SLOVAK JOURNAL OF CIVIL ENGINEERING

2009/3 PAGES 16 – 23 RECEIVED 31. 3. 2009 ACCEPTED 15. 5. 2009

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DEFECTS IN SHEET ROOFING THAT IMITATES ROOF TILES AS A RESULT OF THEIR ANCHORAGE

ABSTRACT

Sheet roofing is one of the materials which provide damp-proofing of roofs. It can be divided according to various viewpoints and criteria. The use of sheet roofing has been increasing in recent years, so the number of defects is increasing as well.

KEY WORDS

- *roofs*
- *sheet roofing*
- *roofing defects*

1. INTRODUCTION

The roof cladding of a building actively participates in the creation of artificial environments. It protects a building and its highest floor against atmospheric exposure. Sheet roofing is a trend in the development of roofing as evidenced by its history, its use in the present and surely also in the future. In collaboration with manufacturers, importers, sellers, realization companies and the Slovak Roofing Association, research in order to find out the actual amount of built-in sheet roofing has been carried out. This research determined that in 2004, 2 058 222 m^2 of sheet roofing was used. In 2006, 2 737 435 m^2 of roofs with sheet roofing were realized, which represents an increase of 33 % in comparison with the year 2004. Along with this current roof cladding trend, when the newest materials, technologies and theoretical knowledge are available, the failure rate is connected. The main area of the failure rate of sheet roofing is in the field of waterproofing techniques, thermal performance, acoustics, aerodynamics, color stability and the protection of the roofing.

2. ROOFING DEFECTS

Based on diagnostics which were carried out using information from specialized literature and papers, conferences and seminars, 92% of the roofs in Slovakia are defective, out of which 71 % are in a state of failure. Longterm observations revealed that 84 % of the failure state of roofs is in the details and 16 % is in fragments [5]. Sheet roofing is included in these statistics. It follows that many roofs are already reconstructed, even if the structures are not yet used for this purpose.

Sheet roofing that imitates roof tiles represents one part of the overall amount of sheet roofing. The defects of this roofing are included in the general defects of sheet roofing, but they also have

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their particularities. When using this roofing with an anchorage with a screw and a sealing washer, we meet with the problem of water leaking through the joint into the spaces directly under the roof (Fig.2.1). This does not occur at only one joint, but on the whole roof, as evidenced by icicles in the winter (Fig.2.2).

The tightness of the anchoring is dependent on the overall solution and tightness of the sealing washers. The tightness of the sealing washer is dependent on the quality of the material, the method of mounting the screws and other properties. We meet with cases where the anchorage screw is mounted incorrectly and the sealing washer is compressed too much (Fig.2.3) or the sealing washer is not pressed sufficiently as recommended by the manufacturer (Fig.2.4). Such joints cannot be leak-proof over the long term. It often occurs that when a sealing washer is pressed too much, then as a result of atmospheric exposure, it loses its original shape and completely falls off (Fig.2.5). Thereafter, there is no barrier preventing water from leaking into the roof cladding. Sometimes water leaks through a joint in spite of the fact that the screws are mounted correctly and the sealing washers are sufficiently compressed, as is required by the manufacturer (Figs.2.1 and 2.2). It often happens that a lot of anchorage elements are used for sheet roofing (Fig.2.6), which is not helpful for the water-proofing properties of the roofing, and it does not look aesthetically attractive as well. Also, the damaged surface layer (Fig.2.7) does not look aesthetically attractive. The damage to the surface layer can be caused by the poor quality of the surface layer, the handling of the sheet when anchoring, the falling of branches onto the roof, removing snow from the roof, etc. Scratching the roofing surface results in a loss of the protective layer of the sheet, which leads to corrosion and to a consequent shortening of the lifespan of the roof. Corrosion occurs on parts of

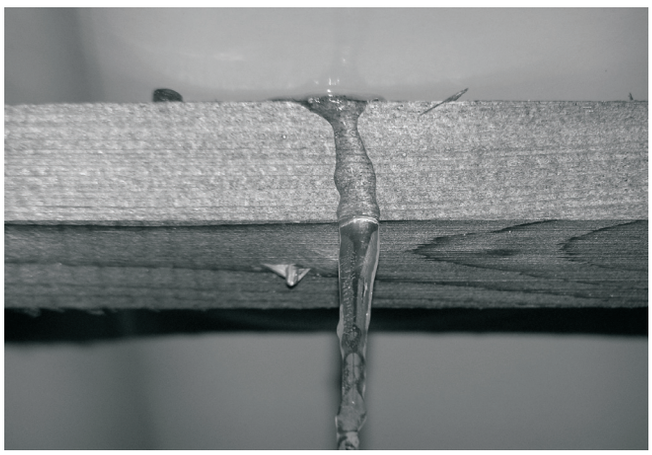

Fig. 2.1 *Detail of leaking water through the screw joint of the sheet roofing imitating a roof tile in the winter.*

Fig. 2.2 *Leaking of screw joints in the winter.*

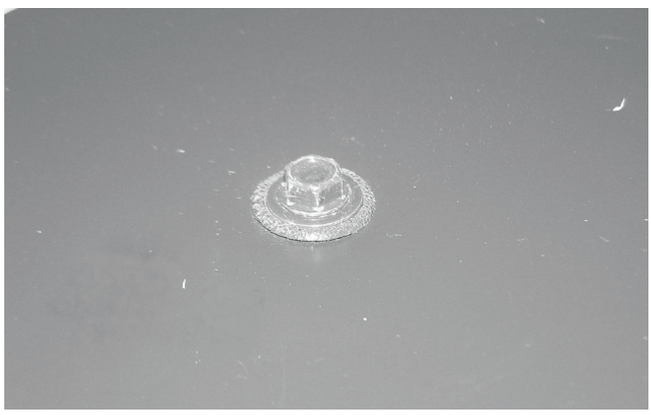

Fig. 2.3 *An anchorage screw with a sealing washer that is compressed too much.*

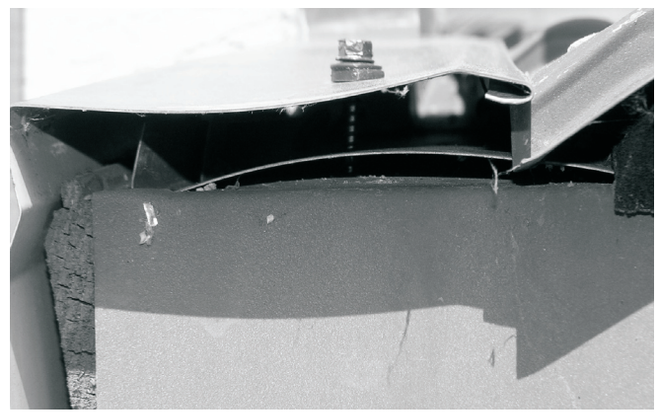

Fig. 2.4 *Incorrectly mounted anchorage screw with an uncompressed sealing washer.*

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Fig. 2.5 *A broken out sealing washer.*

Fig. 2.6 *The anchoring of a sheet with a lot of screws and unprofessional cutting.*

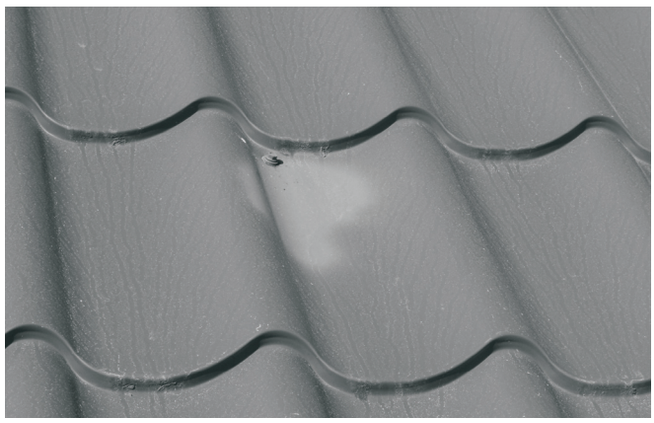

Fig. 2.7 *Damage to the surface layer of sheet roofing.*

a sheet which are not protected by a surface treatment and which can be caused by cutting off the unneeded part of the sheet and not making the treatment. It is a big mistake to cut the sheet roofing with a slitting saw. It should be cut with scissors. Falling sparks and the heat which is generated when cutting sheet roofing incorrectly affect the protective surface layer and deteriorate the whole roofing.

3. EXPERIMENTAL MEASUREMENTS FOR THE ANCHORAGE OF SHEET ROOFING

Sheet roofing that imitates a roof tile was used for the experimental measurement of the water tightness of the anchorage of the sheet roofing. Sheet metal continuously zinc-coated by heat with a coloured surface treatment with a thickness of 0.5 mm and a surface mass of 5.0 kg/m^2 and sheet metal bilaterally galvanized with aluminum and zinc with a stone grainy ceramic-glazed surface and with a bituminous paint coat finish with a thickness of 0.43 mm and a surface mass of 6.6 kg/m^2 were used. As anchorage elements, zinc-coated self-drilling screws with a diameter of 4.8 mm with EPDM sealing washers and special zinc-coated nails with a diameter of 3 mm were used. The water tightness of sheet roofing can only be evaluated by visual assessment according to the STN EN 14782 standard (74 7717): self-supporting metal sheets for roofing, external cladding and internal lining. When the product does not have any gaps (defects), it is considered watertight. If required, the presence of gaps is checked visually on the final product [3]. Since the sheet roofing is joined together by screws with sealing washers fixed directly through the roofing, there is an opening in the sheet, which is overlapped by the sealing washer. There is no standard for evaluating water tightness for this type of roofing. That is the reason why in order to determine the water tightness of the anchorage of the sheet roofing imitating a roof tile, it was decided to use the same method used for determination of the water tightness of bituminous strips and foils, where the assessed sample is put into a pressure device, and the water tightness is measured.

Test samples with a diameter of 156 mm were cut out from a sheet and fixed by the anchorage elements to blocks made from coniferous wood without any defects. The strength class of the coniferous wood was C14. The manufacturer of this roofing recommends checking the mounting of the anchorage screws only visually by pressing the sealing washer. Therefore, the values of the tightening torques were determined. On the first sample the screw was mounted correctly (Fig.3.1). This means that the sealing washer was sufficiently pressed as determined by the manufacturer. The screw was fixed by a tightening torque of 0.50 Nm. On the other two samples the screws were mounted incorrectly. On the second sample the sealing washer of the screw was pressed too much (Fig. 3.2). The screw was

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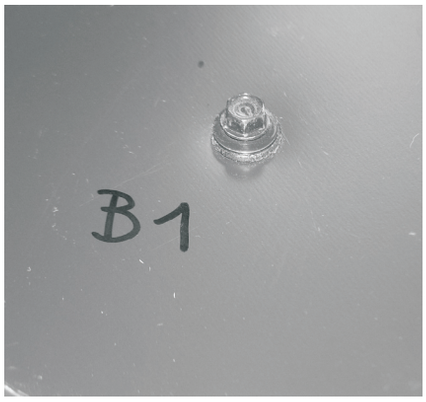

Fig. 3.1 *Sample – a correctly mounted screw. correctly*

Fig. 3.2 *Sample – the screw mounted incorrectly; the washer is pressed too much.*

Fig. 3.3 *Sample – the screw mounted incorrectly; the washer is not pressed.*

fixed by a tightening torque of 0.70 Nm. The third screw was fixed by a tightening torque of 0.20 Nm, so the sealing washer was not pressed (Fig. 3.3). The fourth sample was created by a nail nailed to the cut sheet. The measurements were performed in combinations of these screws with the washers and nail (Fig. 3.4) on the smooth sheet and on the sheet with the granulated slate. Combinations of measurements with various temperatures of the samples were also done. The samples had temperatures of +20°C (laboratory temperature), +70°C (heated sample) and -30°C (cooled sample). The negative values were reached in a MK 70 cryostat and the positive ones in a KCW 100 drying kiln.

Measurement of water tightness by pressure device

The measurements of the water tightness of the anchorage of the sheet roofing imitating the roof tile were performed on a device for testing water tightness (Fig. 3.5). The device is fitted with the pressure vessel and the pressure device – a compressor and barometer. The water tightness of the contact between the roofing and the device was provided by a rubber seal. The water pressure was gradually increased by the compressor step by step and was observed on the barometer. At the moment of the water leaking through the anchorage of the roofing the value of the pressure was read from the barometer scale and written on a table. A total of 24 samples were measured.

Measurement of water tightness by the height of a water column

This test focused on the water tightness and the amount of time of the water tightness of the anchorage of the sheet roofing. Measurements without the pressure device were done on the principle of water pressure at a height of 100 mm over the anchorage of the sheets. The vessels, which were water-tight when fixed on the samples of

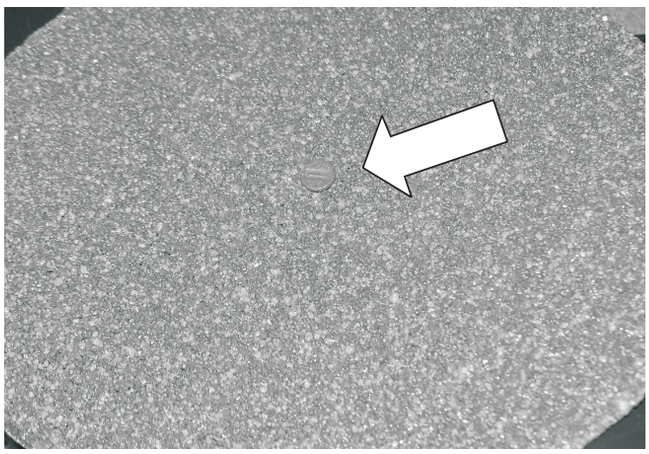

Fig. 3.4 *Sample – the nail in a sheet with granulated slate.*

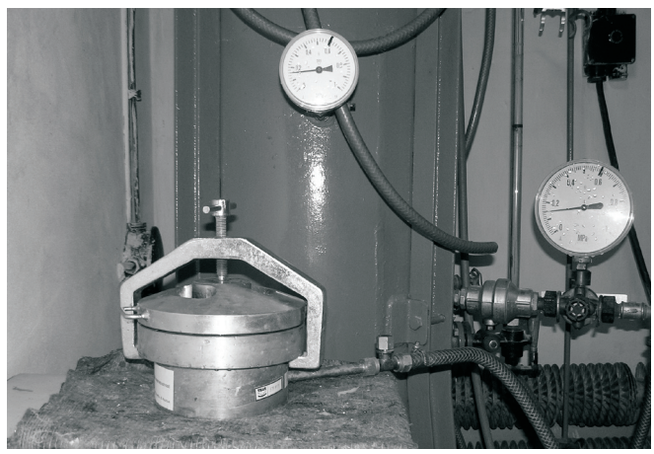

Fig. 3.5 *Device for testing water tightness.*

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Fig. 3.6 *The measurement of the water tightness by the height of the water column.*

the sheets, were filled with 100 mm of water over the joint of the sheets (Fig. 3.6). Then the time in which the water flowed through the anchorage of the sheet roofing was measured. The time in which a given amount of water would flow through a given joint was measured as well. The time was measured by a stopwatch, and the particular values were written on the table. Another measurement simulated the absence of any anchorage elements in the sheet roofing. This means that the time in which a given amount of water would flow through the opening caused by the anchorage elements (the anchorage screw or nail) was measured. The time was read from a stopwatch, and the particular values were written on tables. A total of 12 samples were measured.

4. RESULTS OF MEASUREMENTS

Measurement of water tightness by pressure device

The water tightness of the anchorage of sheet roofing is influenced by its anchorage system. The water tightness of the anchorage of sheet roofing imitating roof tiles is dependent on the method of mounting the anchorage screws. This depends on which tightening torque is used for mounting the anchorage screw, which means that it depends on how the sealing washer is deformed, whether the sealing washer is pressed enough or whether the sealing washer is pressed too much or the washer is not pressed. Another factor which influences the water tightness of the anchorage is the temperature of the environment. In the following tables the values of the

Table 4.1 *Permeability of the anchoring of sheet roofing to a base – screws with sealing washers, smooth sheet.*

Permeability of anchoring of sheet roofing to the base – screws with sealing washers, smooth sheet [MPa]			
Temperature of measurement	Compression of the washer		
	pressed enough	pressed too much	not pressed
+20 [°C]	0.17	0.14	0.09
+70 [°C]	0.19	0.15	0.06
-30 [°C]	0.20	0.16	0.05

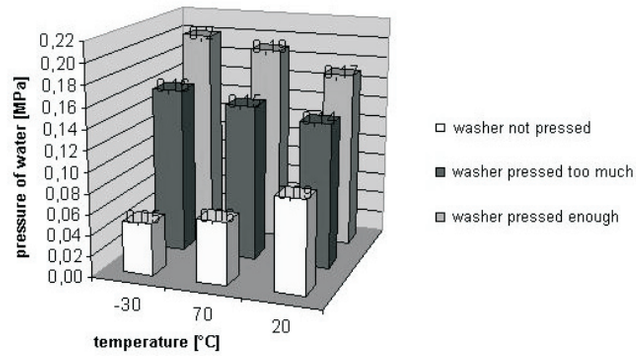

Fig. 4.1 *Dependence of the permeability of the anchoring of sheet roofing to a base – screws with sealing washers, smooth sheet.*

measurements of the water tightness for particular samples are written. The figures show the particular dependencies of the water tightness of the anchorage of the sheet roofing imitating roof tiles. The anchorage of sheet roofing imitating roof tiles with screws with sealing washers must be water tight, and the water should not get through the joint. It can be seen from the measured values of the measurement by the pressure device and the figures at which the values of the water pressure the joint is not water tight, and the water will flow on the other side of the roofing.

Table 4.2 *Permeability of the anchoring of sheet roofing to a base – screws with washers, sheet with posypom.*

Permeability of anchoring of sheet roofing to the base – screws with washers, sheet with granulated slate [MPa]			
Temperature of measurement	Compression of the washer		
	pressed enough	pressed too much	not pressed
+20 [°C]	0.16	0.11	0.035
+70 [°C]	0.17	0.13	0.03
-30 [°C]	0.18	0.14	0.02

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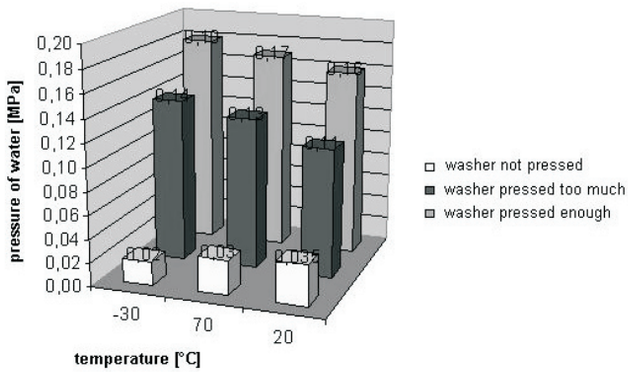

Fig. 4.2 *Dependence of the permeability of the anchoring of sheet roofing to a base – screws with washers, sheet with granulated slate.*

Measurement of water tightness by the height of a water column

This measurement was performed under the assumed pressure of a water column with a height of 100 mm. The water tightness of the anchorage of the sheet roofing is dependent on the type of anchorage, the method of mounting, and the type of sheet. This depends on whether a screw with a sealing washer is used as an anchorage element, if this sealing washer is pressed enough, pressed too much or is not pressed, or if a nail is used as an anchorage element. In this measurement it is assessed whether the anchorage is water-tight or not, which means whether it releases the water or not. In further measurement the amount of water which would flow through a given anchorage in a given time was measured.

Table 4.3 *Permeability of the anchoring of sheet roofing measured by the height of the water level.*

anchorage element	sealing washer	treatment of the sheet	time [min.]
screw	not pressed	sheet with granulated slate	2
		smooth sheet	4
	pressed enough	sheet with granulated slate	10
		smooth sheet	30
	pressed too much	sheet with granulated slate	-
		smooth sheet	-
nail	-	sheet with granulated slate	immediately
	-	smooth sheet	immediately

Table 4.4 *Rate of water flow through an opening from a nail.*

volume of water [$10^{-6}.m^3$]	100	200	300	400	500
time [s]	10	21	36	54	78

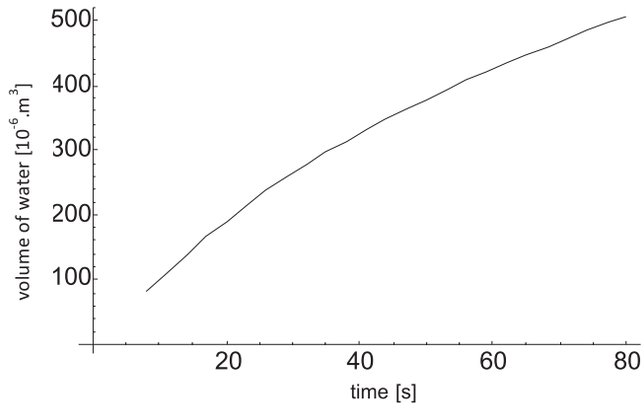

Fig. 4.3 *Graphic representation of the function of the flow of water through an opening from a nail.*

$y = 1254.7102 + 1.7231x - 1084.1564\text{ArcTan}(x) + 183.7643\text{Log}(x)$ [$10^{-6}.m^3$]

Table 4.5 *Rate of water flow through the opening from a screw.*

volume of water [$10^{-6}.m^3$]	100	200	300	400	500
time [s]	5	10	17	26	39

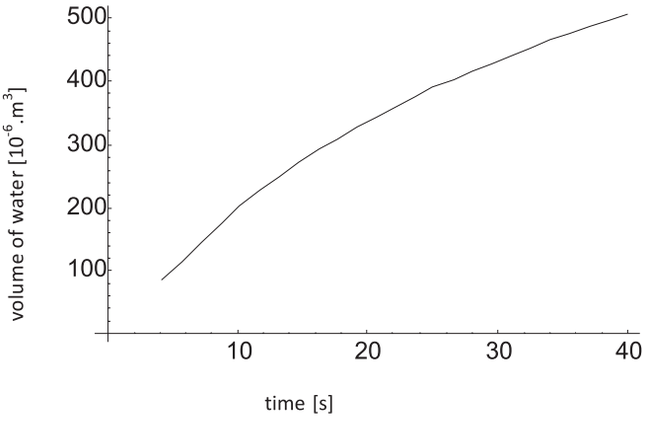

Fig. 4.4 *Graphic representation of the function of the flow of water through the opening from a screw.*

$y = 663.5008 + 1.4110\ x - 683.2858\text{ArcTan}(x) + 228.6718\text{Log}(x)$ [$10^{-6}.m^3$]

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Table 4.6 *Rate of water flow through the anchorage of a sheet by a nail.*

volume of water [$10^{-6}.m^3$]	10	20	30	40	50	60	70	80	90	100	110	120	130	140
time [s]	90	240	410	605	860	1200	1620	2220	2940	3960	5370	7380	10500	16500

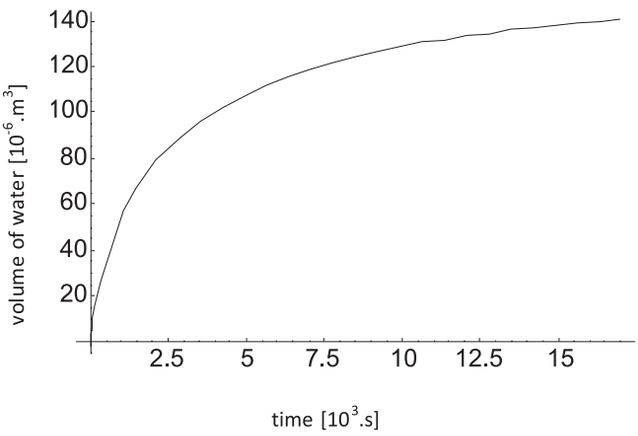

Fig. 4.5 *Graphic representation of the function of the flow of water through the anchorage of a sheet by a nail.*

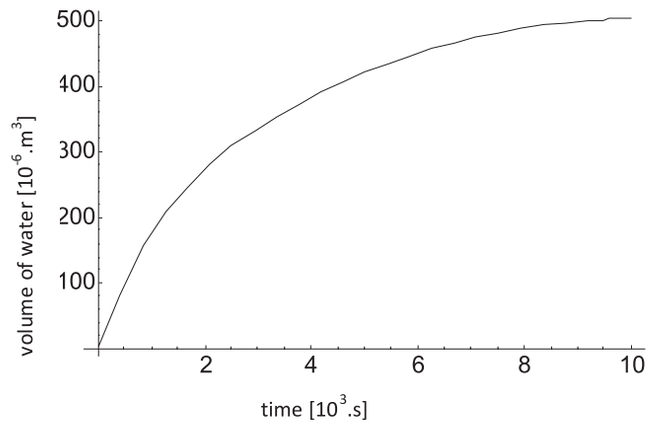

Fig. 4.6 *Graphic representation of the function of the flow of water through the anchorage of a sheet with an untightened screw.*

$y=13.8716+8.4730x-0.4974x^2+0.011x^3+41.271ArcTan(x)+3.5439Log(x)[10^{-6}.m^3]$

$y = -1.3136 + 54.5272x -2.7704x^2 + 0.0009x^3 + 159.8291ArcTan(x) – 0.2608Log(x)\quad [10^{-6}.m^3]$

With the aid of the Mathematica 5.1 program the dependence of the flowing of the water through the anchorage was calculated, and the functions of this flow were determined. According to these functions, it is possible to calculate the amount of water which will flow through a given anchorage in a given time.

The following figures show the particular dependencies of the water tightness and flowing of the anchorages of sheet roofing imitating a roof tile and their measured and calculated values.

It can be seen from the measured values of the measurement of the water tightness by the height of the water level and the figures that these anchorages are not water tight and at which anchorages the water will flow on the other side of the roofing and in which time the given amount of water will flow through the given anchorage.

5. CONCLUSION

Sheet roofing is included in prefabricated roofing. Prefabricated roofing is not resistant to hydrostatic pressure, driven rain or snow. Sheet roofing is laid on a roof structure as a prefabricated part;

Table 4.7 *Rate of water flow through the anchorage of a sheet with an untightened screw.*

volume of water [$10^{-6}.m^3$]	10	20	30	40	50	60	70	80	90	100	110	120	130
time [s]	50	100	140	190	240	290	340	395	450	510	570	630	690
volume of water [$10^{-6}.m^3$]	140	150	160	170	180	190	200	210	220	230	240	250	260
time [s]	750	810	880	950	1020	1090	1165	1260	1365	1480	1590	1720	1855
volume of water [$10^{-6}.m^3$]	270	280	290	300	310	320	330	340	350	360	370	380	390
time [s]	1990	2125	2260	2395	2550	2710	2875	3070	3265	3465	3670	3875	4105
volume of water [$10^{-6}.m^3$]	400	410	420	430	440	450	460	470	480	490	500		
time [s]	4360	4625	4920	5330	5580	6000	6400	6875	7485	8200	9020		

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it is fixed by anchorage elements and connected by joints. These anchorages together with the roofing are constantly exposed to various factors and must resist them. Attention must be focused not only on the sheet roofing itself, but also on the correctness of the realization of the anchorages and details. In real conditions the various negatively affecting influences on their functionality and lifespan come into being by the influence and combination of various factors that affect a roof (sheet roofing and the anchorage as well).

The correct solution to the problems presented by sheet roofing is based on the possibility of particular parts having free dilatation movements. The influence of the temperature on the roofing and its differences and fluctuations result in a stress field, which can effect a gradual reduction in the reliability of the roofing used. When making assessments, it is important to proceed from the real course of year-long temperatures. It is necessary to take into account the impacts of extreme (positive or negative) temperatures and the impacts caused by sudden temperature changes. The human factor plays a major role on which the reliability of sheet roofing is dependent.

The water-tightness of the anchorage of sheet roofing imitating roof tiles is influenced by the method of mounting anchorage elements, the type of sheet metal with a surface treatment and, last but not least, the temperature. Each measured sample released water. It follows from the measurements that every perforation of the sheet leaks therefore negatively influences the damp-proofing of sheet roofing.

It is evident from the values measured that when the anchorage element is a nail, water immediately gets on the other side of the sheet. When the anchorage element is a screw with a sealing washer, the water gets on the other side of the sheet depending on the surface treatment of the sheet and the method of mounting the screw.

The measurements showed that the direct anchoring of sheet roofing into a load-bearing construction without a structural covering with the use of sealing washers is not water resistant. When using the direct anchoring of sheet roofing, the anchorage elements are placed in an area with the greatest concentration of water, and the anchoring relies on the tightness of the materials used, i.e., sealing washers. The water-tightness of the anchorage elements with sealing washers is dependent on the mounting. This means that the reliability of sheet roofing is ensured by the precision of the assembler. So a big role is played by the human factor. It is necessary to ask the question as to whether it is appropriate to anchor the sheet roofing by perforating with several anchorage elements on a square meter and relying on a subsidiary damp-proofing technique. The results of the experimental measurements showed that it is not. In the measurement of the water-tightness by the pressure device, all the test samples leaked water. In the measurement by the height of the water level, the samples leaked water, too.

For the safe and reliable functioning of a roof structure during its lifespan, it is necessary to use quality materials with sufficient dimensions. The reliability of the roof begins with the load-bearing construction and continues right to the roofing. The base under the sheet roofing must be made from quality materials and be without any defects. The anchorage of the sheet roofing must allow for dilatation movements. Then the anchorage must be fixed to the load-bearing construction, and it must be overlaid by another piece of roofing. In this way, the anchorage will not be directly affected by all the influencing factors so that the highest degree of reliability of the sheet roofing will be achieved.

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