ASSESSMENT OF EXTERNAL INFLUENCES ON JOINT QUALITY OF ROOF WATERPROOFING FOIL BASED ON MPVC

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ABSTRACT

The statement deals with the research of how the technology used for single ply roofing membranes based on mPVC can influence the final quality of its joints. It is clear that any roofing company working with waterproofing membranes has its own processes and usage for waterproofing membranes. Besides, not all of the articles study all directions set by manufacturers. Depending on this, if we don’t take into account the quality of material and other factors, the quality and final lifetime of the single ply roof can vary. The article includes a description of how was the research was made, processes used and the conclusions which were found during the research.

Key words: *mPVC, waterproofing membranes,*

1 ISSUES WITH WATERPROOFING MEMBRANE INSTALLATION

Plastic membranes, especially mPVC-based ones, are not new in the construction market. However, we can still find faults during their application. For the sake of comparison, bitu-men strips installation consists of melting the strips onto the roof surface whereas the joints are done by melting the lower side of the strip, while the installation of plastic membranes is more complicated (Šveda, M. 2007). During the installation of plastic membranes there is a higher possibility of making mistakes both when applying the layers as well as joining in-dividual membranes at the joints. The process of membranes installation should begin with meteorological conditions assessment to ascertain if the environmental conditions are ap-propriate for such a type of plastic membrane in the first place. However, this step is usual-ly left out because of the investors´ pressure on the construction speed. That is why mem-branes are often installed during drizzles or low temperatures. Although manufacturers de-clare that their plastic membranes can be welded at up to -10°C they do not specify what risk could such environmental conditions incur.

One should pay all of his/her attention mainly at the process of welding and particular details during the installation. The most common way of joining mPVC-based plastic mem-branes and TPO is by hot air welding. Joints of PVC products are considered the strongest among all membranes (Björk, F. 1993). Less common but of high-quality are EPDM mem-branes. They can be pasted on a large area but it has to be a properly constructed solid base. The advantage of the pasted asphalt or EPDM membrane is that if the roof gets damaged, suffusion should occur where the leak is located. If the roof´s DPC is stabilized by anchor-age or by additional load, for example gravel, water can freely penetrate through the cover-ing layers and the suffusion can appear far from the spot of leakage. Another problem could lay in the so-called T-joints. This kind of joint consists of an additional membrane that overlaps the seam of two already welded membranes whereas at the meeting point of the three membranes a small canal may form. This spot can be a potential source of leakage of water under the roofing. It is therefore appropriate to thoroughly check this joint and rein-force it with a sealing compound. Another problematic detail could be the joints between the mPVC foil and PVC coated metal sheets which are typical on vertical surfaces (Gränne, F. & Björk, F. 2000). An important factor for proper welding of membranes can be attribut-ed to the welding machine and its settings i.e.

temperature, and in case of automatic welder, its speed. Manufacturers prescribe welding guide values for their products but these need to be adapted to the specific environmental conditions on sites.

Welding temperature is influenced by many factors, the main factors are:

- membrane type and manufacturer, the thickness of the membrane;
- welding speed;
- the type of welding device (hand welder or automatic welder);
- base and ambient temperature and humidity;
- wind speed, drizzle, rain, snow etc.

Real life cases have shown that not setting the right temperature is not as damaging for mPVC-based membranes as it is for the TPO-based membranes. PVC membranes can weld sufficiently well even if the welding temperature is fluctuant but only to a certain extent of course. We tried to verify these PVC-based membranes´ properties by testing their joints in a laboratory.

2 LABORATORY EXAMINATION OF WELDS MPVC-BASED WATERPROOFING MEMBRANE

The prerequisite for research of waterproofing membrane joints was to have the quality of their welding, and/or the actual weld itself, affected by the environmental conditions - tem-perature, humidity, wind, rain or snow. On construction sites today we get to see foil weld-ing at very low temperatures, during light rain and even snowfall. The producers themselves recommend that it is possible to weld membranes at temperatures down to about -5 to -10°C, whereas such unsatisfactory conditions have a major impact on the quality of welds. Unsuitable climatic conditions, especially ambient air temperature can be corrected by ad-justing the temperature on the welding machine. In order to determine the correct tempera-ture of the welding machine, trials should be performed and then by pulling the two mem-branes apart we can check if the temperature is correct (if there is a visible grid over the en-tire width of the torn joint, the temperature is correct). However, in most cases a trial such as this is not performed. Thus, the temperature used in welding has a major impact on the quality of joints.

For large dimension flat roofs modern automatic welding machines are used, which great-ly speeds up the whole process of waterproofing membrane welding. The automatic welding machine can have its welding temperature as well as welding speed adjusted. In an effort to speed up the work workers often set the automatic speed higher than what is specified by the manufacturer. This might also affect the final quality of the welds.

Another factor is how clean the membranes are at the point of their subsequent joint - weld. Provided that they are properly stored and all the procedures for installation are fol-lowed membranes should not get unclean on the site. However, due to the fact that con-struction sites have ongoing construction work done with dust produced, even the water-proofing membranes are exposed to various contaminants. Producers of membranes rec-ommend inspection of the purity of the welds before welding. If the membranes are dirty, dirt should be removed. For this purpose, water is used, but it is not very suitable. If it is dried insufficiently, the membrane may welded be badly. That is why so called cleaners - diluents-based cleaners- are produced especially for this purpose. As it was mentioned be-fore, workers often do not remove the dirt from the membranes, either because of financial or time-saving reasons.

Based on the above-mentioned assumptions, following methods of research were deter-mined:

1. Welding the membranes with automatic welding machine set at various temperatures

2. Welding joints of different level of cleanliness

3. Different working speeds of the automatic welding machine

2.1 Preparation of materials and samples

Before the actual welding of waterproofing membranes it was necessary to prepare material samples. Samples were obtained from the membranes in accordance with the standard STN 72 7652 (EN 13416), which defines the rules for obtaining samples from waterproofing membranes based on PVC. Standard waterproofing PVC-based membranes with thickness of 1.5 mm intended for installation of the single layer mechanically anchored waterproofing system were used for the research. These membranes are produced by modern technology of the two-sided application on supporting impregnated polyester plate by extrusion.

An undamaged waterproofing membrane was selected and taken from a warehouse where it was stored for the last 24 hours at a temperature of about 20°C (standard requirements are 20 ± 10°C). Subsequently, the roll was unfolded on a flat surface and pieces -samples- which did not contain any visible imperfections were cut. Next, these pieces were stored for over 20 hours in a room with a temperature of about 22°C (the standard requirement s are 23 ± 2°C). Each membrane was checked once again before welding as it is required by the standard STN EN 1850-2 (72 7642). Selected samples of membranes underwent visual in-spection from both sides for potential blisters, cracks, holes, scratches or sags. The pres-ence of bubbles or any dirt was checked on the section of each sample. After the inspection, the membranes were marked in the corner according to the method of research used.

2.2 Production of welded samples

An automatic welding machine Leister UNIROOF E was used for sampling. It had a welding nozzle attached capable of making 40mm-wide welds. The process of sampling was as fol-lows: at first, the membranes intended for welding were unfolded and spread on the welding surface and were left there for about 30 minutes. Subsequently, those surfaces of mem-branes intended for welding were cleaned using the specialized cleaner depending on the research method used. After the cleaner had dried out, the process of welding started. The following sets of samples were produced this way:

1.Welding of membranes where the variable factor was temperature

- samples had been cleaned by the cleaner prior to welding and the working speed of the welding machine was set to 2m/min.

This is how the sets of samples were produced:

1.A at +560°C

1.B at +540°C

1.C at +520°C

1.D at +500°C

1.E at +480°C

1.F at +420°C

2. Welding of membranes where the variable factor was the purity of joint

- samples were produced by welding at a temperature of 520°C and the working speed of the welding machine was set at 2m/min.

This is how the sets of samples were produced:

2.A - joint uncleaned, the membrane straight off the production line

2.B - joint cleaned with water, then dried

2.C - joint cleaned with cleaner (similar to 1.C)

2.D - joint cleaned with water, not dried (moist membrane)

3. Welding of membranes where the variable factor was the working speed of the auto-matic welding machine

- samples had been cleaned by the cleaner prior to welding and welded at a temperature of 520°C.

- speed range of this particular automatic welding machine is 2 to 5 m/min.

This is how the sets of samples were produced:

3.A - working speed 2m /min. (similar to 1.C)

3.B - working speed 3.5 m/min.

3.C - working speed 5m/min.

The starting temperature of 520°C was selected because this temperature results in prop-er welding of two membranes. The actual welding was carried out in a closed hall with am-bient air temperature of 20°C. After the welding, welded membranes which were produced in the above mentioned way were left to sit for approximately 30 minutes. Subsequently, the process of testing welded samples was performed. These samples were subsequently tested to determine the shear resistance and the peel resistance of joints.

2.3 Sampling and testing:

10 individual strips with width of 5cm were taken from each type of welded and settled membrane which had been labeled according to its method of production. The strips were cut out with a knife with the help of a stainless template. The length of the samples was chosen to make it possible to grip the sample into the pliers of the tensile testing machine in a way that the membrane covers the entire surface of the clamps of pliers. At the same time, special attention was paid to make sure that the weld is right in the middle of the cut sam-ple.

The welds of waterproofing membranes can be assessed on the basis of two laboratory tests regulated by the standard. It is the test for determining the shear resistance of joints - STN EN 12317-2 and the test for determining the peel resistance of joints - STN EN 12316-2.

2.3.1 Determination of shear resistance of joints

Shear resistance is the maximum tensile force that can act on a sample before it is torn or separated on the joint. In this test, the samples (a total of 5 samples were tested in one set) were gripped into the pliers of the tensile testing device that operates by steadily pulling the sample and at the same time recording the progress of the acting force, until the failure of the sample occurs. It is important to ensure that the weld is right in the middle between the two clamps of the pliers. The distance between the clamps has to be 3-4 times the width of the joint, in this case 120mm. The scheme of the device with the clamped sample is shown in image no. 1.

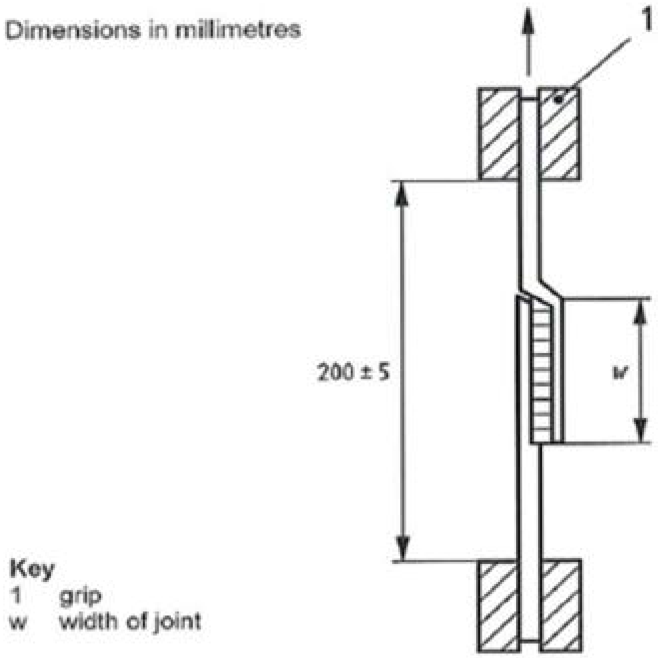

Fig. 1 Test of shear resistance of joints, Source: STN EN 12317-2 (72 7639)

The device continuously records the pulling force up to the time of tearing or separation of the tested sample. The result is recorded in the form of a diagram which marks the course of acting of the force during the testing. After testing each individual sample a maximum tensile force - Fmax and the way of failure of the strip were recorded into the register. The average value was calculated from the five values of Fmax and the standard deviation was indicated.

2.3.2 Determination of peel resistance of joints

Peel resistance test is fundamentally the same as the shear resistance test differing only in gripping the sample into the tensile testing device in regard to the made weld. This test is stricter than the tensile test. The sample must be made in a way to make it possible to grip the sample into clamps of the testing device as shown in mage no.2. The evaluation of the results is different as well, since there may be three different types of failure to the sample: a) membranes can be separated without breaking their surfaces; b) one of the strip is torn outside the joint; c) the sample is damaged, there is a visible grid in the joint (Image no. 3). The evaluation of such damaged samples has to be carried out according to the standard STN EN 12316-2.

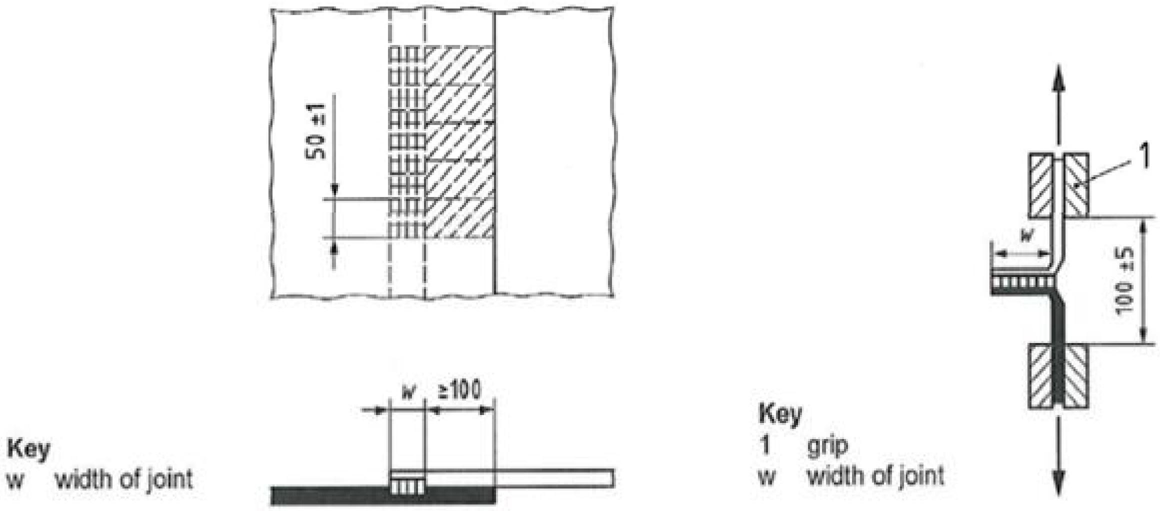

Fig. 2 Preparation of the test strip and testing of peel resistance of joints, Source: STN EN 12316-2 (72 7638)

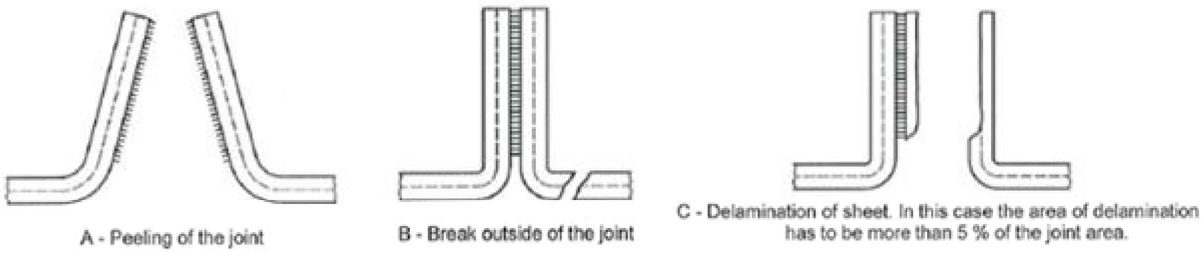

Fig. 3 The modes of sample failure in peel resistance test, Source: STN EN 12317-2 (72 7639)

2.4 Evaluation of measured results of shear resistance of joints and peel resistance

As it is indicated by the measured results, mPVC-based membranes have a certain range of temperatures at which it is possible to make a weld of a good quality (see Table 1). At the temperature of 420°C (1.F) the values of strength of joints were not satisfactory in terms of peel resistance. It is also evident from the above-mentioned statistics that those joints which showed low values in the peel resistance test, had values for shear resistance test un-changed in comparison to joints of correctly welded membranes. It means that the joint which is under the shear stress can withstand more than the same joint under the peel stress. Next, it was proven that if workers increase the workings speed of an automatic welding machine, it has a negative impact on the quality of the joint. A joint made at a higher speed does not have to withstand the stress to which the membrane is exposed on the roof structure. Cleaning the surface of the welded membranes did not affect the quality of the weld. An uncleaned joint showed the same values as a joint cleaned with the cleaner. However, we have to bear in mind that this joint was not exposed to a potentially polluted environ-ment of an actual construction site.

Norm	STN EN 12316-2		STN EN 12316-2	Failure modes samples	
Resistance	$F_{avg.}$ [N/50mm]	F_{max} [N/50mm]	F_{max} [N/50mm]	STN EN 12316-2	STN EN 12316-2
1.A	-	527	1022	C > 5%	TOJ
1.B	-	485	995	C > 5%	TOJ
1.C	-	561	1070	C > 5%	TOJ
1.D	-	575	1068	C > 5%	TOJ
1.E	-	626	1092	C > 5%	TOJ
1.F	235	-	1063	C < 5%	TOJ
2.A	-	572	1088	C > 5%	TOJ
2.B	-	578	1030	C > 5%	TOJ
2.D	-	645	1017	C > 5%	TOJ
3.B	171	-	1032	A = 100%	TOJ
3.C	85	-	1044	A = 100%	TOJ

Note: TOJ (Tear out of joint)

Tab. 1 Evaluation of measured results shear resistance of joints and peell resistance

3 LABORATORY EXAMINATION OF WELDS MPVC-BASED WATERPROOFING MEMBRANE

This article discusses the issue of mPVC-based waterproofing membranes and describes an experiment which aimed at determining the quality of joints made with various factors in laboratory conditions. The assumption from the practice that mPVC-based membranes are made of a material which is easy to work with in all environmental conditions was also con-firmed. The quality of the joints of mPVC-based membranes tends to be good even if weld-ing takes place in non-ideal conditions, such as bad environmental conditions or human er-rors but of course only up to a certain extent. This does not mean that we can fully rely on the quality of the material of mPVC membranes. It is necessary to constantly monitor the accuracy of the technology and installation processes given by the manufacturer. The quali-ty and functionality of a building really depends on quality of the roof structure. That is why special attention has to be paid to the technological discipline during the installation process and individual steps have to be checked on a regular basis.

Literature

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