THE RESEARCH ON GLUING RELIABILITY OF GLUED ROLLER COVER MEMBRANES

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Abstract. The most serious problem of glued roller cover materials for roofs is insufficient reliability of seams between the strips of glued membrane. Early research was focused on the mechanism of seams formation and the determination of seams quality parameters – the thickness of seam, the strength and unglued area of seam. The dependence of seam strength on heating duration of melted surfaces has been determined experimentally. The analysis of resent roofing technologies shows that the heating regime not ensures the necessary gluing level of membrane layers. Paper provides the suggestions for glued roller roofing technologies.

Keywords: roof coverings, polymer-modified, bituminous heat-welded materials, quality of adhesion, glued layers, cavities, operational reliability, heating intensity.

1. Introduction

The way of a gluing of rolled roofing materials by a melting (or heat-welding) of their integumentary (or cover) layer has been offered for the first time by Lithuanian scientists (R.Garalevičius et al) in 1967. Later such materials have been named as “heat-welded” or “melted” materials.

The technology of gluing of heat-welded materials has been in detail investigated in dissertational work of one of authors of article (Karablikovas 1980).

Since roofing materials on the basis of bitumen were used and their thickness did not exceed 2-2.5 mm, the basic attention was given to preservation of their operational properties after a high-temperature heating by a flame of gas torches.

But already then it has been noticed that adhesion of roof layers during the heat-welding essentially differs from adhesion of layers with use of various mastics.

During heat-welding integumentary layers of roof membranes are heating till the cover material of layers reaches the viscosity and plasticity and layers fuse together (Fig 1).

If the heating temperature is high and force of squeeze is high enough, bitumen of integumentary layers could be almost completely crushed out from a glutinous seam that never occurs at use of gluing mastics.

Besides, the long lasting heating of a roofing material by gas torches worsens properties of its reinforcing basis (Joel and Porcher 1987) or bares a basis from bituminous envelop (Dupuis 1989). It imposes certain restrictions on duration and heating temperature of heat-welded materials.

On the other hand, the heating of an integumentary layer to a high temperature is the main condition of obtaining the qualitative glutinous seam (joint) between the rolled membranes.

Whereas both requirements are contradicting, the conclusion could be made that the main problem of roofs from heat-welded materials is formation of a qualitative glutinous seam between the rolled membranes.

The usage of heat-welded materials made on the basis of Styrene-Butadiene-Styrene copolymer (SBS)-modified bitumen and Atactic Polypropylene (APP)-modified bitumen, and usage of glass fibre and polyester as a reinforcing basis has not solved this problem.

On the contrary, the problem of adhesion of layers of a rolled roof membranes became even more actual.

Roofs from bituminous heat-welded materials having a small thickness were installed in 3–5 layers. Poor quality of glutinous joints was partially compensated by the considerable quantity of the layers covering the glued seams of membranes.

Occurrence of new, polymer-modified bituminous heat-welded materials of 4 mm and more allowed installing the roofs of the thickness in 1-2 layers.
Thus the quality of adhesion of glued layers has not improved. On many roofs the first layer is paving on the basis without gluing by fixing mechanically with the help of anchors, and rolls are gluing together only by the width they overlap, i.e. by 120 – 150 mm. In this case unsatisfactory adhesion in glutinous seam can be the reason of a leakage.

Influence of intensity of a heating on change of a thickness of a glutinous seam between layers of a roofing rolls was studied on the samples having a basis of polyester (200 g/m²) and made of the SBS – PYE PV 200 S4s modified bitumen.

Glued surfaces were heated by gas torches Griunprofil Brenner S45 (38 kcal/hour).

Glued samples were rolled by the platen in width creating clamping effort, equivalent to volume which in conditions of construction site is provided by the rolling device in weight of 40 kg at standard width of a roll of 1000 mm.

In details the technique of experiments is presented in former publications (Karablikovas 2007). Experiments have confirmed that modified by polymers heat-welded materials during heating behave similarly to the materials made from oxidized bitumen, and the thickness of a glutinous seam (a bitumen layer) between the membranes decreases in proportion to the intensity of a heating (Fig 2). From the diagram presented on the Fig 2 it is well visible that at duration of a heating of gluing surfaces for 4 seconds and more a thickness of a glutinous seam \(d_x\) becomes less than 50 % of an initial total thickness of integumentary layers of glued rolls \(d_1 + d_2 = 2.2 \text{ mm}\).

It is obvious that the further continuation of a heating is inexpedient because of decrease in the general thickness of a roofing carpet and danger of damage of a reinforcing basis of a material that finally reduces operational properties of a roof.

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In the research authors tried to determine how the quality of gluing of polymer-modified bituminous heat-welded materials using the short heating duration (up to 5 seconds) is ensured.

2. Research object

The object of research was the quality of a glutinous seam between layers of a multilayered rolled roof from polymer-modified bituminous heat-welded materials glued by means of gas torches.

Quality of gluing of layers of a rolled roof is the major factor providing the water resistance of a roof during all term of exploitation. European and American experts (Booth 1987, Sheahan 1991) specify this factor in their articles. Quality and durability of gluing of rolled materials has major importance in single-layered roofs and roofs with mechanical fastening of the first layer to the basis (Oba 1999).

The findings of inspections of already maintained roofs from polymer-modified bituminous heat-welded materials carried out in the USA and Canada showed that poor-quality gluing of layers is one of principal causes of occurrence of defects of a roof. And in one of inspections was underlined that the part of defects of roofs that has been caused by poor quality of gluing of heat-welded materials reaches 36 % of all found out defects of roofs (Joint Committee CIB 2003, Rossiter and Denchfield 1993). Similar results have been got during the inspections of roofs, performed by authors from 2000 to 2009, in Lithuania. Certain regularity was noticed: water leakage through glutinous seams of heat-welded materials is much more often observed in buildings of new construction with slopes of roofs less than 2.5 %. On such roofs after rains or thawing of snow, water is more often stays and the roof surface dries up more slowly.

In buildings of old construction (up to 1990) where the slopes of roofs was not less than 3 % (according to specifications valid at that time), after reconstruction or replacements of a roofing carpet, the leakage through seams of heat-welded materials are meet much less often, though visual quality of all surveyed roofs is almost equal.

For an estimation of quality of works of gluing of heat-welded materials on a building site now only one criterion all over the world is using: along the edge of overlapped adjacent rolls the continuous strip of the squeezed out mastic in width of 5-20 mm should be visible (Dupuis 1989, Oba 1999). But the practice has shown that the use of such criterion not always provides good result (see Fig 3).

For a laboratory estimation of quality of gluing of heat-welded materials the standard LST EN 13707 “Flexible sheets for waterproofing. Reinforced bitumen sheets for roof waterproofing. Definitions and characteristics” recommends testing a glutinous seam for durability at rupture (T-peel test) and at shift (lap-shear test) (LST EN 13707:2005). Both tests were successfully used at research of a way of mechanical fastening of roofs from heat-welded materials to the basis that has allowed optimising the placing of fixing anchors and the sizes of overlaps of a rolled material (Oba 1999).

According to the majority of the experts, the fullest estimation of quality of gluing of heat-welded materials provides the T-peel test. It was widely applied at research of properties of heat-welded materials and technological parameters of gluing and has given good results (Oba et al. 1996). Dependence of durability of gluing of heat-welded materials from intensity of a heating of their surface by gas torches was studied earlier by authors of the present work, simultaneously with research of change of a thickness of a glutinous seam (Karablikovas 2007).

T-peel test of the glued together strips of a material was carried out by standard technique (LST EN 12316-1:2001) using equipment TIRA Fest 2300 with use software CATMAN EXPRESS. It has been established that the gluing durability increases in proportion to increase in duration (intensity) of a heating.

For heat-welded materials made on basis of SBS-modified bitumen, the maximum durability of a seam is reached at a long heating (8–9 seconds). The average thickness of a glutinous seam measured at such samples is 0.4 mm, i.e. less than 20 % from initial (2.2 mm).

Fig 4. Surface of a glutinous seam with the allocated contours of not glued zones
Reduction of duration of a heating up to 4–5 seconds allows receiving the thickness of a glutinous seam in about 1.2–1.0 mm, but thus durability of gluing is decreases twice (Karablikovas 2007).

There is a question, whether there is a necessity for all cases to provide the maximum durability of gluing of heat-welded materials and how much this indicator is connected with reliability and water resistance of seams of a roof covering.

For the answer to this question we offer one more criterion for an estimation of quality of a glutinous seam – presence in a seam of not glued cavities, i.e. zones on which has not provided the gluing of a rolled material. This criterion was widely used in 60–70 years of last century for an estimation of quality of multilayered roofing coverings from rolled materials.

3. Research methodology

By a standard technique the presence of not glued cavities was defined by splitting of just glued samples of a rolled material before cooling of a bitumen layer and the subsequent survey of a glued surface.

Not glued sites were easily found out visually, but quantitative estimation of this indicator was not existed. The presence of not glued cavities testified to insufficiently qualitative pasting of layers of a rolled roof as while in service they became the reason of occurrence of swellings (bubbles) and thinness of a roofing carpet.

Experimental test by this criterion has shown that for roofs from heat-welded materials presence of not glued zones – an everyday occurrence. Other authors (Oba et al. 1996) also specified the presence of not glued cavities in such roofs. It has been determined that with increase in duration of a heating of glued together surfaces the quantity of not glued cavities decreases to their total disappearance.

But for more detailed studying of this process it was necessary to have the quantitative estimation of not glued zones expressed in concrete digital values for each test.

Striving for this aim the original technique of a quantitative estimation of not glued cavities with use of computer software has been developed (Malko 2008). Samples of heat-welded material made of the SBS – PYE PV 200 S4s modified bitumen were prepared by the same way as in T-peel test for definition of a thickness and durability of a seam. Gluing conditions also were similar: a heating by gas torches Griunprofil Brener S 45 and standard squeeze. 10 series of samples, with 3 samples in each series have been prepared. The first series was heated within 1 second then samples were glued together, the second series was heated within 2 seconds, the third – 3 seconds, etc. by rising the heating time to 10 seconds.

At once after the gluing, the not yet cooled samples of a rolled material were split on along the glutinous seam and cooled to a room temperature. The investigated surface of cooled samples was laid down on the scanner (having enclosed a transparent film). The received digitized images of investigated surfaces were located in AUTOCAD software and were displayed. With the texture and color allocated not glued zones (cavities) by means of the software were led round on a contour by the closed lines (see Fig 4).

The allocation and calculation of the area of all not glued zones on an investigated surface (see Figures 5 and 6) and their total area \( F_n \) was made by Region tool.

![Fig 4. Allocation from a total area of the closed contours of not glued zones](image)

As a quantitative indicator characterizing the presence of not glued zones for each sample \( K_n \) was determined as the percentage relation of the calculated area of not glued zones \( F_n \) to the full area of a glutinous seam \( F \):

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K_n = \frac{F_n}{F} \cdot 100 \%,
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4. The analysis of the received results

By average results of each series of samples the diagram of dependence of the total area of not glued zones from duration of a heating of glued together surfaces of heat-welded material (see Fig 7) was drawn. Predictably, the quantity of not glued zones decreases with increase in duration of a heating.
An unpleasant surprise was the finding that not glued zones disappear completely only at duration of heating for more than 9 seconds when bitumen on glued surfaces becomes completely liquid. As a result the thickness of a glutinous seam riches no more than 0.4 mm – less than 20 % from the previous (see Fig 2).

There is not answered question – to what minimum size it is possible to reduce a total thickness of roofing covering from heat-welded materials at the same time not to worsen its operational properties.

As bitumen, polymer-modified bitumen is the basic component providing waterproofing properties of rolled roofs it is possible as limiting size of reduction of a thickness of a bitumen layer between panels of heat-welded material accept 50 % of its initial thickness \( (d_1 + d_2) \) (see Fig 2).

In our tests it corresponds to duration of heating up to 4–5 seconds (see Fig 2).

With similar intensity the heating of heat-welded materials in conditions of construction site was carried out. At such restriction of heating duration (and, accordingly, temperatures), results of the carried out tests (see Fig 6) allow to assert that during the installment of roofs from heat-welded materials the 20 to 40 % of the area of a glutinous seam between glued rolls remain not glued. To minimize the quantity of not glued zones by the increase of intensity of heating is not allowed because of the decrease of thickness of bitumen layers and a roof cover as a whole.

The data received earlier (Karablikovas 2007) and the analysis of results of the executed researches shows what it is not possible to provide the reliability of roofs from heat-welded materials only by improvement of technological parameters of a gluing process.

The problem of such roofs reliability increase should be solved by improving a design of roofing coverings. The roof design should ensure a fast drain of water from its surface as the accumulated water leads to increase in loading at a covering, reduces service life of a rolled material, increases probability of leakage occurrence and damage of a surface by ice. For this purpose for multilayered roofs from heat-welded materials it is purposeful to establish the minimum slope – not less than 3–3.5 %, and for single-layered coverings – not less than 5-6 %.

If, in exceptional cases, the roof from heat-welded materials is arranged with a slope less than 3 %, the quantity of layers in it should be increased to 1-2.

It is offered to refuse to use heat-welded materials in roofs with slopes less than 2.5 % and in maintained roofs, having replaced with rolled materials glued by mastics, or membranes from synthetic films.

Conclusions

1. Gluing quality of rolled heat-welded materials is one of the main indicators of operational reliability of roofs made of these materials.
2. For an estimation of gluing quality of heat-welded materials one more indicator is offered to use – the presence of not glued zones in a glutinous seam.
3. The method for a quantitative estimation of not glued zones in glutinous seams between the rolls of panels heat-welded material is developed.
4. Dependence of change of quantity of not glued zones from the duration (intensity) of heating of glued surfaces is revealed.
5. It is established that for heat-welded SBS-modified materials, not glued zones completely disappear after heating during 9–10 seconds when bitumen of an integumentary layer passes in a liquid state.
6. The possibilities of improvement of gluing quality of heat-welded materials by increase of heating duration (intensity) are limited because of a decreasing thickness of bitumen layers and a roof as a whole.
7. The problem of increase of reliability of roofs from heat-welded materials could be solved by improving a design of roofs, increasing their slopes and quantity of layers, improving a water drainage system.

References


