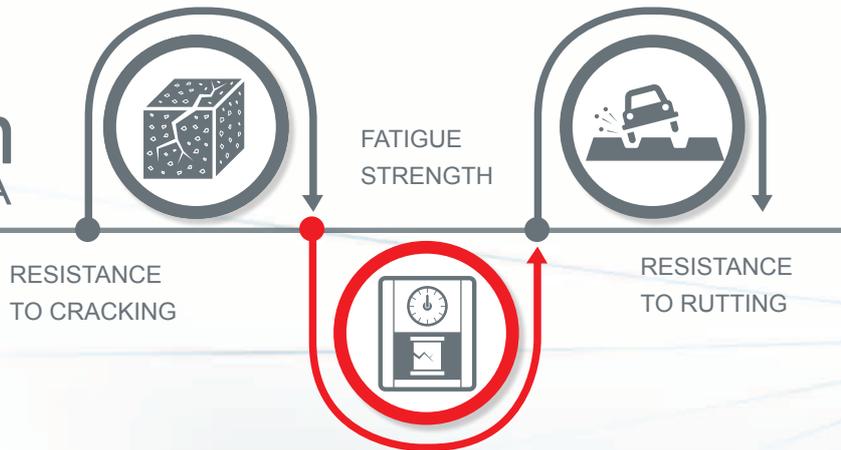


# Highly modified binders ORBITON HiMA



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HiMA





**Highly modified binders**  
**ORBITON HiMA**  
**Application Guide 2019**

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### Highly modified binders ORBITON HIMA

#### Application Guide 2019

ORLEN Asphalt Sp. z o.o., Poland

#### Authors:

Krzysztof Błażejowski (Ph.D. Civ.Eng.)

Marta Wójcik-Wiśniewska (M.Sc. Chem.Eng.)

Wiktoria Baranowska (M.Sc. Chem.Eng.)

Przemysław Ostrowski (M.Sc. Civ Eng.)

This publication contains sections of prior publications by ORLEN Asphalt Sp. z o.o. authored by:

Krzysztof Błażejowski (Ph.D. Civ.Eng.)

Jacek Olszacki (Ph.D. Civ.Eng.)

Hubert Peciakowski (M.Sc. Chem.Eng.)

Marta Wójcik-Wiśniewska (M.Sc. Chem.Eng.)

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ORLEN Asphalt Sp. z o.o.

ul. Łukasiewicza 39

09-400 Płock, Poland

tel. +48 24 25 69874

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## 1. INTRODUCTION

Research conducted by the R&D Department of ORLEN Asphalt to develop and implementation for production a new group of highly polymer modified binders was finalised in 2013 with the execution of an experimental section using this innovative binder. It was the first such pavement section in Poland, and sixth in Europe. In May 2014, the highly modified binders under the trade name of ORBITON HiMA were officially included in ORLEN Asphalt's product portfolio. Since 2015, the application of ORBITON HiMA has been subjected to standard technical procedures used in Polish road construction. The acronym „HiMA” (*Highly Modified Asphalt* in American English) or „HiM” (*Highly Modified* in certain countries) has quickly evolved into an umbrella term for highly modified binders offered by various PMB manufacturers.

This „ORBITON HiMA Application Guide 2019” follows up on prior editions of 2014 and 2015. It includes current information about the applications of ORBITON HiMA acquired in the course of further HiMA binder and HiMA asphalt mixture tests. Additional information can be found in the Bitumen Handbook 2018 published by ORLEN Asphalt.

## 2. HIGHLY POLYMER MODIFIED BINDERS

Higher polymer content in the binder markedly extends service life of asphalt pavements. Achieving a certain limit of polymer content in the binder causes the polymer phase to become a continuous phase in the binder. This in turn results in the reversal of the volumetric phases in the bitumen and polymer mixture (figure 1.1). A continuous polymer network markedly modifies functional properties of the bitumen, and in effect also of the asphalt course. ORBITON HiMA is a binder with the reversed polymer-bitumen phase.

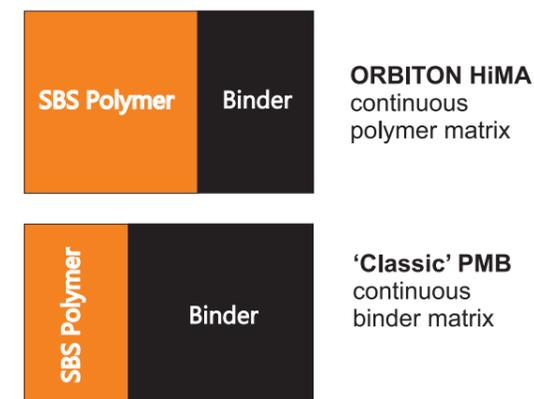


Fig. 1.1. Volumetric proportions between binder and polymer in a conventional polymer-modified binder and in highly polymer modified binder

Many research works and implementations of ORBITON HiMA binders have shown that they are products with very high functional properties. They are characterized by good rutting resistance, excellent fatigue resistance and crack resistance.

Courses with HiMA are very resistant to higher tension-induced strains (so-called fatigue strains), which potentially enables to reduce the thickness of the package of asphalt courses in the pavement. Full-scale research

conducted since 2009 on the experimental track in the US (*NCAT Pavement Test Track*) has shown that reduced-thickness pavement using highly polymer modified binder is extremely resistant to rutting and fatigue cracks [13, 15].

## 2.1. Classification of highly polymer modified binders

All ORBITON HiMA binders are classified according to European Standard EN 14023 „*Bitumen and bituminous binders. Specification framework for polymer modified bitumens*“. The classification of highly polymer modified binders manufactured in accordance with European Standard EN 14023 is shown below:

Standard designation of PMB HiMA: **PMB X/Y-Z**

- Notes to **designations**:
  - X – lower penetration limit at 25°C [0.1 mm] acc. to EN 1426,
  - Y – upper penetration limit at 25°C [0.1 mm] acc. to EN 1426,
  - Z – softening point (R&B) [°C] acc. to EN 1427
- Types of bituminous binder manufactured by ORLEN Asphalt:
  - ORBITON 25/55-80 HiMA**
  - ORBITON 45/80-80 HiMA**
  - ORBITON 65/105-80 HiMA**

## 3. APPLICATION OF ORBITON HiMA BINDERS

Very high properties of ORBITON HiMA binders make them particularly suitable for applications requiring very high durability, such as:

- asphalt pavements subjected to very high stress and strain,
- asphalt base courses with very high fatigue strength,
- courses with high resistance to low temperature.

Highly polymer modified binders are particularly suitable for long service life pavements such as *perpetual pavements*, where the asphalt base course is characterised by very high elasticity and fatigue strength. Application of ORBITON HiMA in the special anti-fatigue layer allows to achieve a very long pavement service life. Despite a relatively short presence on the bitumen product market, the range of applications of ORBITON HiMA products is very broad, both in terms of the possible types of asphalt mixtures and traffic category.

Typical applications of individual types of highly modified binders are shown below.

- ORBITON 65/105-80 HiMA** is primarily designed for wearing courses: BBTM, AUTL, DSH, PA, SMA and special technologies, e.g. SAMI courses (“hot spray” application). Another application of this binder is the production of bituminous emulsions intended for the *slurry seal* or surface dressing. Where high watertight and elasticity is needed, ORBITON 65/105-80 HiMA may be used for the *mastic asphalt*.
- ORBITON 45/80-80 HiMA** is designed for all asphalt courses. It is an universal binder in terms of application, enabling the execution of asphalt courses having high fatigue life and rutting resistance. For this reason, it may be an ingredient of anti-fatigue courses in the *perpetual pavement concept* as well as binder courses and wearing courses of pavement subject to high loads.

- ORBITON 25/55-80 HiMA** is designed for special courses requiring exceptional deformation resistance (parking lots for heavy vehicles, container terminals, etc.) and where very heavy, slow traffic takes place. Since this binder is very hard, **it should be used only in justified cases**, and suitable site conditions need to be ensured. Importantly, **ORBITON 25/55-80 HiMA is not designed for high stiffness modulus EME/HMB/HMAC asphalt mixtures** (further discussed in section 5.5). ORBITON 45/80-80 HiMA is recommended instead of ORBITON 25/55-80 HiMA for conventional pavement structures.

Properly-designed asphalt mixtures produced with highly polymer modified binders allow to achieve much better properties than their counterparts of similar hardness (polymer modified and paving-grade bitumens). More details about designing mixtures with ORBITON HiMA are included in chapter 6.

Suggestions provided in figures 3.1., 3.2. and 3.3. can be used when selecting ORBITON HiMA for application in flexible pavements. Example stiffness modulus data for pavement courses containing ORBITON HiMA can be found in chapter 5, section 5.5.

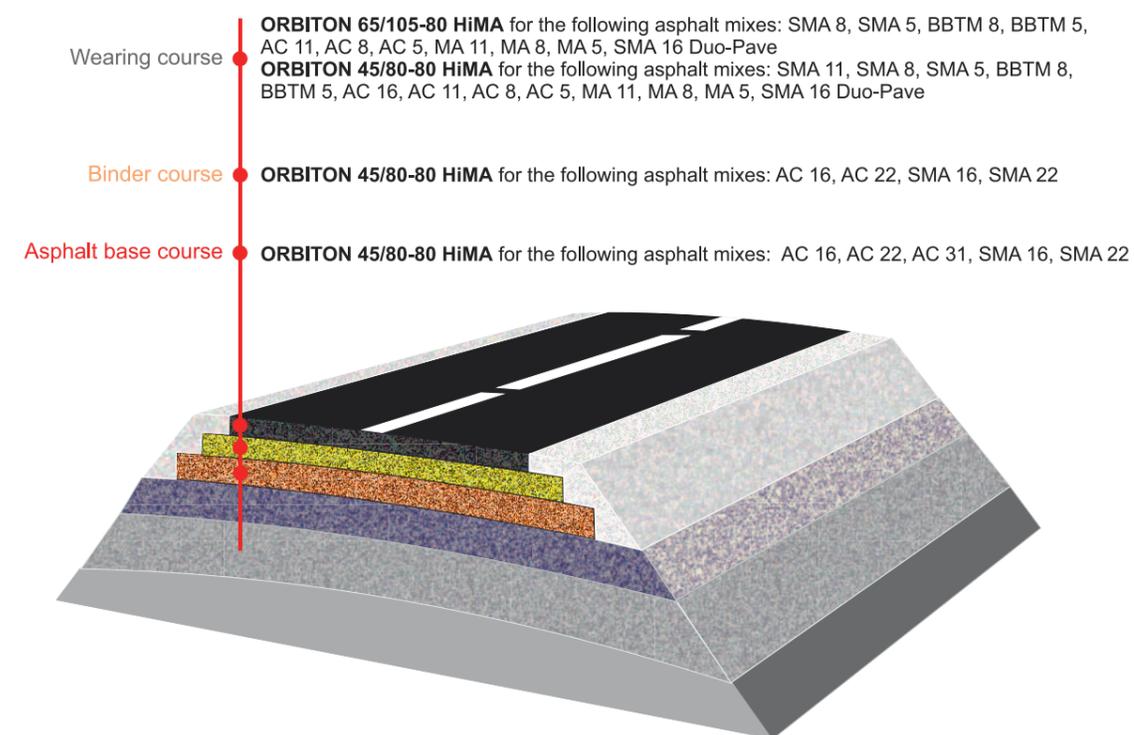


Fig. 3.1. Proposed application of ORBITON HiMA binders for the conventional flexible pavement structure

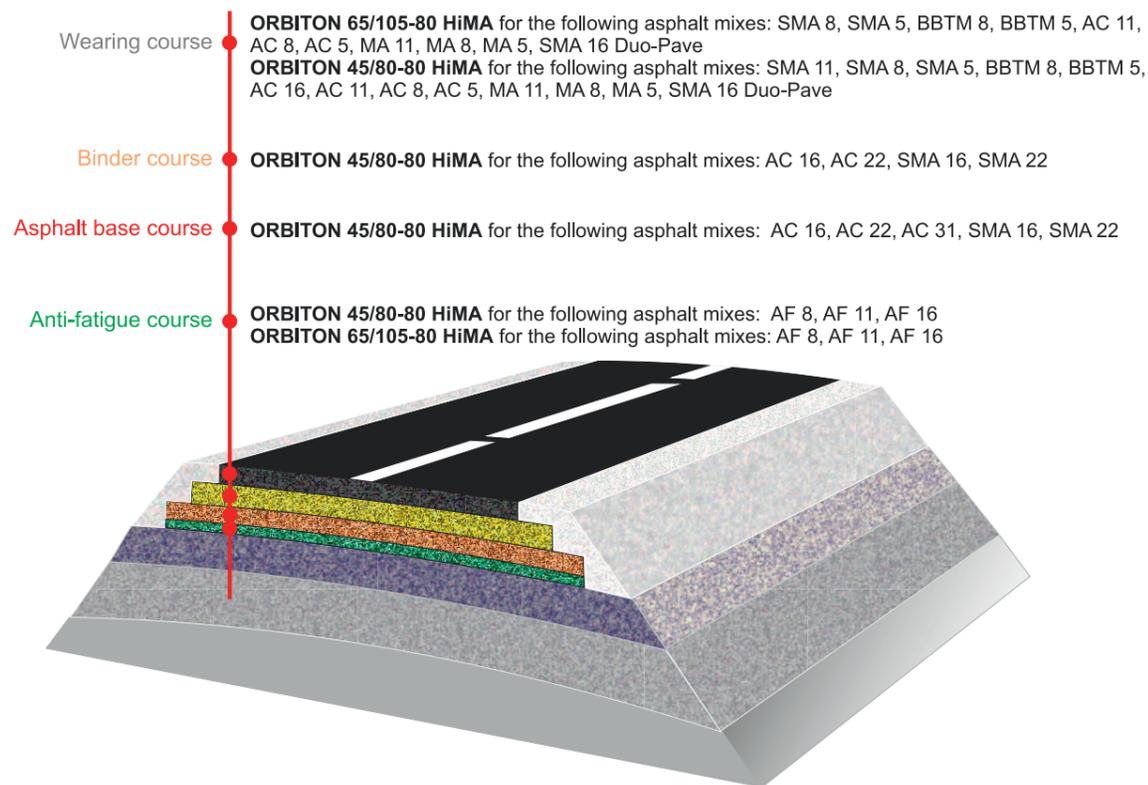


Fig. 3.2. Proposed application of ORBITON HiMA binders for the modern perpetual-type flexible pavement structure

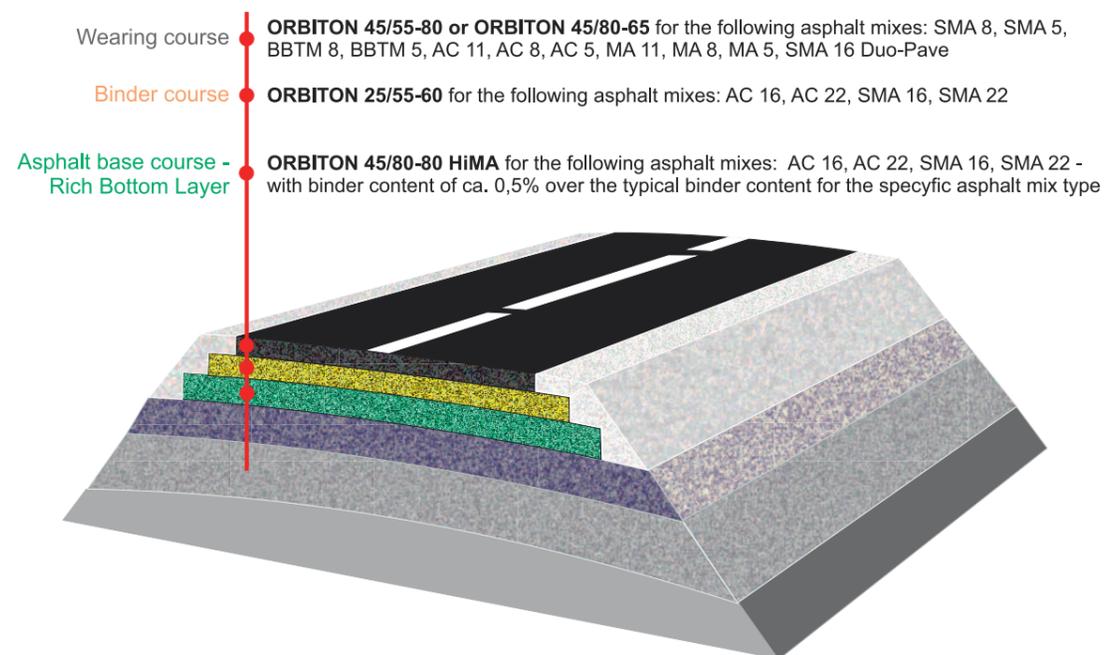


Fig. 3.3. Proposed application of ORBITON HiMA binders for the modern flexible pavement structure with the Rich Bottom Layer

“AF” mixture indicated in figure 3.2. as the anti-fatigue course refers to asphalt mixtures with special properties, other than typical bituminous base course properties. These may be conventional mixtures with changed properties (e.g. lower void content) or special mixtures compliant with Project Owner/Designer specifications.

## 4. PROPERTIES OF ORBITON HiMA BINDERS

All properties of highly polymer modified binders according to EN 14023 are provided below, along with data obtained via tests carried out according to the American *Superpave* method.

### 4.1. Properties according to EN 14023:2010

Test results of ORBITON HiMA binders from 2015 to 2018 are provided in table 4.1.

Table 4.1. Average properties of ORBITON HiMA binders produced in 2015-2018 [source: ORLEN Asphalt internal research]

Property	Test method	Unit	ORBITON HiMA				
			25/55-80	45/80-80	65/105-80		
Penetration at 25 °C	EN 1426	0.1 mm	46	67	85		
Softening point	EN 1427	°C	94.6	92.6	90.8		
Cohesion	Force ductility (50 mm/min)	EN 13589 EN 13703	J/cm <sup>2</sup>	4.0 (at 15°C)	3.8 (at 10°C)	3.5 (at 10°C)	
Resistance to ageing	Change of mass	EN 12607-1	%	0.03	0.00	0.06	
			Retained Penetration	%	78	76	81
			Increase in softening point	°C	1.7	2.1	1.8
Flash point	EN ISO 2592	°C	≥ 245	≥ 245	≥ 245		
Breaking point	EN 12593	°C	-20	-21	-20		
Elastic recovery	at 25°C	EN 13398	%	91	94	95	
	at 10°C	EN 13398	%	77	77	88	
Storage stability (72 h)	EN 13399 EN 1427	°C	0.4	1.8	1.8		
<b>After RTFOT ageing according to EN 12607-1</b>							
Drop in softening point	EN 1427	°C	0.1	1.7	0.5		
Elastic recovery at 25°C	EN 13398	%	87	92	94		
Elastic recovery at 10°C	EN 13398	%	74	79	88		

## 4.2. Properties according to Superpave

### 4.2.1. Testing of properties at high temperatures

#### 4.2.1.1. Conventional method using DSR ( $G^*$ and $\delta$ )

According to the Superpave method described in AASHTO M320 and AASHTO M332, binder resistance to high temperature is determined in the dynamic shear rheometer (DSR) by measuring two parameters: complex stiffness modulus  $G^*$  and phase angle  $\delta$  of the binder.

Table 4.2. presents DSR test results for the properties of ORBITON HiMA binders.

Table 4.2. DSR high-temperature test results of ORBITON HiMA binders [source: ORLEN Asfalt internal research]

Binder type	Upper critical temperature – UCT, [°C]	
	$G^*/\sin\delta=1.0$ kPa Binder before RTFOT ageing	$G^*/\sin\delta=2.2$ kPa Binder after RTFOT ageing
	AASHTO T 315	
ORBITON 25/55-80 HiMA	100.5	90.9
ORBITON 45/80-80 HiMA	98.9	88.9
ORBITON 65/105-80 HiMA	93.5	79.0

#### 4.2.1.2. Multiple Stress Creep Recovery test method

The MSCR test determines high-temperature properties of bituminous binders. The test is used to measure binder properties at the maximum pavement temperature (USA) or at any selected comparative temperature (Europe). MSCR test is carried out using a DSR at two stress levels: 0.1 kPa and 3.2 kPa.

In effect, two pairs of results are obtained for two stress levels, 0.1 kPa and 3.2 kPa:

- non-recoverable creep compliance  $J_{nr}$  in  $[kPa^{-1}]$ ,
- average percent recovery  $R$  in [%].

Of those parameters,  $J_{nr, 3.2}$  kPa is crucial for the binder properties, as it determines the resistance of a given binder to permanent deformation – the lower is value of  $J_{nr, 3.2}$  kPa, potentially, the rutting resistance of the asphalt mixture with that binder is greater.

MSCR tests were performed at 64°C and 70°C. The selected temperatures are relatively high, however they demonstrate very good performance characteristics of ORBITON HiMA binders when the pavement is extremely hot in summer. It should be noted that when MSCR tests are performed at lower temperatures, e.g. 58°C or 52°C, the values of  $J_{nr, 3.2}$  kPa for ORBITON HiMA are close to 0.00 (null), and so outside the precision range of the method.

Figures 4.1 and 4.2 show the comparison of  $J_{nr, 3.2}$  and  $R_{3.2}$  parameters for different binders manufactured by ORLEN Asfalt and MSCR-tested at 64°C and 70°C. All the binders were subjected to RTFOT ageing.

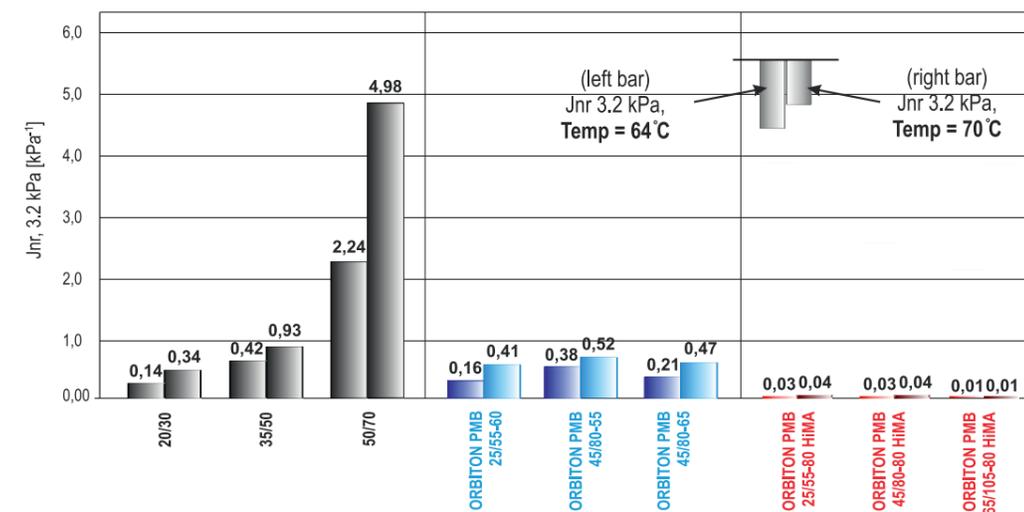


Fig. 4.1. Presentation of  $J_{nr}$  values at stress level of 3.2 kPa at 64°C and 70°C. Binders after RTFOT ageing. Chart interpretation: less = better [source: ORLEN Asfalt internal research]

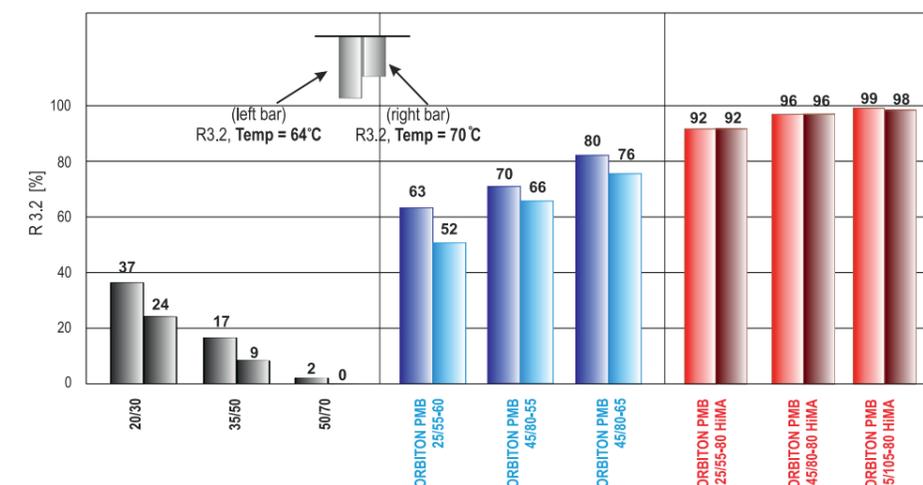


Fig. 4.2. Presentation of percent recovery  $R$  [%] values at stress level of 3.2 kPa at 64°C and 70°C. Binders after RTFOT ageing. Chart interpretation: more = better [source: ORLEN Asfalt internal research]

### 4.2.2. Testing of properties at intermediate temperature

The properties at intermediate temperatures, i.e. fatigue properties, are also tested using the DSR. Binder resistance to fatigue cracks is performed at the temperature that depends on the binder's performance grade (PG). The requirements of AASHTO M332 limit binder stiffness defined as the product of:  $G^* \cdot \sin\delta$  to 5000 kPa as a maximum (for S grade) and to 6000 kPa (for H, V, E grades). Table 4.3. shows the results of critical temperatures in relation to fatigue cracking of highly modified binders.

Table 4.3. Test results of critical temperatures in relation to fatigue cracking of ORBITON HiMA binders. Binder after RTFOT and PAV ageing [source: ORLEN Asphalt internal research]

Binder type	Fatigue cracking critical temperature – FCCT, [°C]	
	G*·sinδ=5000 kPa binder after RTFOT+PAV ageing	G*·sinδ=6000 kPa binder after RTFOT+PAV ageing
	AASHTO T 315	
ORBITON 25/55-80 HiMA	13.2	11.1
ORBITON 45/80-80 HiMA	11.7	10.1
ORBITON 65/105-80 HiMA	11.1	9.6

**4.2.3. Testing of low-temperature properties**

In the *Performance Grade* system, the Bending Beam Rheometer (BBR) is used to test binder properties at low temperatures. It is assumed that creep stiffness S(t) may not exceed 300 MPa, which should ensure the appropriate cracking resistance (no binder over-stiffness). The value of the second parameter obtained from the test, referred to as m-value, should be greater than 0.300, which results from the relaxation of stress in the binder when the temperature drops.

Table 4.4. shows the results of low-temperatures tests of ORBITON HiMA binders aged in the RTFOT and PAV.

Table 4.4. Results of low-temperatures tests of ORBITON HiMA: S(60) = 300MPa, m(60) = 0.3 and stiffness S at -16°C [source: ORLEN Asphalt internal research]

Binder type	Low critical temperature [°C] – LCT		ΔTc T(S) <sub>60</sub> - T(m) <sub>60</sub>	Binder stiffness at -16 °C S(T) <sub>-16</sub> [MPa] <sup>1)</sup>
	at S(60) = 300 MPa T(S) <sub>60</sub> [°C]	at m(60) = 0.300 T(m) <sub>60</sub> [°C]		
	EN 14771, AASHTO T 313			
ORBITON 25/55-80 HiMA	-21.1	-18.4	-2.7	170.0
ORBITON 45/80-80 HiMA	-21.7	-20.7	-1.0	145.0
ORBITON 65/105-80 HiMA	-21.6	-21.8	+0.2	149.0

<sup>1)</sup> parameter unrelated to *Superpave*, given only for comparison

**5. PROPERTIES OF ASPHALT MIXTURES WITH ORBITON HiMA**

Test results of asphalt mixtures with ORBITON HiMA binders are provided below.

**5.1. Rutting resistance at 60°C and 70°C**

Rutting resistance was tested using a small wheel tracking apparatus, procedure B, in the air, according to EN 12697-22: „Bituminous mixtures. Test methods for hot mix asphalt. Wheel tracking”.

Wearing course AC 16 was used for the tests. Parameters of the mixture: binder content 5.6% m/m; V<sub>m</sub> = 2.2% v/v; VFB = 85.8 %; mixture density ρ<sub>bssd</sub> = 2.421 [Mg/m<sup>3</sup>].

The tests were performed at 60°C and 70°C. The test results show the behaviour of the mixtures and binders when the pavement becomes extremely warm.

The results of two primary parameters – WTS<sub>AIR</sub> (Wheel-Tracking Slope) and PRD<sub>AIR</sub> (Proportional Rut Depth) for 9 bituminous binders, including ORBITON HiMA binders, are shown in figures 5.1. and 5.2.

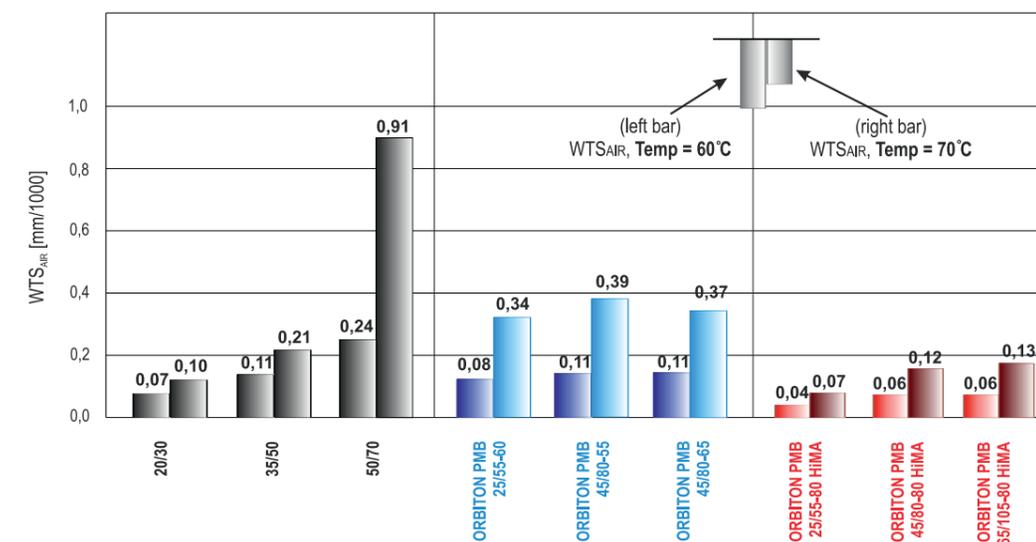


Fig. 5.1. Test results of rutting resistance, parameter WTS<sub>AIR</sub>. Chart interpretation: less = better [source: ORLEN Asphalt internal research]

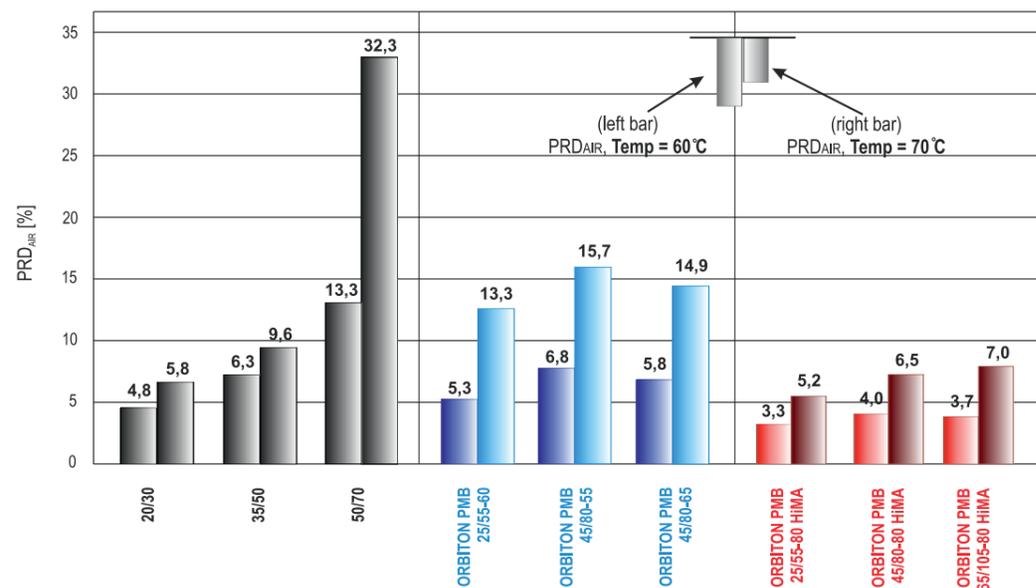


Fig. 5.2. Test results of rutting resistance, parameter  $PRD_{AIR}$ . Chart interpretation: less = better [source: ORLEN Asphalt internal research]

ORBITON HiMA binders present the best resistance to permanent deformation of all the tested bituminous binders.

High-temperature performance tests were also performed for binders itself (section. 4.2.1.2.), the coefficients of determination  $R^2$ , presented in table 5.1., can be specified between the test results.

Table 5.1. Coefficients of determination  $R^2$  between test results of binders and asphalt mixtures [source: ORLEN Asphalt internal research]

Tested binder property	Tested asphalt mixture property			
	$PRD_{AIR}$ $T = 60^\circ C$	$WTS_{AIR}$ $T = 60^\circ C$	$PRD_{AIR}$ $T = 70^\circ C$	$WTS_{AIR}$ $T = 70^\circ C$
$J_{nr}$ , 3.2 kPa, 64°C	$R^2 = 0.95$	$R^2 = 0.92$	---	---
$J_{nr}$ , 3.2 kPa, 70°C	---	---	$R^2 = 0.84$	$R^2 = 0.84$

The coefficients of determination  $R^2$  at the level of 80-90% indicate that, on the basis of MSCR test results, rutting resistance of the asphalt mixture can be determined with a high or very high probability.

## 5.2. Crack propagation – SCB method

Crack resistance of asphalt mixtures was tested using the SCB (*Semi-Circular Bending*) method according to EN 12697-44 „Bituminous mixtures. Test methods for hot mix asphalt. Crack propagation by semi-circular bending test”.

Binder course AC 16 was used for the tests. Parameters of the mixture: binder content: 4.6% m/m;  $V_m = 6.2\%$  v/v; mixture density  $\rho_{bssd} = 2.525$  [Mg/m<sup>3</sup>].

Results of crack resistance tests of asphalt mixtures using PMB ORBITON HiMA are presented in table 5.2. The tests were performed at 0°C.

Table 5.2. Results of crack resistance tests using SCB method, wearing course AC 16 [source: ORLEN Asphalt internal research]

Type of binder in the mixture	Crack resistance $K_{IC}$ [N/mm <sup>1.5</sup> ]	Strain $\epsilon_{max}$ for maximum value of force F [%]	Stress at crack $\sigma_{max}$ [MPa]
ORBITON 25/55-80 HiMA	36.1	1.1	6.7
ORBITON 45/80-80 HiMA	31.9	1.9	5.8
ORBITON 65/105-80 HiMA	23.6	1.9	4.5

Figures 5.3. and 5.4. additionally show the comparison of SCB test results for the entire portfolio of binders manufactured by ORLEN Asphalt.

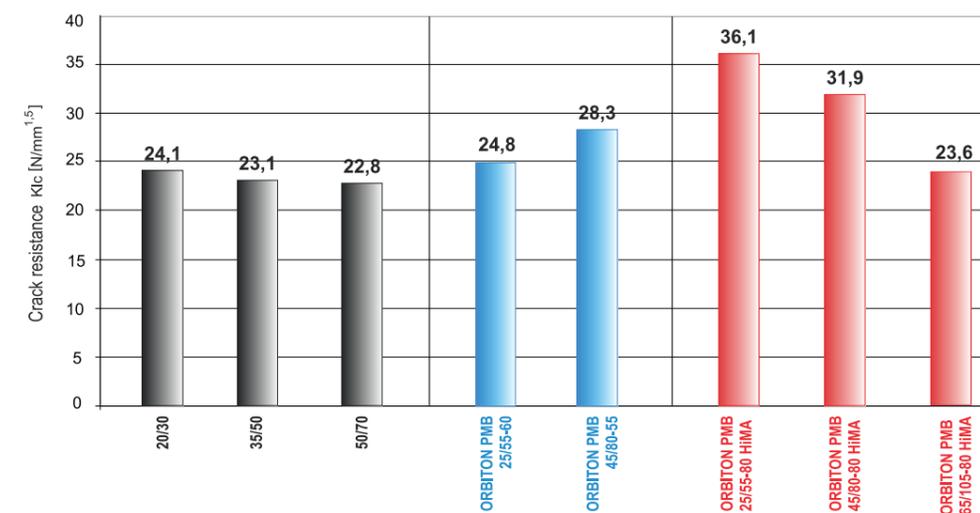


Fig. 5.3. Results of crack resistance tests,  $K_{IC}$ . Chart interpretation according to EN 12697-44: more = better [source: ORLEN Asphalt internal research]

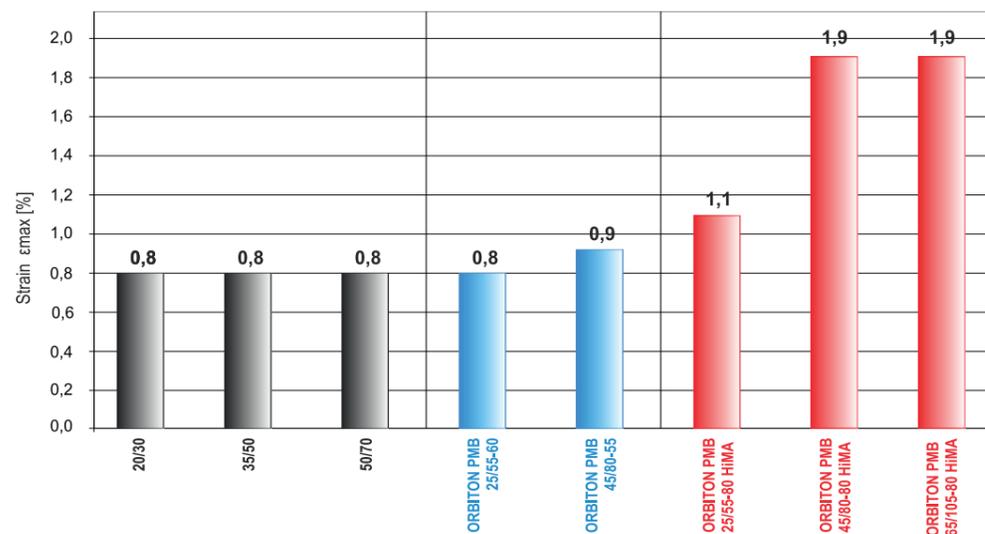


Fig. 5.4. Results of crack resistance tests, strain  $\epsilon_{max}$  [%] at the maximum force  $F_{max}$ . Chart interpretation: more = better [source: ORLEN Asfalt internal research]

Crack resistance index  $K_{IC}$  describes that phase of SCB testing where occur extreme values of force and stress. It should be remembered that  $K_{IC}$  according to the EN 12697-44 formula does not take into account the deformability of the sample at cracking, and only considers the value of breaking stress. Additional analysis accounting for  $\epsilon_{max}$  sample deformation at the maximum force  $F_{max}$  shows how the sample behaves in the cracking process. The combination of two parameters:  $K_{IC}$  and maximum deformation  $\epsilon_{max}$  shows that **the optimum binder is ORBITON 45/80-80 HiMA**.

### 5.3. Resistance to fatigue using the 4PB-PR method

Tests of asphalt mixture fatigue resistance were performed acc. to EN 12697-24 „Bituminous mixtures. Test methods. Resistance to fatigue”, using the 4PB-PR method.

The same binder course AC 16 mixture as in the SCB test was used (described in section 5.2.). The tests were performed at 10°C, in controlled strain mode, at 10 Hz sinusoidal stress frequency.

Fatigue performance of 8 asphalt mixtures, with the same mineral composition and with different binders, including ORBITON HiMA, is shown in figure 5.5.

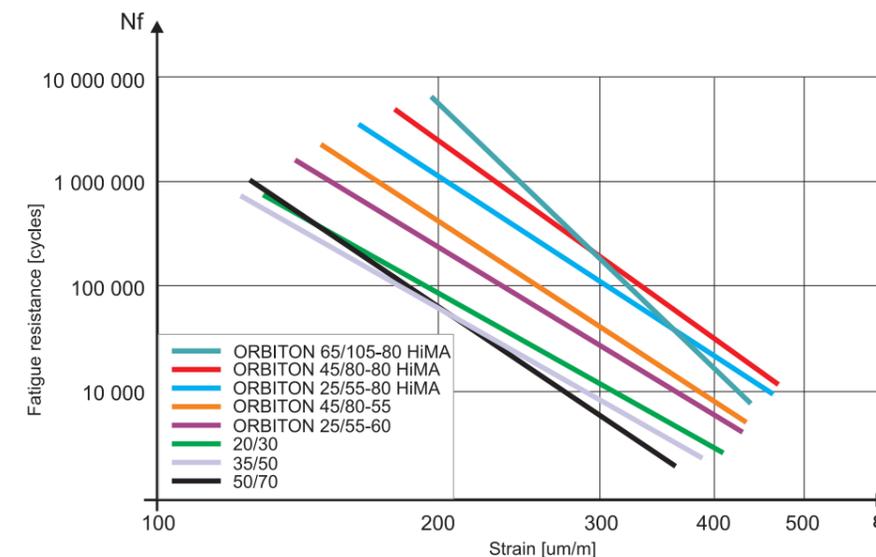


Fig. 5.5. Comparison of fatigue resistance of 8 binder course AC16 mixtures with different binders. Chart interpretation: the higher the curve = the better [source: ORLEN Asfalt internal research]

Due to the continuous polymer network, ORBITON HiMA binders have very good fatigue resistance.

Table 5.3. additionally shows the comparison of  $\epsilon_e$  (strain equivalent for fatigue life  $N_f=10^6$  fatigue cycles) for 8 binders in the tested binder course AC 16.

Table 5.3. Comparison of  $\epsilon_e$  for the tested asphalt binder course AC 16 mixtures with different binders [source: ORLEN Asfalt internal research]

Binder used in the binder course AC 16 mixture	Strain equivalent to resistance of $N_f=10^6$ fatigue cycles $\epsilon_e$ [ $\mu\text{m}/\text{m}$ ]
ORBITON 65/105-80 HiMA	258
ORBITON 45/80-80 HiMA	230
ORBITON 25/55-80 HiMA	203
ORBITON 45/80-55	171
ORBITON 25/55-60	153
Paving-grade bitumen 50/70	125
Paving-grade bitumen 20/30	122
Paving-grade bitumen 35/50	116

The test results indicate that fatigue resistance  $N_f$  of the binder course AC 16 with ORBITON HiMA binders is very high, and it is possible to safely transfer much higher strain of the asphalt course in comparison to conventional binders.

In addition, it can be assumed that, for a typical pavement, the application of HiMA binders in the asphalt base course will upgrade this pavement type close to the perpetual type.

### 5.4. Low-temperature cracking resistance - TSRST tests

Low-temperature cracking resistance of asphalt mixtures was performed using the TSRST method (*Thermal Stress Restrained Specimen Test*), according to EN 12697-46 „*Bituminous mixtures - Test methods for hot mix asphalt – Part 46: Low temperature cracking and properties by uniaxial tension tests. TSRST method*”.

Wearing course AC 16 mixture, described in section 5.1, was used for the tests.

Results of failure temperature ( $T_{failure}$ ) are shown in figure 5.6.

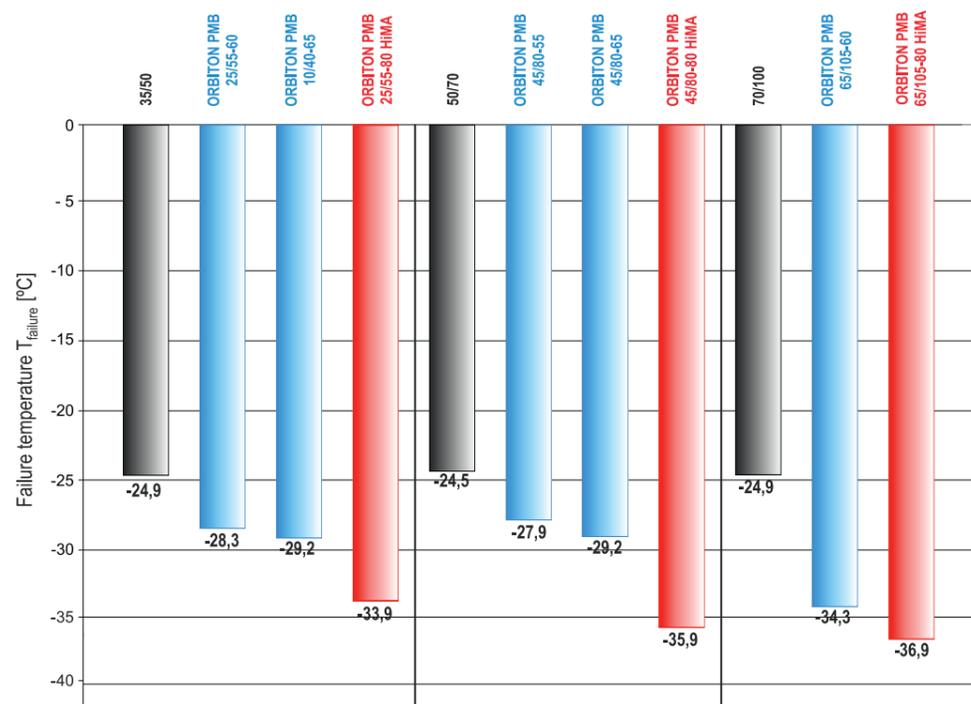


Fig. 5.6. Results of TSRST acc. to EN 12697-46 Chart interpretation: less = better [source: ORLEN Asphalt internal research]

ORBITON HiMA binders have the best low-temperature cracking resistance in comparison with other binders of similar hardness.

### 5.5. Stiffness modulus of asphalt mixtures with ORBITON HiMA

ORBITON HiMA are reversed polymer phase binders. This means that most of their volume is comprised of an elastomer network, which determine HiMA binders' performance. A characteristic property of each polymer network is improving the flexibility of modified binders, resulting in lower stiffness modulus values.

The experiences of using highly modified binders clearly shows that the application of ORBITON HiMA results in much lower stiffness modulus values of asphalt mixtures. Table 5.4. shows the results of the complex stiffness modulus test for the asphalt binder course AC 16 according to EN 12967-26 „*Bituminous mixtures. Test methods. Stiffness*”, using the 4PB-PR system. The tests were performed at 10°C, frequency at 10 Hz.

Table 5.4. Comparison of stiffness moduli for the tested asphalt binder course AC 16 mixture with different binders [source: ORLEN Asphalt internal research]

Binder used in the binder course AC 16 mixture	Complex modulus, 4PB-PR method T=10°C, f=10 Hz [MPa]
Paving-grade bitumen 20/30	13 096
Paving-grade bitumen 35/50	11 720
Paving-grade bitumen 50/70	10 020
ORBITON 25/55-60	11 313
ORBITON 45/80-55	9 686
ORBITON 25/55-80 HiMA	10 488
ORBITON 45/80-80 HiMA	8 799
ORBITON 65/105-80 HiMA	7 590

Even though the mixtures with ORBITON 25/55-80 HiMA show the highest stiffness among all HiMA binders, according to the recommended applications specified in chapter 3, there are no high stiffness modulus asphalt concretes (EME, HMB, HMAC). Conducted tests show that the highest possible value of the stiffness modulus (4PB-PR, 10°C, 10Hz) with ORBITON 25/55-80 HiMA did not exceed 11000 MPa, whereas, for the 20/30 and PMB 25/55-60 binders used in Poland for HMAC, stiffness modulus values above 14000 MPa are easily achieved.

Stiffness modulus of mixtures containing ORBITON HiMA is not as high as stiffness obtained with conventional binders, which determines behaviour of the pavement structure. The application of HiMA asphalt courses with a lower stiffness modulus values results in greater deflection of the pavement structure under load, and hence higher critical tensile strains at the bottom of the asphalt base course. Nevertheless, as shown in figure 5.5., **the range of fatigue strength reserve is much greater than the potential damage from the increased strain.**

Table 5.5. shows an example range of stiffness modulus changes as the temperature changes (-2°C, +10°C and +23°C).

Table 5.5. Stiffness modulus test results for asphalt binder course AC 16 with ORBITON 45/80-80 HiMA at different temperatures, 4PB-PR method, f=10 Hz

Test temperature	Complex modulus, 4PB-PR method, f=10 Hz
-2°C	16 745
+10°C	8 799
+23°C	3 564

## 6. GUIDELINES FOR DESIGN OF ASPHALT MIXTURES WITH ORBITON HiMA

One of the challenges currently facing road technologists is to design a suitable composition of the asphalt mixtures with HiMA binders. Experience of the authors of this publication shows, that commonly used approach for PMB mixtures is not appropriate for HiMA mixes. Even though the basic rules of HiMA asphalt mixture design are similar to the conventional design approach, characteristics of HiMA binders, and notably the impact on maximised benefits from the material, require a slightly different design approach.

### 6.1. ORBITON HiMA binder content in asphalt mixtures

The content of the binder that may be added to the mixture depends on a number of factors. First of all it depends on volumetric properties of the mixture, such as voids in the mixture (VMA) and voids filled with binder (VFB). These two factors should be considered in the design process.

Due to the very good rutting resistance of HiMA mixtures, higher binder content can be used. Practical experience with many asphalt mixture recipes (type tests) and the conducted research work indicate that the optimum content of binder is higher than for conventional binders, as shown in figures 6.1 (for binder course asphalt concrete) and 6.2 (for base course asphalt concrete). It can be stated that by applying too little HiMA to asphalt mixtures, not as many benefits will be achieved as from correctly designed mixture.

Therefore, **it is not recommended to design an asphalt mixture with only minimum permitted quantity of the binder. It is recommended to add ca. 0.3-0.4 per cent of the binder more than for the same mixture with a conventional binder.** It improves the elasticity of the layer, fatigue resistance and resistance to low-temperature cracks, and what is more workability during paving. Finally rutting resistance test verify the amount of the HiMA binder in the asphalt mixture.

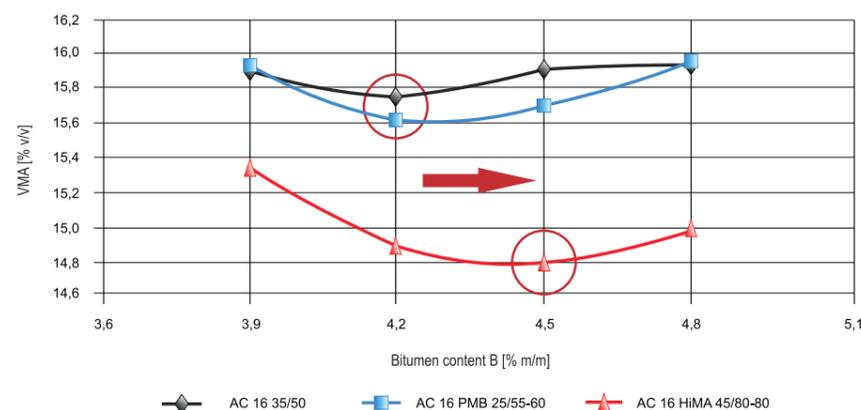


Fig. 6.1. VMA as a function of binder content for binder course AC 16 acc. to EN 12697-8 [source: ORLEN Asphalt internal research]

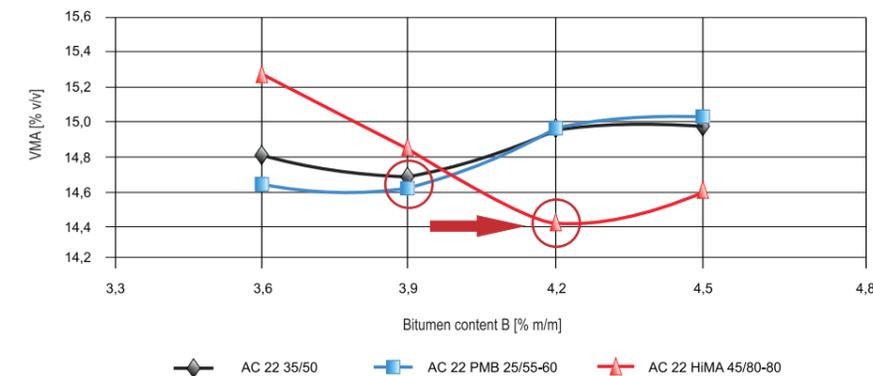


Fig. 6.2. VMA as a function of binder content for base course AC 22 acc. to EN 12697-8 [source: ORLEN Asphalt internal research]

## 7. RECOMMENDATIONS FOR ORBITON HiMA BINDER APPLICATION

### 7.1. Determination of the application temperature

Authors of this guide propose that, for HiMA binders, reliance on the conventional approach, in determining the process temperature, that is based on binder viscosity, may result in a number of errors.

A special type of SBS polymer used for the modification of HiMA binders has slightly different specification as the standard SBS used for the production of PMB binders. Therefore, process temperature values should be selected very carefully and be rather based on experimental sections.

Due to the short period of HiMA binders' readiness for placement, their long-time storage in the hot mix plant tanks is too risky. It is recommended that the binders should be used immediately upon delivery. **It is recommended to store HiMA binder at 160°C - 170°C. At this temperature, the binder may still be used for the asphalt mixture production.** Heating up the binder and the mixture to significantly over 180°C is counter-productive, because it does not reduce viscosity but rather increases it, which renders the mixture lay-down more difficult.

Table 7.1. shows the proposed process temperatures for ORBITON HiMA binders at the lab, mixing plant and at the construction site.

Table 7.1. Recommended process temperatures for ORBITON HiMA binders

	ORBITON 25/55-80 HiMA	ORBITON 45/80-80 HiMA	ORBITON 65/105-80 HiMA
<b>Laboratory:</b>			
Recommended Marshall/gyratory press sample compaction temperature	150-160°C	150-155°C	145-150°C
<b>Ingredient temperature at the mixing plant:</b>			
Pumping of binder	over 150°C	over 150°C	over 140°C
Short-term binder storage at the mixing plant (up to 3 days)	recommended below 170°C	recommended below 170°C	recommended below 170°C
Long-term binder storage at the mixing plant (more than 3 days)	150-160°C	150-160°C	150-160°C
<b>Asphalt mixture temperature in the mixing plant's mixer:</b>			
Asphalt concrete	max. 180°C (recommended 175°C)	max. 180°C (recommended 175°C)	max. 175°C
SMA	max. 180°C (recommended 175°C)	max. 180°C (recommended 175°C)	max. 175°C
Porous concrete	max. 180°C (recommended 175°C)	max. 180°C (recommended 175°C)	max. 175°C
Mastic asphalt	--	max. 180°C (recommended 175°C)	max. 180°C (recommended 175°C)
<b>Temperature on site:</b>			
Minimum temperature of the supplied asphalt mixture (in the spreader's hopper)	160°C	160°C	155°C
End of effective layer compaction temperature	>130°C	>125°C	>120°C

**Note:** temperature data provided in table 7.1 are specified on the basis of conclusions from various applications of HiMA binders. They are subject to change as further experience is acquired.

### 7.3. Storage of ORBITON HiMA

Because of the special properties of ORBITON HiMA binders, it is recommended to immediate application of the binder upon delivery. ORBITON HiMA should not be stored at temperatures higher than 170°C.

If storage is required, the product should be homogenised by closed-cycle mixing in one or multiple tanks. At least one of the tanks should be fitted with an agitator. Excessive storage time (more than 3 days) at a high temperature (in excess of 170°C) may lead to a gradual increase in the viscosity of highly modified binders, reducing its potential applicability.

If storage in excess of 3 days in a tank is planned, it is recommended to reduce the temperature to 160°C maximum and mix regularly.

It is recommended to conduct basic inspection tests of highly modified binder properties after 3 days in order to make sure that the product has not lost its properties. The following inspection tests should be performed: penetration at 25°C according to EN 1426, softening point according to EN 1427, viscosity at 160°C according to EN 13302.

#### Other comments:

- Before changing the type or grade of bitumen in the tank, the user must make sure that the tank is empty.
- HiMA binders should not be mixed with other binders. Such mixing would markedly downgrade the performance of the binder and affect the durability of the pavement.
- Multiple heating and cooling cycles for ORBITON HiMA binders are not recommended.

### 7.4. Highly modified binder samples at the lab

The way binder is handled in the laboratory has a major effect on the test results of both binders and asphalt mixtures. It should be remembered that a binder sample which is heated and/or overheated in the oven multiple times may significantly harden, and thus the obtained results will differ from the results for non-aged binder.

Therefore, multiple heating of binder samples should be avoided. The authors of this guide suggest using a greater number of small samples (for one-off use) rather than a single, large binder-holding container. If it is necessary to use the binder from one, large container, careful heating of the container for the first time is recommended, its homogenisation through mixing, and subsequently pouring into a few smaller containers to be used later.

The method of handling ORBITON HiMA samples is shown in table 7.2.

Table 7.2. Laboratory sample heating temperature

Size of sample in container	ORBITON 25/55-80 HiMA	ORBITON 45/80-80 HiMA	ORBITON 65/105-80 HiMA
container volume up to 1 litre, - max. sample heating time of 2 hours	max. 170	max. 170	max. 170
container volume 1+2 litres, - max. sample heating time of 3 hours	max. 170	max. 170	max. 170
container volume 2+3 litres, - max. sample heating time of 3.5 hours	max. 170	max. 170	max. 170
container volume 3+5 litres, - max. sample heating time of 4 hours	max. 170	max. 170	max. 170
container volume more than 5 litres, - max. sample heating time of 8 hours	max. 160	max. 150	max. 140

#### Additional comments:

- the sample-holding container must not be tightly closed (during heating-up),
- samples should not be heated at the temperature exceeding 180°C,
- after heating the samples in the containers, they should be homogenised mechanically by using a slow-rotating agitator, and care must be exercised to avoid the entry of air bubbles into the sample; maximum mixing (homogenisation) time is 10 minutes,
- binder samples obtained from the extraction of asphalt mixture acc. to EN 12697-1, EN 12697-2, and EN 12697-4 should be tested promptly upon extraction in order to avoid reheating.

#### Samples for modified binder tests

If samples are used to test binder properties, according to EN 12594, section 7.1, ORLEN Asphalt as the supplier recommends that, after the samples are heated and homogenised, the material should be passed through a metal screen, mesh size of #0.5 mm to eliminate impurities affecting the test results.

### 7.5. Asphalt mixture production

Considering the particular properties of HiMA, the time of binder mixing with the aggregate (so-called „wet mixing” time) should be carefully selected.

HiMA binders should not be overheated and the indications in Table 7.1 should be followed. Increasing the temperature above the stated recommended values may result in an opposite reaction, i.e. significant stiffening of the binder caused by viscosity increase.

Temperature values provided in Table 7.1 do not apply to asphalt mixtures containing WMA additive. ORLEN Asphalt has not performed tests on the compatibility of such agents with ORBITON HiMA binders, and therefore their use should be preceded by the testing at the lab.

### 7.6. Asphalt mixture transport

During the transport of asphalt mixtures containing highly modified binder, the same rules apply that exist for PMB binders. The mixture should be covered by tarpaulin and any drops in the mixture temperature should be avoided.

### 7.7. Placement

The same rules as for conventional modified bitumen apply to the placement of mixtures containing ORBITON HiMA. The number and type of rollers, and the number of passes may be increased and the final parameters should be selected in a test section, considering the layer thickness, ambient temperature and type of the asphalt mixture. A key factor to be considered is the temperature of mixture production and placement according to table 7.1.

It may be necessary to increase the number of rollers for the placement of ORBITON 25/55-80 HiMA and ORBITON 45/80-80 HiMA, in particular if there is a sudden drop in the mixture temperature at the site (autumn).

Note: during compaction, the mixture may behave in an elastic way in the layer and move slightly under the weight of the rollers, especially in the first phase of compaction at high temperatures.

After the completion of the paving, it is recommended to clean the equipment promptly (spreaders in particular) to remove residual mixture when it is still hot.

### 7.8. Acceptance tests

The same testing methods as for standard binders are used for the acceptance of asphalt mixture courses with ORBITON HiMA.

Where the inspection includes the determination of polymer content in the recovered binder, it should be noted that the result may be less precise if the polymer content is high.

## 8. SECTIONS WITH ORBITON HiMA

Since 2013, a number of road sections with ORBITON HiMA binders have been paved in Poland. The application has offered new and sometimes surprising experience both to contractors and ORLEN Asphalt experts, demonstrating that ORBITON HiMA with reversed polymer-binder phase actually are a new type of binders. In 2013-2014, the binder was only applied for experimental sections, however since 2015 the number of road sections where ORBITON HiMA was used has exceeded 70.

Fig. 8.1. shows the current map of ORBITON HiMA binder application for various road projects in Poland.

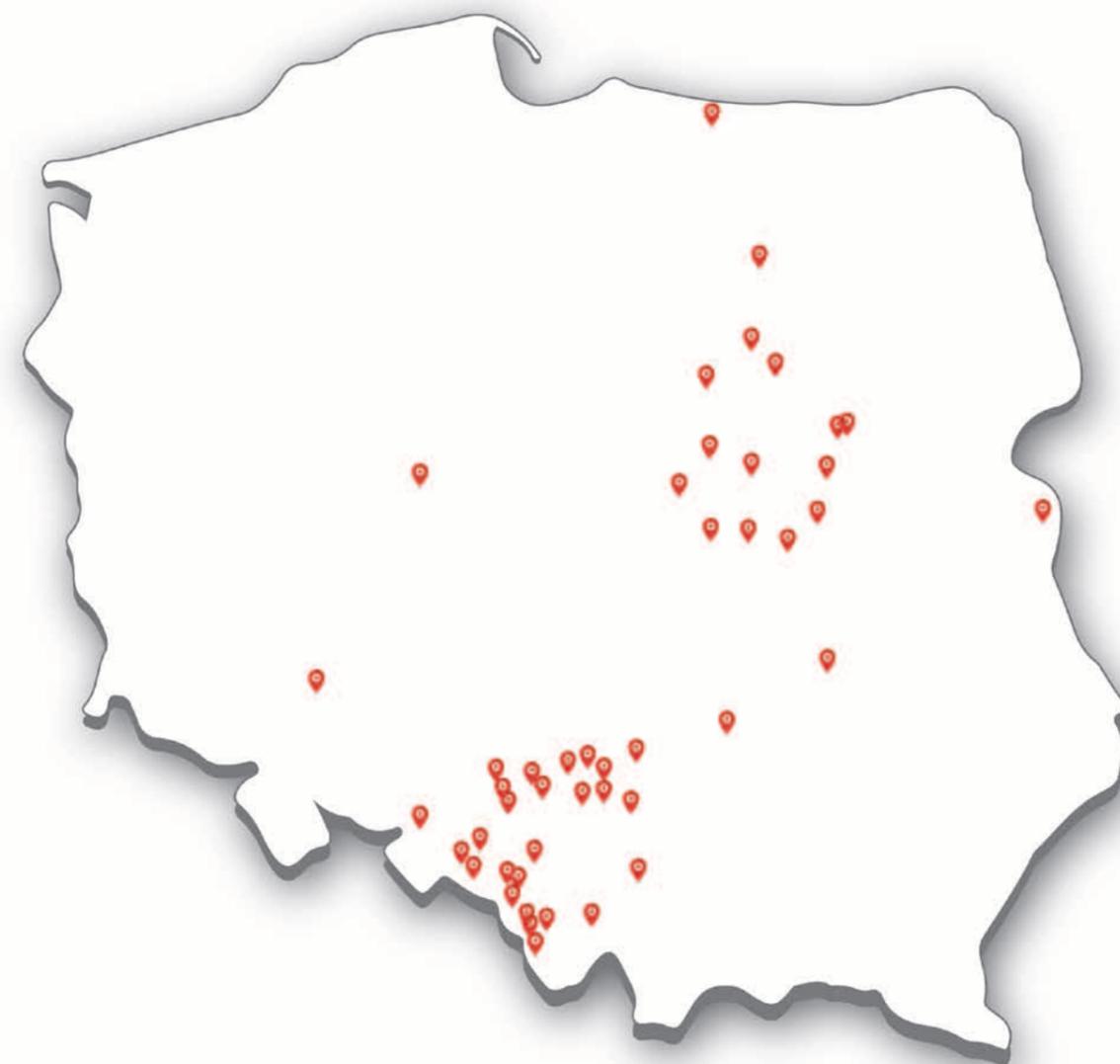


Fig. 8.1 Locations of ORBITON HiMA applications in 2013-2018

## 9. FINAL NOTES

ORBITON HiMA binders represent an important step towards more durable asphalt pavements. The range and number of road sections where ORBITON HiMA was used and the diversified methods for the application of HiMA binders clearly help gather valuable technical and practical information.

Even though the use of HiMA binders currently requires a special process regime, careful designing of the mixture and understanding of the working characteristics of the material, we are confident that the future for HiMA looks bright.

Tests described in this publication were performed by

- ORLEN Laboratorium S.A. (accredited with Polish Accreditation Centre (PCA) under No AB 484, Płock, Poland, and laboratory accredited with PCA No AB 496, Trzebinia, Poland);
- Research Institute of Inorganic Chemistry, Inc. (Unipetrol výzkumně vzdělávací centrum, a.s. UniCRE), Litvinov, Czech Republic;
- Gdańsk University of Technology, Civil Engineering and Environment Faculty, Gdańsk, Poland;
- Road and Bridge Research Institute, Warsaw, Poland;
- Road Laboratory Wojciech Bogacki, Rzgów, Poland.

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## INFORMATION ABOUT THE COMPANY

ORLEN Asphalt Sp. z o.o is a member of ORLEN Group and one of leading bitumen providers for road applications in Poland and Central Europe. We supply our Customers with top-quality products, as proven by numerous industry awards and distinctions. Since October 2012, ORLEN Asphalt has been the sole shareholder of a Czech company ORLEN Asphalt Česká republika, formed as a result of the acquisition of all shares in Paramo Asphalt, selling bitumen manufactured in Litvinov and Pardubice.

### Management of ORLEN Asphalt Sp. z o.o.



Marek Pietrzak  
President of the Management Board



Maciej Jankiewicz  
Member of the Management Board

### Our objective

We make efforts for the slogan „We drive the future by supplying top-quality bitumen” to apply to all aspects of our business. Our Customers are provided with both unrivalled product and service quality, as well as top customer service standards, including technical support.

### A solid brand

As an expert in asphalt pavements, we have been developing our business and designing new products for many years based on the knowledge of the industry’s top specialists. We are an innovative company not only to meet the market requirements and expectations, but also to stay ahead of them and create progress. As the first ones in Poland, in October 2013 we executed a test section using highly modified bitumens. A year later, the highly polymer-modified binders under the trade name of ORBITON HiMA were officially introduced to ORLEN Asphalt’s portfolio. The product was awarded the gold medal during the 20th International Road Construction Fair Autostrada-Polska, and received the prize of Leader of Innovation for 2015 in the Diamonds of Polish Infrastructure competition. Our business also comprises various research in the scope of assessment of properties and new applications of products offered by the company. In this field, we cooperate with numerous academic and research institutions. We additionally provide technical assistance to our Customers in the scope of bituminous binders covering the selection, properties, and applications. We are a modern and Customer-oriented company, and therefore, we endeavour to adjust both our objectives and actions to the needs of the market and road construction companies.

## Our products

As ORLEN Asphalt Capital Group, we supply road bitumens, modified and industrial, from five production sites located in Poland (Plock, Trzebinia), the Czech Republic (Pardubice, Litvinov), and Lithuania (Mažeikiai). We manage a total annual production capacity of 1.5 million tonnes of bitumen. In the year 2018, as part of the bitumen segment of ORLEN Group, we achieved record-high sales of 1.45 million tonnes while delivering our products to 44 countries around the world, including 20 in Europe.

## AUTHORS



### **Krzysztof Błażejowski, Ph.D. Civ. Eng.**

Graduate of the Civil Engineering Faculty at the Warsaw University of Technology (1992). Ph.D. in Civil Engineering at the Kielce University of Technology (2008). Author of over 100 publications, papers and books on bituminous binders and asphalt pavements. Director of the Department of Research and Development at ORLEN Asphalt. Road Pavement Expert of the Association of Polish Transportation Engineers and Technicians (SITK RP).



### **Marta Wójcik-Wiśniewska, M.Sc. Chem. Eng.**

Graduate of the Faculty of Chemistry at the Silesian University of Technology in Gliwice (2011). Specialises in testing methods of bituminous binders. Her additional area of interest is research in rheology and low-temperature properties of bitumen. Staff member of the Department of Research and Development at ORLEN Asphalt.



### **Wiktoria Baranowska, M.Sc. Chem. Eng**

Graduate of Chemical Technology at the Warsaw University of Technology (2018). Specialises in bituminous binder research. Her primary area of interest is high-temperature properties and colloidal stability of binders. Staff member of the Department of Research and Development at ORLEN Asphalt.



### **Przemysław Ostrowski, M.Sc. Civ. Eng.**

Graduate of the Civil Engineering Faculty at the Warsaw University of Technology (2012). Specialises in research on asphalt mixture properties and in the engineering of asphalt layer properties to design and develop durable and safe asphalt pavements. Staff member of the Department of Research and Development at ORLEN Asphalt.

## RESEARCH AND DEVELOPMENT DEPARTMENT

Corporate unit of ORLEN Asphalt. Active from the company's foundation in 2003. The RDD performs research and development work related to bituminous binders and asphalt mixtures, deals with technical marketing, new technologies and application of new materials.

It offers technical consultancy to company customers as regards the application of bituminous binders manufactured by the company.

The RDD's achievements include patent applications, gold medal received at the International Warsaw Invention Exhibition IWIS 2007 (BITREX multigrade binder), and the prize awarded by the Polish Minister of Science and Higher Education for achievements in the area of inventions (2007). In 2016, ORLEN Asphalt was awarded the Leader of Innovation prize in the Diamonds of Polish Infrastructure competition for ORBITON HiMA highly modified binder.



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