State Office for Motor Roads of Ukraine (UKRAVTODOR)

**State Road Research Institute**

# CONCLUSION

## Re.: Characteristics of McAsphalt-Evotherm Warm Mix Asphalt with "Evotherm-3G" Additive

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# General Provisions

The Department of Organic Binding Materials of Derzhdorni, conducted studies of McAsphalt-Evotherm Warm Mix asphalts, which contained "Evotherm-3G" additive.

The "Evotherm-3G" additive allows the production of McAsphalt-Evotherm Warm Mix Asphalt (WMA) at temperatures of 50 °C less, compared to production of hot asphalt mixes, as well as up to 45% usage of Reclaimed Asphalt Pavement (RAP).

The content of binder in McAsphalt-Evotherm WMA comprises 4.0-5.5% of the mixture mass.

The manufacturer recommended preparation temperatures of McAsphalt-Evotherm WMA are between 115 - 130 °C, paving between 110 - 125 °C, compaction between 110 - 125 °C. The specified temperatures may be decreased to 98 °C, 92 °C and 90 °C, respectively.

When using standard crushed aggregate, sand and mineral, the content of "Evotherm-3G" additive comprises 0.3% of the mass of bitumen. When partially replacing the aggregate with RAP, the content is 0.5%.

The additive is injected into the bitumen at a temperature of 150-165 °C and they are mixed together for 30 minutes.

Apart from the lowered temperatures and the added procedures of adding the additive and of feeding crushed RAP, the McAsphalt-Evotherm WMA preparation technology is identical to that of hot mix asphalt.

## DESCRIPTION OF STUDIES

The studies of McAsphalt-Evotherm WMA with "Evotherm-3G" additive were performed as follows:

Исследование теплого асфальтобетона McAsphalt-Evotherm с добавкой "Evotherm-3G" выполнялись по такими направлениями:

1. The possibility of producing McAsphalt-Evotherm WMA at lowered temperatures, using standard aggregate materials, was examined. For that purpose, components were heated and mixed, as well the formation and compaction of samples was performed under recommended limit temperatures of 95 °C and 90 °C. The content of binder in the mix comprised 5.5 %, the content of additive – 0.3 % of the mass of the binder.

2. The properties of McAsphalt-Evotherm WMA were determined, with RAP content of 30% and 45% (maximum allowable quantity), including both milled from the upper layer of the pavement and crushed at the asphalt bitumen plant, after the removal of the entire pavement. The bitumen content constituted 4% to 5% (the varying content of bitumen is due to the necessity to examine the effects of additional amount of binding material from old pavement on the characteristics of McAsphalt-Evotherm WMA). The content of "Evotherm-3G" additive constituted 0.5 % of the bitumen mass.

McAsphalt-Evotherm WMA was evaluated based on standard properties of warm mix properties and was tested for compliance with requirements of the local standard: “Asphalt mixes and asphalt for roads and airfields. Specifications.”

For comparison, testing of hot mix asphalt was conducted, with the same composition as McAsphalt-Evotherm WMA, prepared using standard aggregate materials.

The preparation and testing of asphalt samples was conducted based on the methodologies described in the local standard: “Materials based on organic binder for road and airfield construction. Test methods" rev. 1.

## RAW MATERIALS

For the preparation of hot and warm McAsphalt-Evotherm asphalt mixes, the following materials were used:

- Crushed aggregate – granite, fraction 5-10 mm;
- Sand from sieving of crushed igneous rocks, fraction 0-5 mm ;
- Limestone mineral powder;
- Milled asphalt from the upper layer of the pavement;
- Crushed RAP, obtained following the removal of the old pavement;
- "Evotherm-3G" additive – yellow coloured liquid, based on the manufacturer's specifications;
- Road bitumen, grade BND 60/90;

The physical and mechanical properties of bitumen are provided in table 1.

Table 1

| **Property name** | **Property value** | **Requirements of local standard for grade BND 60/90** |
|---|---|---|
| | BND 60/90 | |
| 1. Needle permeability depth (penetration): | | |
| 1.1 At temperature 25 °C, $m \cdot 10^{-4}$ (0,1 mm) | 80 | 61-90 |
| 1.2 At temperature 0 °C, $m \cdot 10^{-4}$ (0,1 mm) | 12 | - |
| 2. Softening temperature (ring and ball method), °C | 47 | 47-53 |
| 3. Extensibility (ductility), $m \cdot 10^{-2}$(cm): | | |
| 3.1 At temperature 0 °C | 3,5 | 3,0 |
| 3.2 At temperature 25 °C | > 100 | 55 |
| 4. Modification of properties after heating: | | |
| 4.1 Softening temperature modification, °C, | 5 | 6,0 |
| 4.2 Residual penetration, % | 65 | 60 |
| 5. Brittleness temperature, °C | - 23 | - 12 |
| 6. Adhesion to the glass surface, % | 35 | 20,0 |
| 7. Ignition temperature in an open crucible, °C | 237 | 230 |

The injection of "Evotherm-3G" additive, practically, does not modify the bitumen properties.

## SELECTION OF ELEMENTS AND TESTING RESULTS OF HOT

## AND MCASPHALT-EVOTHERM WARM ASPHALT

Selected based on a local standard, the granulometric composition of the mineral portion of hot fine asphalt of type B and McAsphalt-Evotherm warm asphalt is shown in table 2.

Table 2

| Aggregate material | Contents of mineral grains in mixture, % | Content by mass, % of mineral grains, smaller than a given size, mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 15.0 | 10.0 | 5.0 | 2.5 | 1.25 | 0.63 | 0.315 | 0.14 | 0.071 |
| Granulometric composition of the raw materials | | | | | | | | | | |
| Crushed granite, fraction 5-10 mm | – | 100 | 96.0 | 9.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sand from crushed mineral sieving | – | 100 | 100 | 92.0 | 72.0 | 59.0 | 45.0 | 31.0 | 19.0 | 9.0 |
| Mineral powder | – | 100 | 100 | 100 | 100 | 100 | 98.0 | 93.0 | 88.0 | 71.0 |
| Selected granulometric composition of the mineral portion of asphalt | | | | | | | | | | |
| Crushed granite, fraction 5-10 mm | 38.0 | 100 | 36.5 | 3.42 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sand from crushed mineral sieving | 55.0 | 100 | 55.0 | 50.6 | 39.6 | 32.45 | 24.75 | 17.05 | 10.45 | 4.95 |
| Mineral powder | 7.0 | 100 | 7.0 | 7.0 | 7.0 | 7.0 | 6.86 | 6.51 | 6.16 | 4.97 |
| Completely screened through the sieve | 100 | 100 | 98.5 | 61.02 | 46.6 | 39.45 | 31.61 | 23.56 | 16.61 | 9.92 |

Prior to use, the crushed RAP was screened through a sieve with 10mm openings.

The test results of standard hot mix asphalt and McAsphalt-Evotherm WMA, with various compositions and preparation temperatures, are shown in Table 3.

Table 3

| Property name | Actual values of asphalt properties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Standard hot mix asphalt | McAsphalt-Evotherm WMA | | | | | | |
| | | On standard rock materials | | With milled asphalt | | | With asphalt, crushed at asphalt plant | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. Contents of RAP, % | - | - | - | 30 | 30 | 45 | 30 | 45 |
| 2. Content of bitumen, % | 5.5 | 5.5 | 5.5 | 5.5 | 5.0 | 5.0 | 5.0 | 4.5 |
| 3. Content of additive, % | - | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 4. Temperature, °C | | | | | | | | |
| - mineral portion | 160 | 90 | 100 | 145 | 165 | 175 | 165 | 175 |
| - bitumen | 155 | 90 | 95 | 150 | 150 | 150 | 150 | 150 |
| - mixing | 145 | 90 | 95 | 130 | 125 | 125 | 125 | 125 |
| - compaction | 140 | 90 | 95 | 125 | 125 | 125 | 125 | 125 |
| 5. Density, g/cm$^3$ | 2.35 | 2.34 | 2.35 | 2.35 | 2.36 | 2.35 | 2.35 | 2.34 |
| 6. Water saturation, % by volume | 2.4 | 2.9 | 2.8 | 0.9 | 1.5 | 1.1 | 1.5 | 1.4 |
| 7. Swelling, % by volume | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 8. Endurance limit during compression, MPa, at temperature: | | | | | | | | |
| 0 °C | 8.8 | 8.5 | 8.8 | 8.6 | 10.6 | 9.6 | 11.6 | 12.0 |
| 20 °C | 3.5 | 3.0 | 3.3 | 3.1 | 3.75 | 3.25 | 3.55 | 4.0 |
| 50 °C | 1.2 | 1.1 | 1.2 | 1.0 | 1.45 | 1.1 | 1.2 | 1.5 |
| 9. Coefficient of water resistance | 1.0 | 0.93 | 0.94 | 0.97 | 1.0 | 0.95 | 1.0 | 1.0 |
| 10. Coefficient of prolonged water resistance: | | | | | | | | |
| 14 days | 0.97 | 0.87 | 0.88 | 1.0 | 0.93 | 1.0 | 1.0 | 0.96 |
| 28 days | 0.94 | 0.82 | 0.83 | 1.0 | 0.91 | 0.98 | 1.0 | 0.85 |

## ANALYSIS OF TEST RESULTS

The performed tests confirm, that the physical and mechanical characteristics of McAsphalt-Evotherm WMA, prepared at minimal recommended temperatures (90 °C) using standard aggregate materials (column 3), satisfy the requirements of the local standard for hot asphalt mixes.

Increase to the warming temperatures of aggregate materials to 100 °C, of bitumen to 95 °C, of mixing and compaction temperatures to 95 °C (column 4) improve the properties of McAsphalt-Evotherm WMA.

WMA, prepared at temperatures of 90 °C and 95 °C, other than its strength characteristics is, practically, completely identical to hot mix asphalt, but has some lower indicators of water resistance which, however, satisfy the requirements of the local standard.

When replacing a portion of the aggregate with milled or crushed RAP, the recommended temperatures for heating the aggregate are between 160 - 170 °C, for bitumen - 140 - 150 °C, for mixing and compaction - 120 - 130 °C.

McAsphalt-Evotherm WMA containing 5,5 % bitumen, in which 30 % of the aggregate is replaced by milled RAP (column 5), does not satisfy the requirements of the local standard based on water saturation and compressive strength at a temperature of 50 °C. Decreased strength at 50 °C and low water saturation indicates a surplus of bitumen in the mix, which is due to the presence of additional binding material from the RAP. WMA with bitumen content reduced to 5% (column 6) has characteristics, which fully satisfy the requirements of the local standard.

McAsphalt-Evotherm WMA with 5 % bitumen content, with milled asphalt content of 45% (column 7), corresponds to the requirements of the local standard. At the same time, an analysis of characteristics indicates the possibility of reducing the content of bitumen in the mix to 4.5 %.

McAsphalt-Evotherm asphalt mixes, with optimally selected milled RAP content between 30 % and 45 %, have the same characteristics as regular hot asphalt mixes.

McAsphalt-Evotherm WMA with bitumen content of 5.0 % and 4.5 %, which contains, respectively, 30 % and 45 % of asphalt plant crushed RAP (columns 8 and 9), satisfy the requirements of the local standard.

McAsphalt-Evotherm WMA containing 30 % crushed RAP has the same quality indicators as regular hot mix asphalt.

The higher durability of McAsphalt-Evotherm with 45% RAP content, compared to hot asphalt mixes and other McAsphalt-Evotherm compositions, is explained by the presence of a higher amount of aggregate material with fraction of 2.5-10 mm, contained in the lower layers of the reclaimed pavement.

**CONCLUSIONS:**

1. The use of "Evotherm-3G" additive produces McAsphalt-Evotherm Warm Mix Asphalt, which satisfies the requirements of the local standard and, according to its characteristics, is not inferior to the standard hot mix asphalt.

2. The required additive content in the preparation of McAsphalt-Evotherm WMA from standard aggregate materials comprises 0.3 % of the bitumen mass. With partial replacement of the aggregate materials with RAP – 0.5 %.

3. McAsphalt-Evotherm WMA can hold up to 45 % of crushed RAP, which guarantees significant savings on conditioned crushed aggregate and sand.

4. Warm asphalt can be produced and used at lower process temperatures. The minimum allowable temperature of preparation and application of McAsphalt-Evotherm on standard mineral materials is 90 °C.

Taking into account, that bitumen in RAP is more viscous and hard, in order to guarantee the homogeneity of the mix during the preparation of McAsphalt-Evotherm WMA with RAP, the minimum mixing temperature should be between 120 - 130 °C. In cases where RAP is used when it is cold, to guarantee the specified temperature, the aggregate with the sand should be heated to 160 - 175 °C, the bitumen – to 145 - 150 °C.

The 50 °C decrease in the preparation and pavement temperature of the asphalt mix reduces energy costs by 30% and allows work to be performed at lower temperatures, compared to when hot asphalt mixes are being used.

5. When choosing the optimal bitumen content it is necessary to consider the binder, contained in the RAP. The approximate bitumen content during the preparation of McAsphalt-Evotherm WMA of type B from standard aggregate materials comprises 5.0-5.5 %, when replacing 30-45 % of the aggregate material with crushed RAP – 4.0-5.0 %.

**Therefore, the use of "Evotherm-3G" additive, during the preparation of McAsphalt-Evotherm Warm Mix Asphalt, allows savings of up to 25% in the bitumen quantity.**