The effect of VIATOP® plus FEP on the stiffness and low temperature behaviour of hot mix asphalts

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Abstract

The trade-off regarding stiffness and low-temperature behaviour of hot mix asphalt (HMA) mixes is well known – the higher the stiffness of an asphalt mix is, the lower its relaxation during fast cooling down in winter, resulting in thermal cracking at higher winter temperatures. The accumulated tensile stress together with the stress deriving from heavy traffic load leads to severe transverse cracking of the pavement. The German company J. Rettenmaier & Söhne has developed several fibre based pellet additives in its research laboratories in Germany. The most commonly used pellet product is used for stone mastic asphalt mixes to prevent the binder drain-down from the surface of the aggregates.
An innovation of the company presented in 2014-2015 was a new type of additive named VIATOP® plus FEP (*Functional Elastomer Pellet*), consisting of approx. 20% special cellulose fibre and 80% elastometric additive. This new type of pellet is designed for HMA wearing courses of heavy duty roads, improving pavement performance through superior binder properties. VIATOP® plus FEP is probably a competitive of common modified binders regarding performance versus price and simplicity in its application. It is expected to improve stiffness of the mix while somewhat improving low temperature behaviour as well.
As there is little chance of the selected modifications to decrease fatigue life, it is assumed to be at least adequate in all cases and no need to be analysed. Low and high temperature behaviour, however, is a challenge to all modifications. In our research stiffness and low-temperature behaviour of three asphalt mixes were tested and compared: one with polymer modified bitumen and one with the new additive, together with a standard mix used for reference. Plastic deformation at high temperature is tested according to EN 12697-22 using small wheel tracker, low temperature cracking is tested using equipment developed at the laboratory of the BME Department of Highway and Railway Engineering, according to EN 12697-46 *Thermal Stress Restrained Specimen Test* (TSRST) method, and stiffness using test method C of EN 12697-26, *Indirect Tensile strain on Cylindrical Specimen* (IT-CY). Stiffness was measured at different temperatures to obtain a more comprehensive picture of the mixes. To make the research more interesting the chosen mix contains approx. 10% reclaimed asphalt according to endeavours of sustainability in the asphalt industry.
Based on the results, the manufacturer's estimations on mix performance and some prior tests made in Germany an evaluation was made on a mix commonly used in Hungary. The benefits of the selected modifications were compared to each other and the results are presented and evaluated.
Keywords: Hot Mix Asphalt, VIATOP® Plus FEP, additives, stiffness, low temperature behaviour, asphalt mix modification.
Kulcsszavak: aszfaltkeverék, Viatop® Plus FEP, adalékszer, merevség, hidegviselkedés, modifikált aszfaltkeverék

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1. Introduction

Since weather conditions and road traffic, especially road freight became more and more extreme there is a constantly increasing demand for higher performance asphalt mixes.

Worldwide road administrations, being always in the lack of funds, are seeking methods and materials to build pavements with higher quality, durability, lower upkeep needs, in one word - improved life cycle. Performance of pavement structures depends highly on the quality of its components, especially the type and quality of the binder which essentially determines the most important properties of the asphalt mix.

In this respect there are various modification technologies available and there are ongoing researches to develop new methods. The most frequently used technique is to modify the binder itself (modified bitumen) using various polymers, or e.g. using recycled rubber recently. Results lead to improved binder quality at a given, or maybe at even multiple temperature levels.

Additionally to the growing need for structural performance, the need for new techniques and materials is also increased due to the experienced uncertainties in supply and in prices of the most commonly used polymer-modified binders in the past few years. There are ongoing researches to study the effects of various modifiers on the properties of the binders [1, 2], or the effects of certain fillers on the performance of the asphalt mastic [3, 4]. There are numerous researches which involve methods to improve the performance of the pavement structure itself, using structural improvements [5].

A known issue for Stone Mastic Asphalt (SMA) mixes is the possible drain off of binder from the aggregate due to the gap-graded composition, despite the high (around 20%) fine aggregate content, resulting in inadequate mix quality. This problem is commonly solved by the use of various additives, e.g. the VIATOP® products manufactured by the company J. Rettenmaier & Söhne in Germany, which apply a fibre stabilizing effect. Ongoing research at the company has led to a similar, but novel cellulose-based additive presented in 2014-2015, which is designed to improve asphalt mixes. The new additive is the VIATOP® Plus FEP (Functional Elastomer Pellet). The greatest advantage of this additive is that it may be added directly to the mixing drum during production, thus actually modifying the asphalt mix itself, rather than modifying the binder prior to mixing [6]. This is a useful application as modified binders often require special storage conditions, in some cases even continuous mixing and heating, and often can only be purchased in high volumes from the manufacturer. The possibility of producing smaller volumes, to reach higher independence from binder manufacturers, and competitive prices are all important in the asphalt industry. However, the performance of such mixes must, at a minimum, reach the performance of mixes made with normal or polymer-modified binders.

VIATOP® products were tested in Germany on asphalt mixes to study the performance of the additive, but common mixes used in Hungary were not studied so far.

In the present research, the Indirect Tensile strain on Cylindrical Specimen (IT-CY) stiffness, cold- and warm-temperature behaviour of asphalt mix made with normal bitumen, a mix modified with VIATOP® Plus FEP were tested, with a comparison to a mix made with polymer modified bitumen. The goal of the studies was to find if the properties of asphalt mixes using VIATOP® Plus FEP additive can reach that of conventional mixes made with polymer-modified binder, apart from the several technological advantages, and competitive price attributed to the additive.

2. Materials

The manufacturer recommends the additive primarily for improving wearing courses, thus the tested mix was chosen to be AC11 wear (F), a commonly used wearing course mix in Hungary. During the research it was assumed that a modified mix would probably have better results than a conventional mix made with B50/70 binder. Therefore, three mixes were tested: one made with B50/70 normal binder, one made with VIATOP® Plus FEP additive, and one made with polymer-modified B50/70 binder, PmB 25/55-65. For comparison, one mix containing reclaimed asphalt material was studied as well.

2.1. VIATOP® Plus FEP additive

The additive contains 20% ABROCEL® cellulose fibre and 80% elastomer, and its density is 1.2 g/cm³. The additive is available in grey coloured pelletized, cylindrical form (3-20 × 3-6 mm size) with about 280 kg/m³ density. Breakdown temperature is about 200°C, maximum recommended mixing temperature is 170°C. The VIATOP® products obtained Hungarian Construction Technical Approval in transportation construction in 2011 (ÉME 16/2011).

2.2. Binders

Properties of the binders were tested as well since the goal of the research was to determine the effects of given modifications. Although VIATOP® additive is designed to modify the asphalt mix itself, eventually it dissolves in the binder. Using wet method, it is possible to modify the binder with the additive under laboratory conditions, and perform conventional rating tests. Results are shown in *Table 1*.

Test	B50/70	B50/70 + VIATOP® Plus FEP	PmB 25/55-65
Softening point [°C]	50.2	65.4	78
Penetration [0.1mm]	55	32	32

Table 1. Softening point and penetration of base binders and binder modified with VIATOP® Plus FEP
1. táblázat A referencia és a modifikált kötőanyagok lágyuláspontja és penetrációja

It can be seen in *Table 1*, that modification with VIATOP® Plus FEP results lower softening point for the same penetration of the polymer-modified bitumen, which suggests better warm-temperature behaviour.

2.3. Aggregates

Normal aggregates commonly used in Hungarian asphalt mixes were used in the studies. The reclaimed asphalt was of high quality, graded, properly and selectively stored, originating from AC11 wearing course. Its soluble binder content was 5.5 m%, density was 2.793 Mg/m³.

2.4. Mixing ratio

The composition of the mixes, complying with current Hungarian standards, is shown in *Table 2*.

Component	„A" AC11 wear (F) 50/70	„B" AC 11 wear (mF) 50/70 + VIATOP® Plus FEP	„C" AC 11 wear (mF) 25/55-65
Aggregates [aggregate mass%]			
Filler (Dorog)	4.0		
NZ 0/2 limestone, Iszkaszentgyörgy		14.0	
NZ 0/4 basalt, Uzsa	16.0		
NZ 4/8 basalt, Uzsa	29.1		
KZ 8/11 basalt, Uzsa	27.0		
11 RA 0/10 Reclaimed asphalt, Győrújfalu	9.9		
Binders [mix mass%]			
B 50/70, MOL	4.6%	4.6%	-
VIATOP® Plus FEP	-	0.9%	-
PmB 25/55-65, MOL	-	-	4.6%

Table 2. Composition of the studied mixes
2. táblázat A vizsgált keverékek összetétele

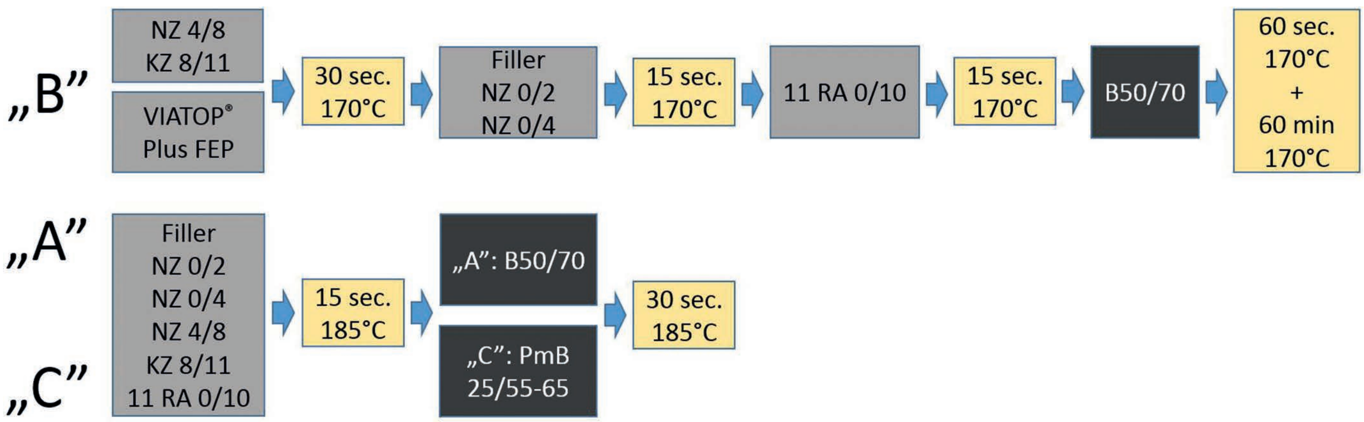

Fig. 1. Mixing sequence of mixes A, B and C
1. ábra Az A, B és C jelű keverékek keverési sorrendje

3. Laboratory mixing

Regarding the mixing procedure, mixes *A* and *C* needed attention only for the proper use the reclaimed asphalt. In case of mix *B*, besides the use of reclaimed asphalt, extra mixing steps were required to mix the additive properly in dry mixing.

3.1. Adding the reclaimed asphalt

Although a study about recycling of asphalt mixes [7] concluded that the technique of adding reclaimed material to the mix may have a great impact on the performance of the mix, the European practice in this topic is considerably diverse [8].

To achieve appropriate bond between the aged bitumen in the reclaimed material and the newly added bitumen, and to ensure the adequate blending of the materials, it is critical to determine the proper mixing sequence and the mixing temperatures. The determination of the dry mass of the reclaimed material was also a challenge, since the material may become gnarly at high temperatures, and the same time water must get evaporated to get a dry mass. It was found that at about 60°C it is possible to dry the reclaimed material and maintain its granulated form.

It was found by numerous literature reviews that the optimal mixing sequence is to first homogenise the coarse aggregate with the reclaimed material, and only add the binder during the last step. According to a questionnaire in [7], 17 out of 23 Western-European asphalt laboratories apply this technique, and in 3 cases they mix the reclaimed asphalt with the binder first, and then add it to the previously homogenised coarse aggregates.

Mixing temperature is also important, since the aged binder may be damaged and easily oxidised during mixing at high temperatures otherwise optimal for normal binders. If the mixing temperature is low then proper bond cannot form between the aged and new binder. If the mixing temperature is optimal then aged binder is not damaged, and forms a good bond with the new bitumen. If the mixing temperature is high then both the aged and even the new bitumen may get burned.

3.2. Adding the VIATOP® Plus FEP additive

The greatest advantage of VIATOP® Plus FEP additive is that it may be added directly to the aggregate at the mixing plant. Thus it does not require special feeder, storage, pre-heating, and makes mixing more independent of the bitumen provider.

In order to obtain mix quality as close to the mix made at a mixing plant as possible, dry mixing in the laboratory was applied during which the distribution of the pelletized material is done by dry-mixing it only with the aggregate. To minimise the loss of dust of the aggregate during dry mixing, only the coarse aggregate was used for this purpose.

The manufacturer suggests heating the aggregate and the additive to 170 °C while mixing, and continuing mixing for 15 sec while maintaining 170 °C. The hot binder may then be added, and further mixing is required for about 105 sec to gain complete homogenisation. If the mixing time is short then the pellets are not distributed properly, thus the cellulose fibres are not able to bond with the binder, and modification does not take place. If the mixing time is optimal then pellets can crumble, fibres are separated and homogenised with the aggregate, no caking and additive-free parts remain, and the additive makes bond with the bitumen. If the mixing time is long then cellulose fibres may be damaged or broken, such changes will hamper the success of modification.

Optimal mixing process depends on the mixer properties and its performance. To obtain optimal blending, multiple mixing times were tested, sieving after each step, and observing the condition of the additive. It was found that optimal dry mixing time for the additive under laboratory conditions is about 30 sec.

3.3. The mixing sequence

The usual mixing technique is needed to be modified to achieve proper dissipation of the VIATOP® Plus FEP additive, and the proper adding of the reclaimed asphalt. The developed mixing sequence for this case is shown in *Fig. 1*.

Marshall density of the specimens were determined to make sure the only relevant difference between the mixes is the binder type (see *Table 3*).

Table 3 shows that a somewhat better compaction can be achieved with the polymer-modified mix, while the density of the mix modified with VIATOP® Plus FEP is about 0.5% lower than that of the reference mix that can be considered irrelevant, since the dose of the additive is 0.9 m%.

Mix	Specimen	Density [Mg/m³]	Avg. density [Mg/m³]
„A" AC11 wear (F) 50/70	A1	2.493	2.490
	A2	2.499	
	A3	2.483	
	A4	2.491	
	A5	2.486	
	A6	2.485	
„B" AC11 wear (mF) 50/70 + VIATOP® Plus FEP	B1	2.470	2.476
	B2	2.470	
	B3	2.479	
	B4	2.466	
	B5	2.486	
	B6	2.484	
„C" AC11 wear (mF) 25/55-65	C1	2.487	2.495
	C2	2.492	
	C3	2.503	
	C4	2.503	
	C5	2.487	
	C6	2.500	

Table 3. Density of the prepared specimens
3. táblázat Próbatestek testsűrűsége

4. Laboratory tests

The viscoelastic behaviour of asphalt mixes and asphalt pavement structures is rather complex and is strongly dependent on temperature and load history (frequency) [9]. Asphalt mixes are usually tested for typical failure modes, which occur at typical temperature ranges:

- at low temperature the thermal crack resistance,
- at normal temperature the stiffness and fatigue failure,
- at high temperature the plastic deformation resistance.

Fatigue was not tested during this study since Hungarian fatigue criteria is not governing parameter for most of the mixes. Cracking temperature was tested on four specimens for all mixes, stiffness was tested on six specimens for all mixes at different temperatures to obtain more comprehensive results, and plastic deformation was tested on mixes *B* and *C* on two specimens for the mixes.

4.1. IT-CY stiffness

Stiffness of the asphalt mixes is one of their most important feature, as it determines the ability of the material to resist loads and deformations. Stiffness depends highly on temperature and varies with depth from the surface in a pavement structure [10]. The effect of stiffness on fatigue performance and thus service life of a layer has also been shown [11]. Stiffness should be interpreted together with the testing temperature and should be tested at different temperatures [12]. The stiffness tests were carried out at 20 °C according to European standard EN 12697-26 and at further three temperature levels (10 °C, 30 °C, 40 °C). Results are shown in *Fig. 2*.

Stiffness at 20 °C shows higher values than usually found due to the stiffening effect of the aged bitumen added with the reclaimed asphalt. As it was expected, the modified mixes have higher stiffness. At high temperatures, however, the mix made with VIATOP® Plus FEP had the highest stiffness: stiffness is only 6% higher at 10 °C than that of mix *A*, but 90% more at 40 °C. It means that this mix loses less of its stiffness with the increase of temperature. Accordingly, a more favourable performance is expected at plastic deformation tests, carried out at 60 °C.

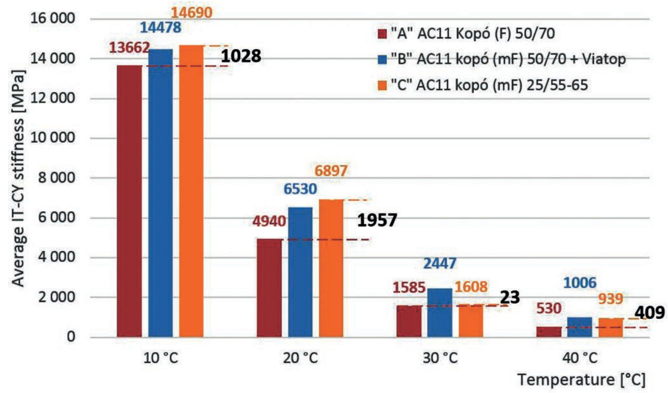

Fig. 2. IT-CY stiffness in function of test temperature for all mixes
2. ábra A vizsgált keverékek IT-CY merevsége a hőmérséklet függvényében

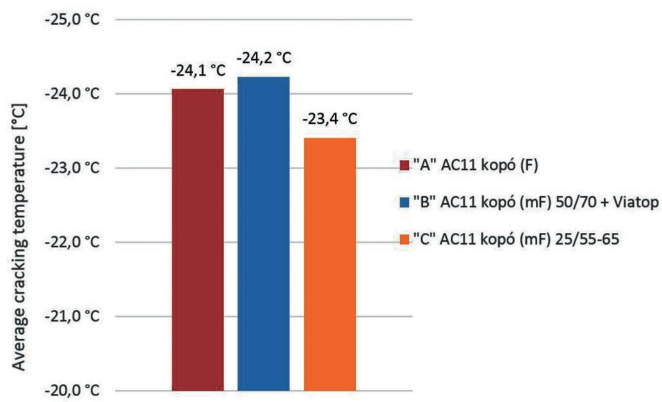

Fig. 3. Average cracking temperature for all mixes
3. ábra A vizsgált keverékek repedési hőmérséklete

4.2. Low temperature behaviour

The laboratory of BME Dept. of Highway and Railway Engineering is the only laboratory in Hungary capable of testing low temperature cracking of asphalts. The equipment – although its development started in the 80s [13] – is fully compatible with the Thermal Stress Restrained Specimen Test (TSRST) method described in European standard EN 12697-46. This test has relevance for fast winter cooling downs during which the relaxation of the asphalt mixes is lower than the increasing thermal stress, due to the higher stiffness of the binder (thus the mix). The slowly accumulated thermal stress is able to form transverse cracks in the pavement structure. The stress deriving from heavy traffic loads results in an even higher tensile stress [14]. The load induced stress and the thermal stress together reach the tensile strength of the material faster that leads to thermal cracking. However, thermal stress alone is also capable of reaching the tensile strength, and the test of EN 12697-46 relates to this phenomenon.

During the test a moderate winter is modelled with a constant -10 °C/h rate of cooling. The thermal stress is accumulated in the specimen (50×50×250 mm) due to physical restraints which allow no thermal shrinking. As the stress reaches the tensile strength of the specimen, cracks are forming, and the temperature at which this occurs is called cracking temperature. Averages of results for the 4 specimens for each mix are shown in *Fig. 3*. Lowest cracking temperature is achieved by mix *B* made with VIATOP® Plus FEP additive.

4.3. Plastic deformation

Both mixes *B* and *C* were tested for plastic deformation since high stiffness was found at high temperature for mix *B*. The temperature of the pavement on hot summer days may exceed even 60 °C and plastic deformation can be critical. At this temperature, the material deforms at a low level of stress, the pavement usually does not crack and there is usually no fatigue damage either. However, due to its viscoelastic properties, only a small part of deformations is elastic, and large part is plastic, which accumulates and and results in rutting.

Tests were performed according to EN 12697-22 small wheel tracking, for both *B* and *C* mixes. Results are shown in *Fig. 4*. According to the expectations drawn from the stiffness evaluation, results of mix *B* made with VIATOP® Plus FEP were somewhat better, tested on two specimens. Mix *A* was not tested.

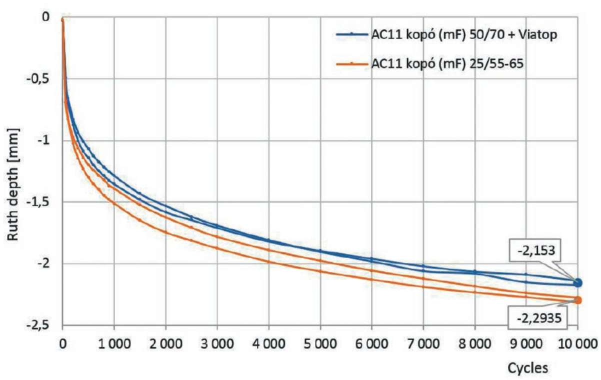

Fig. 4. Plastic deformation in function of load cycles, for mixes B and C
4. ábra Plasztikus deformáció a terhelési ciklusok függvényében (B és C keverék)

4.4. Relationship between stiffness and low-temperature behaviour

The higher is the stiffness, the lower is the relaxation capability of the asphalt mix, which results in faster accumulation of thermal stresses. It is known, that most modifications are designed and capable in improving performance at a given temperature range, only few hybrid-modifications are capable of improving the performance of mixes in a wider range of temperature. This means that the effects are lower at all temperatures. *Fig. 5* shows the stiffness and cracking temperatures of all three mixes tested.

Fig. 5 indicates that the stiffness and cracking temperature performance of the mix made with VIATOP® Plus FEP is better than that of mix *C* (made with polymer-modified bitumen), achieving higher stiffness and resulted in higher cracking temperature.

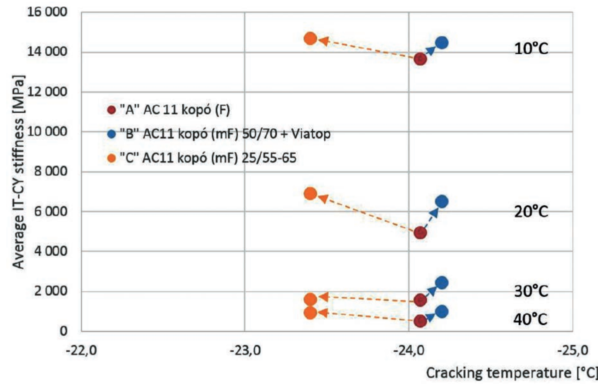

Fig. 5. Stiffness and thermal cracking temperatures for all mixes
5. ábra A vizsgált keverékek merevsége és repedési hőmérséklete

5. Conclusions

Test results of an innovative new asphalt additive have been shown. Accepting that modification would obviously lead to better performance of mixes, the additive was tested on the most commonly used modification in Hungary, a mix made with PmB 25/55-65 bitumen, together with a normal mix. To be able to find the effects of the binders and the modifications, all other components and techniques were the same for all mixes. For comparison, a mix containing 10% of reclaimed asphalt was also tested.

Due to the statistically low number of tests it cannot be stated that adding VIATOP® Plus FEP instead of any other modification would result in a better performance of the mix in all cases, however, it was shown that this additive is probably a true rival to the commonly used modifications. Further laboratory tests are required to reach statistical justification. The presented results indicated high possibility for the additive in improving mix performance, which should be verified on test tracks.

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