

CETRA²⁰¹⁴

3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

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Department of Transportation



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IMPACT OF HIGH PROCESS TEMPERATURE ON VISCOELASTIC PROPERTIES OF POLYMER MODIFIED BITUMEN IN WATERPROOFING AND BRIDGE PAVEMENTS

Michał Sarnowski, Piotr Radziszewski, Karol J. Kowalski, Jan B. Król

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Abstract

This paper presents the most widespread materials and technological solutions of pavement systems on bridge decks used in countries of central Europe, including Poland, with particular emphasis on the impact of high process temperatures on bridge surfacing systems durability. In Europe, the dominant system solutions on bridges is to lay on the steel or concrete deck bridge waterproofing layer (insulation) and then asphalt layers, consisting of waterproofing protective course and a wearing course. For the bridge pavements several kinds of asphalt mixtures containing polymer modified bitumen can be used. In recent years, the protective and wearing courses are mostly built from mastic asphalt. In the research was proved that the impact of high process temperatures (above 250°C) was particularly destructive for commonly used polymer modified bitumen in bridge pavements and waterproofing layers.

Keywords: bitumen, polymer, waterproofing, bridge pavement

1 Introduction

Properly designed and constructed pavement on a bridge deck should meet the following requirements [1], [2]:

- sealed, resistant to water and de-icing measures;
- stable, resistant to deformation bridge deck;
- durable in diversified operating temperatures to ensure a long service life;
- resistant to thermal cracking and fatigue at low and medium operating temperatures and resistant to rutting at high operating temperatures;
- resistant to shear stress;
- rough, ensuring comfort and traffic safety;
- well bonded with waterproofing and bridge deck;
- lightweight, while maintaining sufficient thickness to provide protection of the bridge deck.

On the bridge decks it is possible to construct pavements in both cement concrete and asphalt technologies. In Poland (and in Europe) asphalt pavements are commonly applied. Bridge concrete pavements are commonly used material and technological solution in the United States but asphalt pavements are rarely used. As one of the reasons for avoiding bridge asphalt pavements in the United States is possibility of water penetration through the conventional asphalt layers that cannot be compacted by vibration on bridge structures [3]. In Europe and in Poland it is common to lay on a previously primed surface the waterproofing layer and afterwards the asphalt pavement courses (Figure 1). Pavement together with waterproofing compose a pavement system. This system is the most common used technological solution on steel and concrete bridges. Current usage of polymer modified bitumen

in pavement systems (waterproofing + pavement) enforces sharp technical requirements not exceeding the temperature limits of technological process, which according to the polymers manufacturers instructions should be in the range of about 200°C. It is permitted to raise the temperature to 220°C temporarily, up to two hours. Numerous failures of asphalt pavement systems containing polymer modified bitumen were caused by non-compliance with the temperature requirements. The layout of asphalt pavements on a bridge deck is shown in Figure 1.

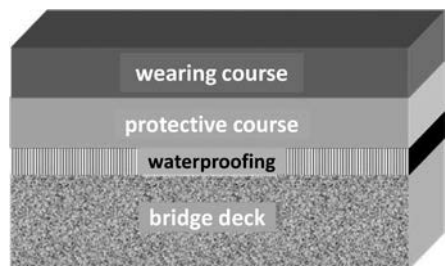


Figure 1 Diagram of the pavement system on a bridge deck [4].

The asphalt pavement laid on a waterproofing layer consists of a protective and wearing course. The protective course protects the waterproofing from damage during constructing of pavement upper layers and during operation time. Wearing course provides pavement sealing and its surface should ensure safe traffic conditions. There are different technologies for constructing waterproofing layers and the most frequently used include [5]:

- asphalt based waterproofing:
 - torch-on membranes;
 - self-adhesive membranes;
 - asphalt mixtures;
 - conventional mastic waterproofing (grain size <4 mm);
- synthetic waterproofing:
 - polyurethane spray waterproofing;
 - methacrylate-methyl waterproofing;
 - polymer cement mortar waterproofing;
 - softened epoxy resin waterproofing.

In Poland the technical requirements for asphalt mixtures and the conditions of their production have been developed by the General Directorate for National Roads and Motorways (GDDKiA) in the form of Technical Requirements (WT-2). These requirements are often verified in recent years and the most recent draft version of the 2013 [6] does not recommend the use of polymer modified bitumen in mastic asphalt (MA), that requires high production temperatures. Polymer modified bitumen is replaced by multigrade binder 35/50. The following materials are used to construct bridge wearing courses [6]:

- mastic asphalt MA 8 and 11 (with binder 35/50 or multigrade binder 35/50);
- stone mastic asphalt SMA 5, 8 and 11;
- asphalt concrete for very thin layers BBTM 8 and 11;
- asphalt concrete AC 16S.

In stone mastic asphalt (SMA), asphalt concrete for very thin layers (BBTM) and asphalt concrete (AC) mixtures it is required to use the following polymer modified bitumens: PmB 45/80-55, PmB 45/80-65, PmB 65/105-60. The natural asphalt additive "Trinidad" in an amount of 1.5 to 2.0% by weight of the bitumen is recommended to use for the wearing course, which improves resistance to permanent deformation, limits aging processes, increases resistance to fatigue and low temperature and increases roughness [4].

2 Material and technological solutions of bridge waterproofing and pavements

Warsaw University of Technology in the years 2011-2013 conducted research project “Material and technological solutions of bridge waterproofing and pavements”. The aim of the project was the analysis of technical solutions of waterproofing and pavements on bridge concrete and steel decks, with particular emphasis on the impact of high technological temperatures on the durability of the materials used for constructing waterproofing and pavement layers. Asphalt binders used for pavement and waterproofing should have such properties that they do not crack at low temperatures in winter and do not go to the plastic state during the summer. Viscoelastic properties of asphalt binders in a wide temperature range can be achieved by modifying the bitumen with polymers. The most commonly used type of elastomeric polymers are in the form of a styrene-butadiene-styrene SBS copolymers.

2.1 The impact of high temperature on the bridge waterproofing destruction

In Poland, in recent years, polymer-modified materials are used for waterproofing of bridge decks.

2.1.1 Torch-on membranes

Waterproofing made of torch-on membrane can be easily damaged during installation by coating mass overheating with the burner flame. It should be noted that the temperature at the outlet of the burner flame reaches approximately 1000°C, and the process requires heating in a suitable distance. Overheating of the coating mass breaks the polymer bonds, which existence guarantees the good properties of polymer modified bitumen [7].

Research conducted at Warsaw University of Technology on the destructive impacts of high temperatures on materials containing polymer modified bitumen led to the formulation of interesting statements about the behaviour of torch-on membranes at high temperatures. Thermal annealing at temperatures of 200, 250 and 300°C of torch-on membranes containing polymers in its composition showed partial or complete degradation of the coating mass and reinforcement. Figure 3 shows the view of membrane annealed at 300°C.

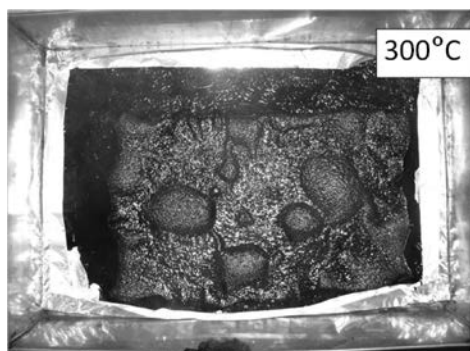


Figure 2 Bridge torch-on membrane annealed for 1 hour at 300°C

Membranes manufacturers quote the minimum temperature for SBS modified torch-on membranes of 100°C, at which no damage to the membrane should appear. In case of torch-on membranes containing polymer modified bitumen it should be noted that the maximum allowable temperature at which they can be used with no physical deterioration has not yet been determined. It is desirable that all SBS polymer modified torch-on membrane manufacturers defined for their products the maximum thermal resistance limits.

The results of torch-on membrane flexibility research conducted according to PN-EN 1109 at a temperature of -30°C showed that the membrane after annealing at 200°C has been damaged. The membrane upper surface showed cracks of the top layer of the coating mass up to the surface of the reinforcement. Higher temperatures (of 250 and 300°C), resulted in membrane cracks through the thickness of the coating weight and the reinforcement.

2.1.2 Mastic waterproofing

Asphalt mixtures for the bridge waterproofing during the production, transport and paving may be exposed to high temperatures that exceed the temperatures required for technological processes. Moreover, the mastic waterproofing is again heated up when mastic protective course, produced at 200-240°C, is placed. The impact of high temperatures above 200°C can result in changes in the properties of binders and thus changes the viscoelastic properties of asphalt mixtures.

In order to determine the impact of high temperature on the functional properties of mastic bridge waterproofing, the tests of the traditional mastic of grain size up to 2 mm were carried out. Mastic tolerance to high temperatures during manufacturing, transport and paving was determined while warming at 200, 250 and 300°C. Thermal annealing time was 1 hour. For comparative purposes of the tested mastic samples the binder 35/50 and polymer modified bitumen PmB 45/80-55 were used.

In order to assess the consistency changes of asphalt mixtures (traditional mastic, mastic asphalt) under high temperature of 200, 250 and 300°C, penetration tests were carried out with indentation penetrometer in accordance with EN 12697-20. This test determines the depth of penetration in the traditional mastic or in mastic asphalt, under the force of 525 N, transmitted through a cylindrical indenter pin with a circular flat ended base of 500 mm². Load time is up to 60 minutes. Penetration (hardness) test results of mastic waterproofing as a function of temperature is shown in Figure 3 and 4.

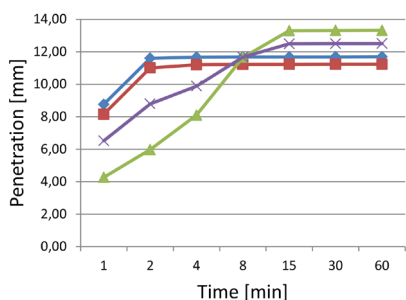


Figure 3 The impact of high temperatures on the changes of the penetration (hardness) of the mastic waterproofing with bitumen 35/50

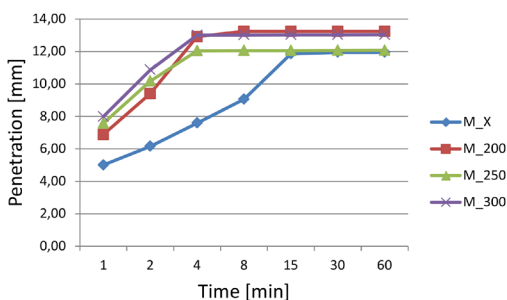


Figure 4 The impact of high temperatures on the changes of penetration (hardness) of the mastic waterproofing with polymer modified bitumen PmB 45/80-55

The results of the penetration of the annealed at high temperatures mastic asphalt with binder 35/50 (Figure 3) lead to the conclusion that both annealed at 200°C and not annealed mastic shows similar hardening rate. At temperatures of 250 and 300°C a large scale hardening can be observed, most likely due to changes in the bitumen group constitution (resins, oils, and asphaltenes). Penetration test results of mastic with polymer modified bitumen PmB 45/80-55 (Fig. 4) shown that mastic containing not annealed binder has initially low penetration of about 5 mm. Mastic with polymer modified bitumen annealed at 200, 250 and 300°C shows a significant increase in penetration due to a loss of elastic properties caused to loss of polymer bonds network, which was destroyed by high temperatures.

2.2 The impact of high temperature on the protective layer destruction

The high temperature of mastic asphalt (MA) used as a protective layer of the waterproofing membrane, causes dissolution of binder located in the waterproofing and penetration of this binder into the mastic asphalt and thus, a reduction in the thickness of the waterproofing layer. The impact of high temperature during laying the protective layer of mastic asphalt on the waterproofing membrane also causes melting of the polymer contained in the waterproofing, which penetrates into the mastic asphalt layer [7].

In order to determine the impact of a high temperature of 200, 250 and 300°C on the functional properties of the 8 mm grain size mastic asphalt protective course, penetration tests were carried out in accordance with EN 12697-20. Binder 20/30 or polymer modified bitumen PmB 25/55-60 were used in mastic asphalt. Annealing time of the mastic asphalt was one hour. Penetration (hardness) test results of the mastic asphalt MA8 containing mentioned binders are shown in Figures 5 and 6.

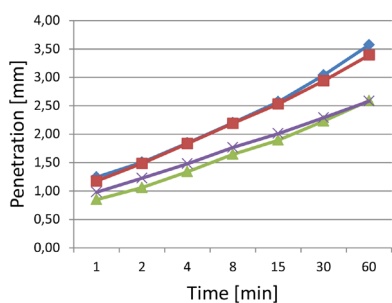


Figure 5 The impact of high temperatures on the changes of the penetration (hardness) of the mastic asphalt MA8 with bitumen 20/30

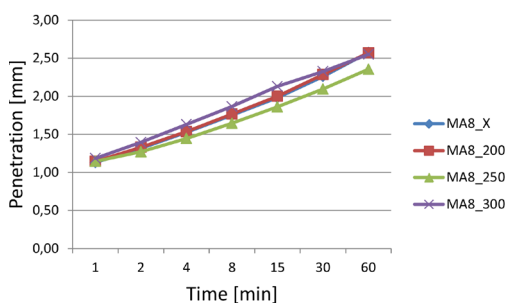


Figure 6 The impact of high temperatures on the changes of the penetration (hardness) of the mastic asphalt MA8 with polymer modified bitumen PmB 25/55-60

The penetration test results of mastic asphalt with bitumen 20/30 shown in Figure 5 indicate that the mastic asphalt (MA) is hardened slightly by changes in the bitumen group constitution and a partial transition of asphaltenes into resins. Hardening of the mastic asphalt both annealed at 200°C and not annealed is similar. Larger rate of hardening of mastic asphalt with binder 20/30 is observed after annealing at 250 and 300 °C.

The impact of high temperature on hardness change of mastic asphalt with polymer modified bitumen PmB 25/55-60 shown in Figure 6. Hardness test results show little variation of penetration, which means that the impact of high temperatures affects the hardness of mastic asphalt than traditional mastic to a lesser extent. Mastic asphalt contains less binder and more grits than the traditional mastic, so the effect of the deterioration of the elastic properties of polymer modified bitumen is not apparent.

3 Conclusions

The widespread use of asphalt pavement and waterproofing materials containing polymers creates the danger of damage to bridge pavements due to the impact of high technological temperatures. High temperatures above 200°C result in the destruction of polymer bond network in materials containing polymers, which is the cause for the loss of the durability of waterproofing or the pavement. As the right direction of the works over the quality of pavement systems a review of requirements concerning the bridge pavements should be considered to eliminate the use of polymer modified bitumen. Eliminating the use of polymer modified bitumen in mastic asphalt for protective course and the recommended use of bitumen 35/50 and multigrade binder 35/50, allows using high-temperature annealing up to 240°C. Such mastic asphalts used for protective layers will be highly durable and have good technical properties.

Even the use of the highest quality materials, with poor workmanship does not guarantee durability of the waterproofing systems. This statement can be supported by the opinion quoted below [8]: “Bridges built in Denmark are characterized by their pavement durability. One reason for this is to comply with stringent technical requirements, extensive control of materials as well as thorough supervision of the works.”

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