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# DETERMINATION OF THE COMPOSITION OF ASPHALT CONCRETE MIXTURES BASED ON EPOXY COMPONENTS FOR THEIR APPLICATION AS THIN-LAYER COATINGS OF ROAD BRIDGES

***Onishchenko Arthur***
*National Transport University, Kyiv, Ukraine*
*ORCID ID: 0000-0002-1040-4530*

***Zelenovsky Vladimir***
*M.P. Shulgin State Road Research Institute State Enterprise (DerzhdorNDI SE), Kyiv, Ukraine*
*ORCID ID: 0000-0001-5834-5456*

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**ABSTRACT**

This paper presents the results of the analysis of world and domestic experience, theoretical and practical research to assess the impact of thermosetting additives on the main indicators of bitumen and physical and mechanical properties of asphalt concrete.
Ensuring increased track resistance, strength and crack resistance of pavements on road bridges today is one of the most important problems facing scientists and road workers in Ukraine. An urgent task is to improve the performance of these coatings in order to extend their service life and minimize the frequency of repair work, which, especially on bridges, cause great difficulties and require significant additional costs. There is no doubt that when using epoxy asphalt concrete as a thin-layer pavement, we get a strong, flexible surface, resistant to cracking and rutting. However, this is not yet a sufficiently researched material for its possible wide application, as it requires a special approach to the establishment of the composition and technology of its preparation. The application of a thin-layer coating on an orthotropic or reinforced concrete slab of the carriageway of the bridge made of epoxy asphalt-concrete mixture requires special attention in establishing the optimal selection of its composition and cooking technology. Particular attention should be paid to ensure the required viability of the epoxy asphalt mixture, the use of the desired hardener, which affects its properties, determining the required number of thermosetting modifiers, determining the duration of curing depending on temperature.

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**Introduction.**

The safety and comfort of movement on the bridge should be ensured by a high-quality road surface. On bridges, the road surface is arranged on an orthotropic or reinforced concrete slab, which deforms under the action of a wheel load and affects its operation. Practice shows that the service life of the road surface on the bridge is about 5 years, several times less than the expected service life (15 years or more). Usually, after the first year of operation, longitudinal cracks appear in the road surface. On bridges, the road surface is laid on the slab of the carriageway, which receives the load from the transport, moving, and therefore deforms between the main beams of the superstructure. Therefore, the occurrence of the most common defects in the form of cracks can occur mainly from top to bottom with a negative bending moment in the road surface, arises above the walls of the main beams [2].

In connection with the imperfect work of the pavement on bridges made of dense asphalt concrete (the appearance of cracks in the upper layer of the pavement, loss of adhesion between layers, etc.), more modern types of asphalt concrete (crushed stone mastic or cast asphalt concrete) [3]. The use of these types of asphalt concrete reduces the risk of cracking due to their good flexural tensile performance. Thus, it is possible to significantly reduce the thickness of the road surface, which in turn will reduce the load on the bridge structure.

These types of coatings, in comparison with thin-layer coatings based on synthetic resins, are not capable of performing a waterproofing function and a function of a wear layer. But at present, the active use of thin-layer coatings is restrained by insufficient experience in their operation and the lack of methods for establishing their composition and preparation.

**Presentation of the main material.**

*Determination of the composition of epoxy asphalt concrete mixtures.*

To establish the composition of epoxy asphalt concrete mixtures for their use as a thin-layer coating on bridges, a set of studies was carried out. In their implementation, the following source materials were used [4]:

– viscous oil road bitumen, grade «БНД 70/100»;
– diesel fuel;
– hardener for epoxy resin «Л-19»;
– hardener for epoxy resin «І-6М»;
– hardener for epoxy resin «MTHPA»;
– epoxy resin «LE 826»;
– sand from screenings of crushing rocks;
– mineral powder.

To prepare the epoxy asphalt concrete mixture, the granulometric composition of the mineral part of hot fine-grained asphalt concrete of type «Г» was selected. The selection results are shown in Table 1.

Table 1. Selection of the grain size composition of the asphalt concrete mixture.

| Mineral material | Content of mineral grains in the mixture by weight, % | Content by weight, % of mineral grains, smaller than this size, mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10,0 | 5,0 | 2,5 | 1,25 | 0,63 | 0,315 | 0,14 | 0,071 |
| Grain composition of raw materials | | | | | | | | | |
| Sand from crushing screenings | - | 100,0 | 95,38 | 65,27 | 42,25 | 23,62 | 11,48 | 4,10 | 0,80 |
| Mineral powder | - | 100,0 | 100,0 | 100,0 | 100,0 | 100,0 | 99,90 | 98,00 | 83,20 |
| Selected grain composition of the mineral part of asphalt concrete | | | | | | | | | |
| Sand from crushing screenings | 88 | 88,0 | 83,93 | 57,44 | 37,18 | 20,79 | 10,10 | 3,61 | 0,70 |
| Mineral powder | 12 | 12,0 | 12,0 | 12,0 | 12,0 | 12,0 | 11,99 | 11,76 | 9,98 |
| Full passages through sieves | 100 | 100,0 | 95,93 | 69,44 | 49,18 | 32,79 | 22,09 | 15,37 | 10,69 |
| Requirements ДСТУ Б В.2.7-119 (full aisles) | 100 | 100 | 100-95 | 83-68 | 67-45 | 50-28 | 35-18 | 11-24 | 8-16 |

The preparation of epoxy asphalt concrete mixtures carried out in compliance with the standard sequence of technological operations according to DSTU B V.2.7-319 but with the variability of the following technologies [4].

*Technology 1* – epoxy components are injected directly into the finished asphalt concrete mixture.

The bitumen was prepared in the following sequence:

- heating the initial bitumen to a temperature of 140 °C;
- gradual introduction of diesel fuel into heated bitumen with constant mechanical stirring;
- mixing bitumen with diesel fuel for 60 minutes at a temperature of 140 °C.

*Technology 2* – preparation of asphalt concrete mixture on epoxy bitumen binder.

Modification of bitumen with epoxy components was performed in the following sequence:

- heating the original bitumen to a temperature of 140 °C;
- gradual introduction of diesel fuel into the heated bitumen with constant mechanical stirring;
- mixing bitumen with diesel fuel for 60 min at a temperature of 140 °C;
- cooling of rarefied bitumen to a temperature of 90 °C;
- gradual introduction of the hardener with constant mechanical stirring;
- mixing the binder with the hardener for 60 min at a temperature of 90 °C;
- gradual introduction of epoxy resin with constant mechanical stirring;
- mixing the binder with epoxy resin for 10 min at a temperature of 90 °C.

*Technology 3* – an asphalt concrete mixture is prepared using two binders, the first binder contains a hardener, and the second – epoxy resin.

The preparation of binders was performed in the following sequence:

- heating the original bitumen to a temperature (40 °C);
- gradual introduction of diesel fuel into the heated bitumen with constant mechanical stirring;
- mixing bitumen with diesel fuel for 60 min at a temperature of 140 °C;
- cooling of rarefied bitumen to a temperature of 90 °C and its division into two parts;
- gradual introduction of the hardener with constant mechanical stirring in one of the parts of the diluted bitumen;
- mixing the first part of the diluted bitumen with a hardener for 60 min at a temperature of 90 °C;
- gradual introduction of epoxy resin with constant mechanical stirring in the second part of the diluted bitumen;
- mixing the second part of the diluted bitumen with epoxy resin for 10 min at a temperature of 90 °C.

The ratio (epoxy resin – hardener) when using hardener «Л-19» and «MTHPA» was 100:80, with «I-6M» – 150:100.

The objects of study were:

- asphalt concrete on the original bitumen brand «БНД 70/100»;
- asphalt concrete on rarefied bitumen;
- epoxy asphalt concrete with hardener «L-19», with a total content of epoxy components 10,0 % by weight of bitumen obtained by all technologies;
- epoxy asphalt concrete with hardener «L-19», with a total content of epoxy components 5,0 %, 10,0 % and 20,0 % by weight of bitumen obtained by the third technology;
- epoxy asphalt concrete with hardeners «L-19», «I-6M» and «MTHPA», with a total content of epoxy components of 10,0 % by weight of bitumen, obtained by the third technology.

*Determination of viability of epoxy asphalt concrete mixtures.*

The viability of the mixture is determined by its mobility and compaction. The indicator that characterizes the compaction of the asphalt mixture is the density of the asphalt concrete obtained from it. As the compaction increases, the density of asphalt concrete increases. Under equal conditions, the compaction of the mixture and the density of asphalt concrete depend on the viscosity of the binder. In turn, the increase in viscosity leads to a decrease in the density of asphalt concrete [4].

When determining the viability of epoxy asphalt concrete mixtures, «L-19» was used as a hardener. Epoxy asphalt concrete mixtures were obtained using three technologies. The test results are shown in Figures 1 and 2.

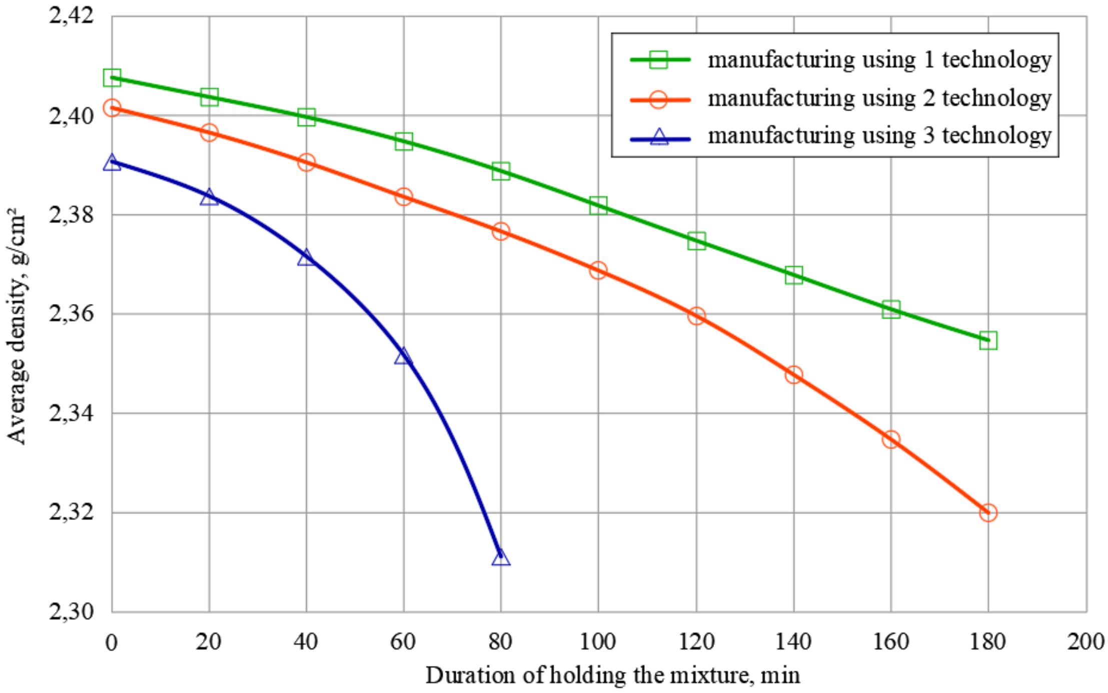



***Figure 1.*** *Average density of epoxy asphalt concrete obtained by various technologies.*

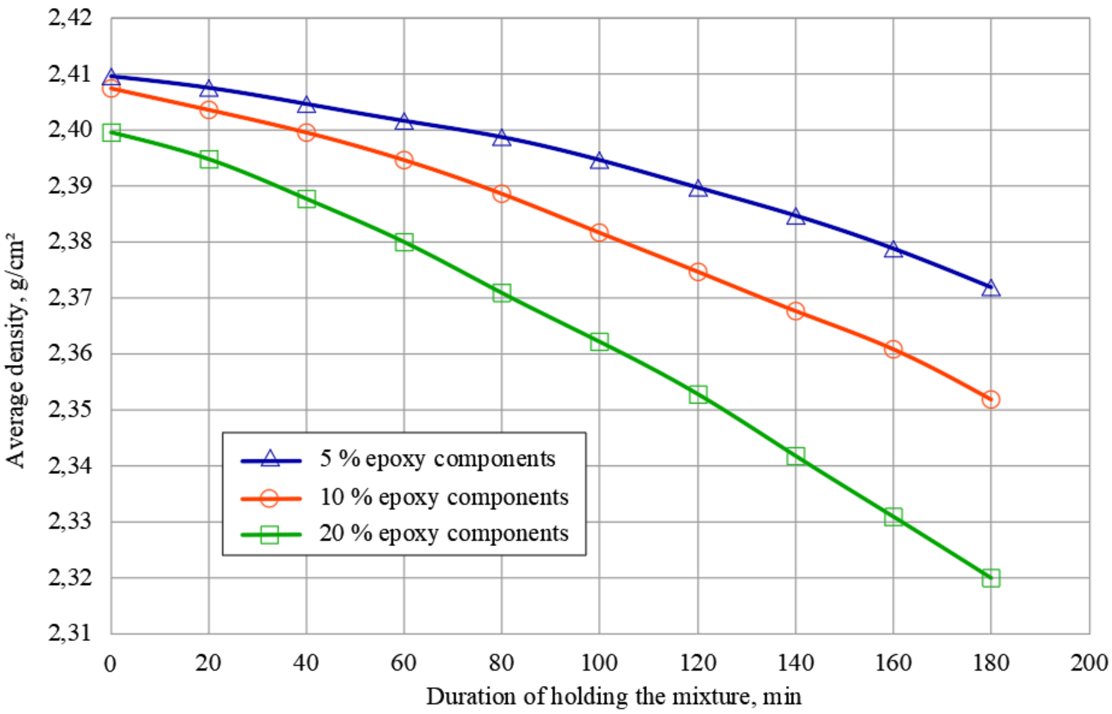



***Figure 2****. Average density of epoxy asphalt concrete with different content of epoxy asphalt obtained for 3 technologies.*

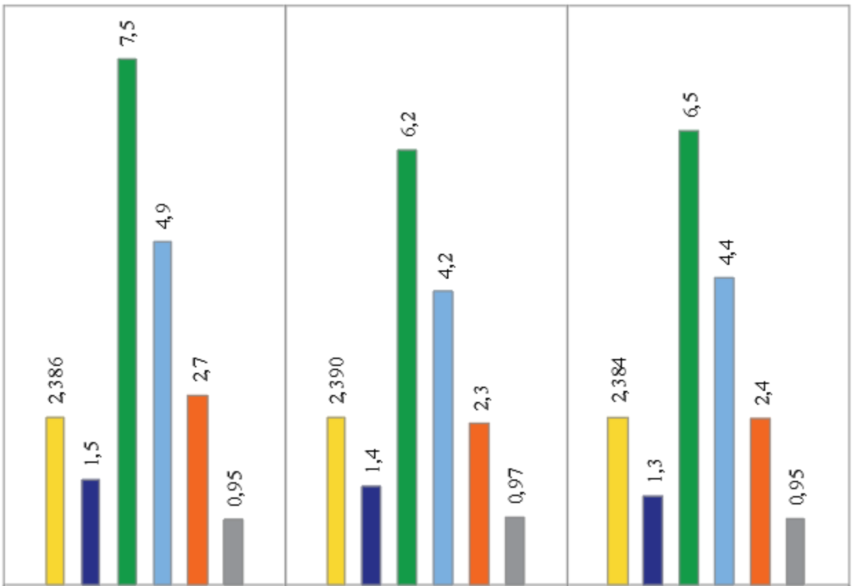
The test results show that the average density of epoxy asphalt concrete obtained by the first technology after 60 minutes of aging of epoxy asphalt concrete mixtures at a compaction temperature decreases from 2,391 g/cm³ to 2,352 g/cm³. Increasing the holding time of epoxy asphalt concrete mixtures leads to the formation of lumps in the mixture and the impossibility of its high-quality compaction.

At the same time, epoxy asphalt concretes obtained by the second technology have a similar average density after 130 minutes from their preparation, and according to the third technology - after more than 180 minutes. Thus, the most effective technology for the preparation of epoxy asphalt mixtures is the third. Therefore, in the future, the preparation of epoxy asphalt concrete is carried out using this technology.

The viability of epoxy asphalt concrete mixtures decreases as the amount of epoxy asphalt in them increases. So, with practically the same initial values of the average density of epoxy asphalt concrete with different content of epoxy layer, the average density of epoxy asphalt concrete obtained after 180 min of exposure of the mixtures differs significantly. Epoxy asphalt concrete with 5,0 % of epoxy beds has an average density of 2,372 g/cm, with 10,0 % of epoxy beds – 2,355 g/cm, and with 20,0 % of epoxy beds – 2,320 g/cm. Further, the preparation of epoxy asphalt concrete samples is carried out within a time not exceeding 30 minutes after the preparation of epoxy asphalt concrete mixtures.

*Influence of hardeners on the properties of epoxy asphalt concrete.*

For comparative analysis, epoxy asphalt concretes with hardeners «L-19», «I-6M» and «MTHPA» were adopted. The total content of epoxy components was 10%. Testing of epoxy asphalt concrete is performed 28 days after preparation. The test results of epoxy asphalt concrete in Figure 3.




| | 1 | 2 | 3 |
|---|---|---|---|
| Average density, g/cm³ | 2,986 | 2,390 | 2,384 |
| Water saturation, % | 1,5 | 1,4 | 1,3 |
| Strength at 0 °C, MPa | 7,5 | 6,2 | 6,5 |
| Strength at 20 °C, MPa | 4,9 | 4,2 | 4,4 |
| Strength at 50 °C, MPa | 2,7 | 2,3 | 2,4 |
| Coefficient of water resistance | 0,95 | 0,97 | 0,95 |
| | Hardener L-19 | Hardener I-6M | Hardener MTNRA |

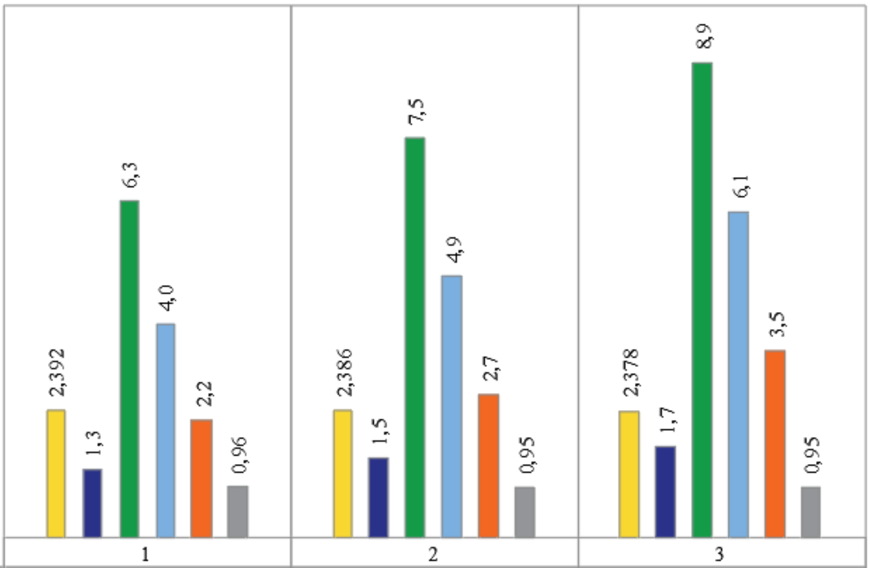
***Figure 3*** – Test results of epoxy asphalt concrete with different hardeners.

The test results showed that all epoxy asphalt concretes, regardless of the brand of hardener, have similar values of water resistance coefficient, values of average density and water saturation.

At the same time, the strength characteristics of epoxy asphalt concrete differ significantly. Epoxy asphalt concrete with «L-19» hardener has the highest strength at all test temperatures. Epoxy asphalt concretes with hardener «I-6M» have the lowest strength, and epoxy asphalt concretes with hardener «MTHPA» occupy an intermediate position and are closer to epoxy asphalt concretes with hardener «I-6M».

*Influence of the content of thermosetting modifiers on the properties of asphalt concrete.*

To study the effect of thermosetting modifiers on the properties of epoxy asphalt concrete, «L-19» was used as a hardener. The content of epoxy components was 5,0 %, 10,0 % and 20,0 %. Epoxy asphalt concretes were tested after keeping them at ambient temperature for 28 days [4]. The test results of epoxy asphalt concrete with different content of thermosetting modifiers are shown in Figure 4.




| | 1 | 2 | 3 |
|---|---|---|---|
| Average density, g/cm³ | 2,392 | 2,386 | 2,378 |
| Water saturation, % | 1,3 | 1,5 | 1,7 |
| Strength at 0 °C, MPa | 6,3 | 7,5 | 8,9 |
| Strength at 20 °C, MPa | 4,0 | 4,9 | 6,1 |
| Strength at 50 °C, MPa | 2,2 | 2,7 | 3,5 |
| Coefficient of water resistance | 0,96 | 0,95 | 0,95 |
| | 5 % epoxy components | 10 % epoxy components | 20 % epoxy components |

***Figure 4.*** *Test results of epoxy asphalt concrete with different content.*

According to the test results, the increase in the content of epoxy components leads to a decrease in the average density of epoxy asphalt concrete. At a content of 5,0 % epoxy components, the average density of epoxy asphalt concrete is 2,392 g/cm². When the content of epoxy components increases to 10 %, the average density decreases to 2,386 g/cm³, and when increasing to 20 % decreases to 2,378 g/cm³.

Along with the decrease in the average density there is an increase in water saturation. Epoxy asphalt concrete with 5,0 % of epoxy components has a water saturation of 1,3 %, with 10 % and 20 %, respectively, 1,5 % and 1,7 %.

As the content of epoxy components increases, the strength of epoxy asphalt concrete increases. At a temperature of 0 °C epoxy asphalt concrete with 5,0 % epoxy components has a strength of 6,3 MPa. When the content of epoxy components increases to 10 %, the strength increases to 7,5 MPa, and with 20 % of epoxy components – up to 8,9 MPa. It should be noted that in the entire range of epoxy components, the strength at a temperature of 0 °C meets the requirements of DSTU B V.2.7-119.

With increasing content of epoxy components, there is also an increase in the strength of epoxy asphalt concrete at a temperature of 20 °C. At this temperature, epoxy asphalt concrete with 5,0 % epoxy components has a strength of 4,0 MPa. When the content of epoxy components increases to 10 %, the strength increases to 4,9 MPa, and at 20 % – to 6,1 MPa.

The strength of epoxy asphalt concretes at a temperature of 50 °C increases most intensively with the increase of epoxy components content. If the strength of epoxy asphalt concrete with 5,0 % of epoxy components is 2,2 MPa, then when the content of epoxy components increases to 10 %, it increases to 2,7 MPa, and at 20 % – to 3,5 MPa.

The content of epoxy components in epoxy asphalt concrete has almost no effect on its water resistance. Epoxy asphalt concrete with 5 % epoxy components has a water resistance coefficient of 0,96, and epoxy asphalt concrete with 10 % and 20 % epoxy components – 0,95.

**Conclusions.**

Based on a set of studies and analytical review of world and domestic experience in the use of epoxy asphalt pavement on road bridges, we can confidently conclude that the use of thermosetting additives as modifiers of bitumen can significantly improve its properties, and hence the properties of asphalt concrete [5]. The use of such a coating requires special attention in determining the optimal composition and cooking technology.

The method of determining the composition of epoxy asphalt concrete coating is based on the following works:

– determination of viability of epoxy asphalt concrete mixture;
– determining the effect of hardeners on the properties of epoxy asphalt concrete;
– determination of the influence of the content of thermosetting additives on the properties of asphalt concrete.

The obtained research data allow to perform the optimal selection of the composition of epoxy asphalt concrete mixtures taking into account the variation of temperatures and the content of epoxy components in order to achieve their best technical characteristics.

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