing all the samples mentioned in Table 1 achieved the results that are presented in *Table 2*. From the results it is clear that the constant water column with a height of 50 mm had adverse effects on the microperforated protective waterproof membrane and on the asphalted microporous protective waterproof membrane with a glass fabric bearing insert (250 g/m^2).

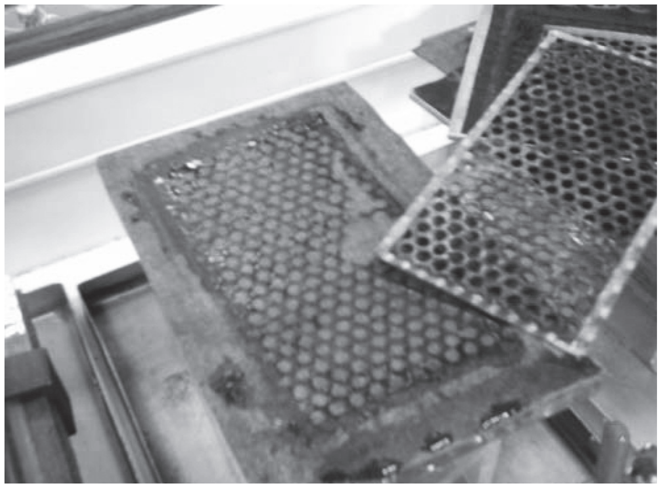

Fig. 3 *View of Sample No. 12 after the test.*

3.2 Laboratory measurements of watertightness by the method of a maximal water column up to 1500 mm

Methodology of laboratory measurement

The laboratory measurement is concentrated to reach the maximal possible pressure up to 1500 mm of a water column. It is one of the tests that cannot occur in practice and in the actual situation of a sloped roof, though it is a laboratory value that partly characterizes the watertightness qualities of protective waterproof membranes. Three samples of every material were tested; the test principle is: during a period of up to 3 minutes, the water column increases from 0 mm up to 1500 mm; the sample surface resisting the water pressure is 100 cm2. The testing device consists of stationary and movable parts. The sample is connected to the stationary part; on the sample a laboratory filter paper indicates the water leakage through the sample; on the stationary part there is also a device for reading the water level. The movable part assures direct movement and an increase in the water level and also the water pressure on the sample. The height of 1500 mm is interesting, as the dispersion at the measured heights from 0 mm up to 1500 mm is the greatest. The illustrations of the laboratory device are presented in figures 4 and 5.

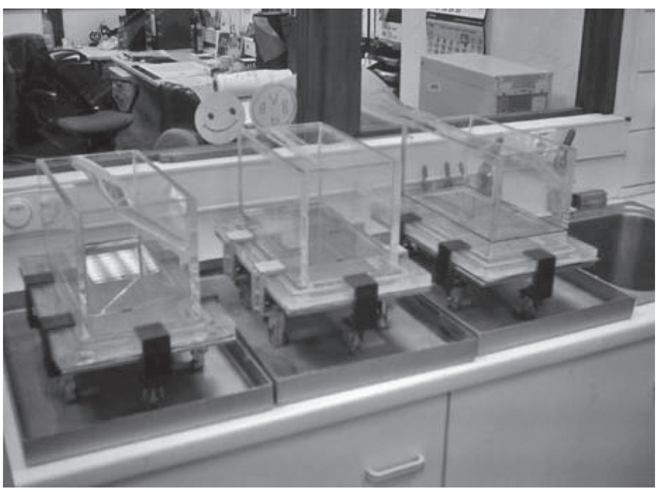

Fig. 2 *View of testing appliances.*

Fig. 4 *View of the testing device for the measurement of watertightness by the method of a maximal water column up to 1500 mm during the test.*

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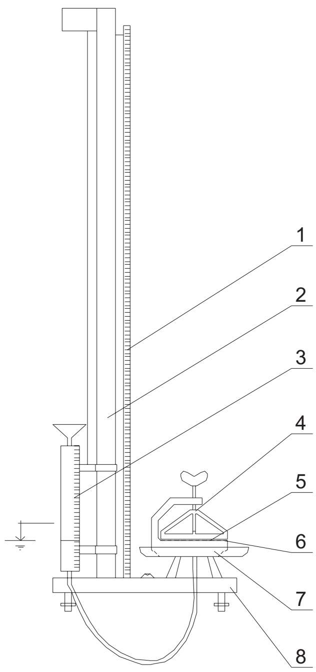

Fig. 5 *Principal picture of the laboratory unit section for measuring watertightness by the method of a maximal water column up to 1500 mm.*

1 – Reading device of water level´s height, 2 – Bearing structure and structure assuring movement of the valve with distilled water, 3 – Moving cylinder with distilled water, 4 – Withdrawable structure of the pressure tub´s upper part, 5 – Filter paper over protective waterproof membrane, 6 – Protective waterproof membrane, 7 – Water collecting tub, 8 – Bearing structure of the device

Limiting conditions during the measurement process

The measurement was performed in laboratory conditions under a temperature of 20°C and 50% relative humidity.

Evaluation of the laboratory measurements for the method of maximal loading by a water column up to 1500 mm

During the testing all the samples mentioned in Section 3.2 achieved the results that are presented in Table 3. From the results it is clear that the maximal water column measured up to 1500 mm,which was reached in 3 minutes, had very adverse effects on the microperforated protective waterproof membrane and on the microporous asphalted protective waterproof membrane with a glass fibre bearing insert.

3.3 Laboratory measurements of watertightness by the dynamic method through rain simulation

Methodology of laboratory measurement

The aim of the laboratory measurement is to load the protective waterproof membrane by the falling of simulated rain. The rain was simulated by the falling and flow of water from two rosette heads on the protective waterproof membrane inbuilt into an inclined plane. Water with a specified flow ran into the rosette heads and fell down to the protective waterproof membrane placed on the filter paper and plexiglass. The plexiglass was fixed on an inclined “roof “ surface; the reason why was that there was a base under the waterproof membrane, filter paper and plexiglass. Through the plexiglass you can observe the filter paper where the protective

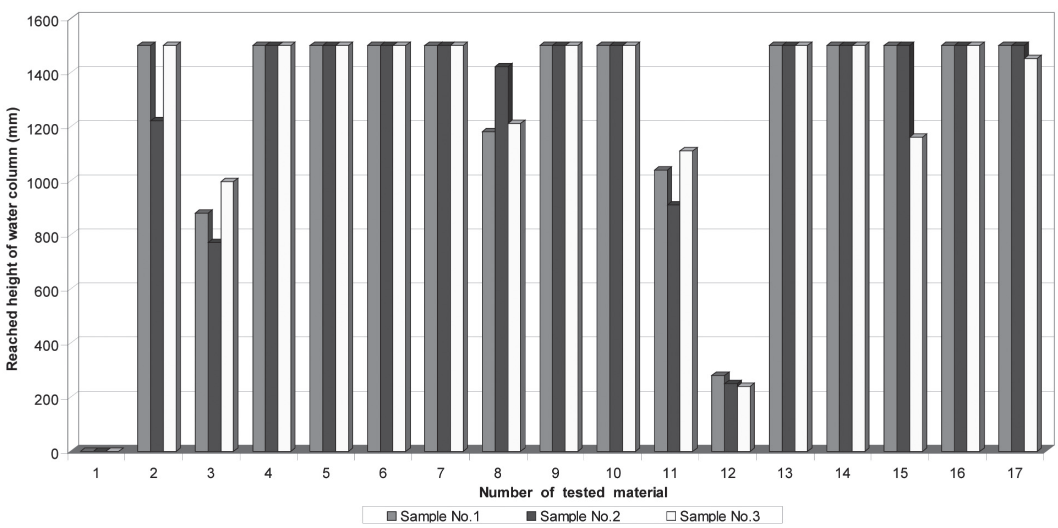

Fig. 6 *Overview of the results of the laboratory measurement of watertightness by the method of maximal loading by a water column up to 1500 mm presented in the diagram.*

Tab. 3 *Overview of the results of the laboratory measurement of watertightness by the method of maximal loading by a water column up to 1500 mm.*

	Type of protective waterproof membrane		Basis weight (g/m^2)	Test result /Sample number			Note
				1	2	3	
1	Microperfo-rated	Microperforated	140				Cannot be measured, material is microperforated
2	Microporous	Based on non-woven fabrics	115	N 1500mm	P 1220mm	N 1500mm	Fold saturated on surface by water
3		Based on non-woven fabrics	150	P 880mm	P 770mm	P 995mm	Fold saturated on surface by water
4		Based on non-woven fabrics	120	N 1500mm	N 1500mm	N 1500mm	Fold saturated on surface by water
5		Based on non-woven fabrics	140	N 1500mm	N 1500mm	N 1500mm	Fold saturated on surface by water
6		Based on non-woven fabrics + dispersion coat	220	N 1500mm	N 1500mm	N 1500mm	
7		Based on non-woven fabrics + microporous coat na	190	N 1500mm	N 1500mm	N 1500mm	
8		Microfibre	60	P 1180mm	P 1420mm	P 1210mm	
9		Microfibre	80	N 1500mm	N 1500mm	N 1500mm	
10		Microfibre	127	N 1500mm	N 1500mm	N 1500mm	Fold saturated on surface by water
11		Asphalted strip type A	610	P 1040mm	P 910mm	P 1110mm	
12		Asphalted with glass fibre bearing insert	250	P 280mm	P 250mm	P 240mm	
13		Asphalted with glass fibre bearing insert	610	N 1500mm	N 1500mm	N 1500mm	
14		Asphalted with polyester mat bearing insert	630	N 1500mm	N 1500mm	N 1500mm	
15	PE foils	Polyethylene foil with non-woven fabrics	150	N 1500mm	N 1500mm	P 1160mm	
16		PE Foil	140	N 1500mm	N 1500mm	N 1500mm	
17	Monolithic	Monolithic	127	N 1500mm	N 1500mm	P 1450mm	Fold saturated on surface by water

Note: N = Not leaked through; P = Leaked through

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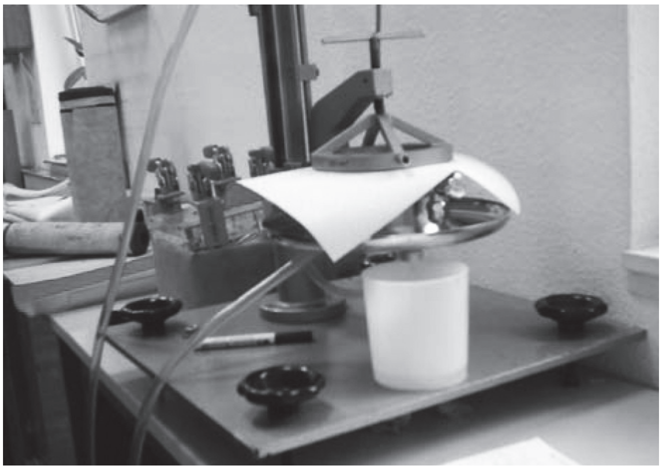

Fig. 7 *View of tested sample and testing device during the test.*

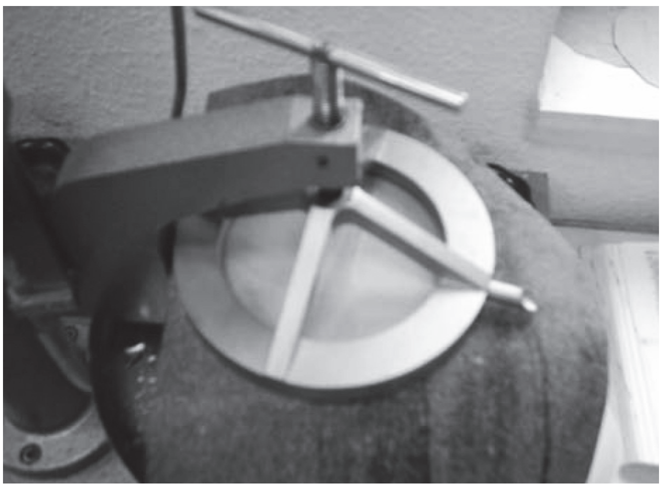

Fig. 8 *Detailed view of tested sample during the test.*

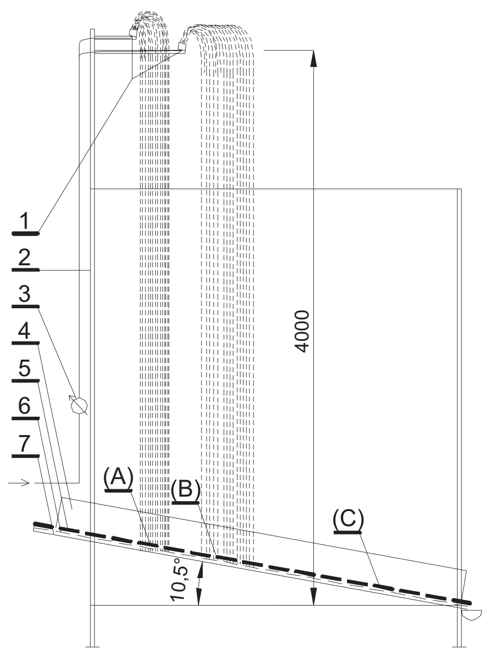

Fig. 9 *Schematic drawing of the testing device and the principle of the watertightness test by the dynamic method through rain simulation.*

1 – Rosette heads securing spreading the water, 2 – Bearing structure of steel profiles, 3 – Water inlet through water meter, 4 – Protective and sealing part along the structure, 5 - Protective waterproof membrane, 6 – Filter paper, 7 – Adjustable part of the structure of galvanized steel profiles; the roof plane consists of plexiglass (A), (B), (C) – type of loading by rain

waterproof membrane flowed or leaked through. The flow of 2.4 l/min. for one rosette head was simulated for 4 hours. The inclination of the roof plane was 10.5° (18.53 %, 1:5.396). The test monitored how long from the beginning of the test the protective waterproof membrane resisted the simulated rain falling from a height of 4 m. The laboratory device consisted of a stationary part, i.e., a frame and movable and adjustable parts, i.e., an inclined "roof plane". On an inclined roof plane made of steel profiles plexiglass was put, on which was laid filter paper. The protective waterproof membrane was laid parallel to the gutter. Two to three strips were put on the roof plane parallel to the gutter (according to the width of the strips). The strips overlapped, and the overlap met the specifications of the individual strip producers. For a schematic drawing of the testing device, see Figure 10.10; for views of the testing devices, see Figures 9, 10.

Limiting conditions during the measurement process

The measurement was done outside without the direct effects of wind and the sunrise. During the measurement the air temperature ranged from 13°C to 22 °C; the relative humidity was 83 %.

Evaluation of the laboratory measurements for the dynamic method by rain simulation

For all the samples mentioned in chapter 6.1 that were tested, there were results achieved that are developed in Table 4. From the results it is clear that in general the simulated rain caused three kinds of loading:

- Falling of rain drops on the protective waterproof membrane (A*)
- Fall of rain drops on a protective waterproof membrane (B*)
- Effects of water flowing on the protective waterproof membrane (C*)

Note: Specification (A), (B), (C) see Figure 9.

These three types of stress affected the protective waterproof membrane for 4 hours

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4. RESULTS OF LABORATORY MEASUREMENTS OF PROTECTIVE WATERPROOF MEMBRANE

The laboratory measurements were aimed at loading watertightness, the diffusion of water vapour and the mechanical qualities of protective waterproof membranes. The laboratory measurements of watertightness were performed by three methods:

- Method of constant load by a water column
- Method of load by a maximal water column up to 1500 mm
- Dynamic method of rain simulation.

Knowledge gained and conclusions from the laboratory measurements aimed at watertightness

- Watertightness is the main function of protective waterproof membranes; the monitored laboratory measurements prove that this most important function is not met by all the tested protective waterproof membranes.

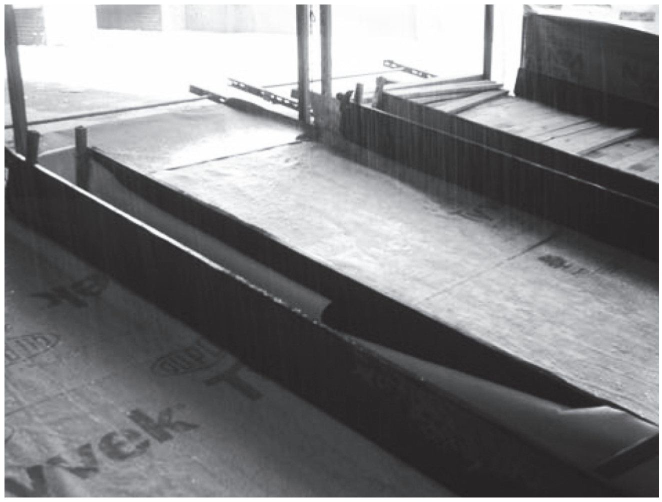

Fig. 10 *View of 2 testing devices during the test.*

Tab. 4 *Overview of results of the laboratory measurement of watertightness by the dynamic method through rain simulation.*

	Type of protective waterproof membrane		Basis weight (g/m^2)	Test result
1	Microperforated	Microperforated	140	After 15 min leaked through
2	Microporous	Based on non-woven fabrics	115	Not leaked through
3		Based on non-woven fabrics	150	After 4 hours soaked
4		Based on non-woven fabrics	120	Not leaked through
5		Based on non-woven fabrics	140	Not leaked through
6		Based on non-woven fabrics + dispersion coat	220	Not leaked through
7		Based on non-woven fabrics + microporous coat	190	Not leaked through
8		Microfibres	60	Not leaked through
9		Microfibres	80	Not leaked through (on the verge of leakage)
10		Microfibres	127	Not leaked through
11		Asphalted strip Type A	610	After 4 hours leaked through, flowed through
12		Asphalted with glass fabric bearing insert	250	After 20 min flowed through
13		Asphalted with glass fabric bearing insert	610	After 4 hours leaked through, flowed through
14		Asphalted with polyester mat bearing insert	630	Not leaked through (soaked on the area 2x10cm2)
15	PE foils	Polyethylene foil with non-woven fabrics	150	Not leaked through
16		PE Foil	140	Not leaked through
17	Monolithic	Monolithic	127	Not leaked through

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Fig. 11 *View of microperforated protective waterproof membrane during the test.*

Fig. 12 *View of asphalted strip with 250 g/m² glass insert after finishing the test, leakage on the whole surface of the strip.*

- The samples of microperforated protective waterproof membrane met none of the watertightness tests; their material and structural design did not meet the basic requirements for protective waterproof membranes.
- The watertightness results of the microporous protective waterproof membranes based on non-woven fabrics were various. As is obvious from the laboratory measurements, their watertightness is not dependent on the basis of their weight. It is necessary to note that their watertightness is dependent on the waterproof layer being diffusionally open between the two non-woven fabrics, while the producer is responsible for its quality.
- The microporous protective waterproof membranes made of microfabrics achieved positive results except for the laboratory measurement conducted by the method of a maximal water column up to 1500 mm, whereas the microporous protective waterproof membrane 60 g/m^2, sample No.8 achieved lower values. It is necessary to note that the watertightness of this material clearly depends on the basis of weight. The reason is due to the structure of the material; it is a compact material made of polyethylene fibres with a high degree of density.
- Asphalted strip Type A did not meet the requirements in two of the three measurements tested.
- Microporous protective waterproof membrane asphalted with glass fabric bearing insert 250 g/m^2 proved to be unreliable. It did not meet the requirements in any of the tests; the thickness of its asphalted layer did not provide watertightness. The producer prefers these materials to be contactless into three membrane roofs.
- The microporous protective waterproof membranes asphalted with a 610 g/m^2 glass fabric bearing insert and a 630 g/m^2 polyester mat did not achieve positive results during the laboratory measurement by the rain simulation method. It is necessary to state that the test by falling rain is the most unfavourable of the tests according to the loading. In the falling of the simulated rain, point (A) could be seen as the most loaded place where the rain drops fell directly.

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