WARM MIX ASPHALT WITH FT ADDITIVE – RESULTS OF LABORATORY TESTS

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Abstract: Modern production and use technologies of asphalt mixtures using lower temperatures have many advantages. These advantages are mainly of ecological and energy saving matters. Lower temperatures enable reduction of energy consumption, more acceptable working environment for workers, reduction of negative environmental effects – greenhouse gas emissions, improvement in workability of mixtures and prolongation of working period with them. This technology is currently becoming popular in many countries. This article is focused on low-temperature technologies of asphalt mixtures using FT additive.

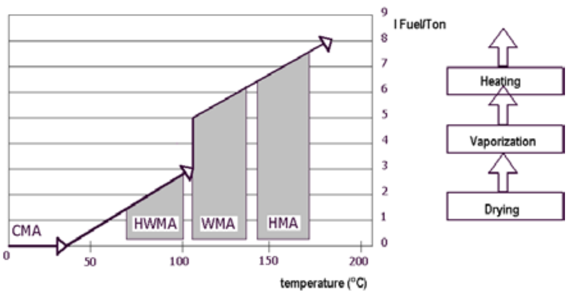
Keywords: warm mix asphalt (WMA), low-viscosity additive, asphalt binder, laboratory tests.

1 Warm mix asphalt

This technologie was first mentioned in Europe in 1995. In the year 2002 by the initiative of NAPA (National Asphalt Pavement Association) testing of these mixtures started in Europe, in the USA the practical testing was underdone under the supervision of technical working group established by US Ministry of Transport and NAPA. National Center for Asphalt Technology and various Universities were participated on this research. Consequently, as continuation, AASHTO (American Association of State Highway and Transportation Officials) and US Ministry of Transport moved the research to Europe. First public display was in the USA in 2004. In 2007, team of 13 American researchers has visited 4 European countries (Belgium, France, Germany and Norway) to collect theoretical and practical knowledge on this matter. Nowadays, warm asphalt mixtures are used in many countries all over the world such as China, Denmark, Italy, Malaysia, Russia, Sweden, Switzerland, South Africa, Great Britain and many others. [1], [2]

1.1 Advantages of WMA

As was mentioned before for the production of this type of asphalt mixtures is not necessary to have so high temperature as in the case of hot asphalt mixtures, which brings economical and ecological advantages. Picture No. 1 indicates connection between temperature and fuel amount needed for 1 tone of produced mixture and temperature scale for asphalt mixtures. Abbreviation HWMA (Half Warm Mix Asphalt) is used for transient asphalt mixture from cold mixtures CMA (Cold Mix Asphalt) to mixtures produced by higher temperatures WMA (Warm Mix Asphalt), abbreviation HMA (Hot Mix Asphalt) is used for mixtures produce by very hot temperatures. [1]



Pic.No.1 – Classification by temperature range, temperatures, and fuel usage are approximations

Main advantages:

- Production and working temperatures – with using various additives it is possible to reduce production and working temperatures on 20 to 55 °C. Temperature reduction offers the most satisfying conditions by mixtures laying and also for the workers.
- Working conditions – Regulation of the European Union REACH (Registration, Authorisation and Restriction of Chemicals) oblige every company to inform about and to register chemicals they use. Staff should have sound knowledge on chemicals they deal with and which can negatively impact their health. Asphalt binder is one of these chemicals. Reduction of production and working temperatures causes also reduces asphalt vapours - positive for working comfort. Measurement of evaporation, aerosols and polycyclic aromatic hydrocarbons in the production of warm mixtures shows lower values as in the production of hot mixtures, they are lower than limit values. Reduction is from 20 to 50 %.
- Advantage by laying – Between advantages connected with laying of asphalt mixtures can be included laying by lower temperatures still with required consistence, mixing time prolongation, use of larger amount of recycled material, possibility to compact the mixture by lower strength in standard conditions and prolongation of working season.
- Amount of emissions – Reduction of emissions depends on several factors (used aggregate, way of production, temperature reduction, used recycled material, aggregate moisture). On the basis of results from Belgium, France and Norway, with the use of warm mixtures comes reduction of production emissions. This reduction is closely connected to temperature. On the conference Bitumen forum was presented that by the temperatures under 80 °C no emissions are produced, by temperature 150 °C are emissions round 1 mg/h, more considerable amounts are produced only from 180 °C. Reduction of particular chemical compounds recognised from research: CO_2 (30 to 40 %), SO_2 (30 to 40 %), CO (10 to 30 %), (NO_x 60 to 70 %), volatile organic elements (50 %), dust elements (20 to 25 %).
- Fuel saving – fuel savings by WMA due to warming of the mixture is approximately on 11 to 35 % lower or can by also higher (to 50 %), this in the case of Low Energy asphalt or Low Energy asphalt concrete, where the aggregate is warmed to temperature below boiling point.

1.2 WMA Technologies

Selection of the technology depends on the temperature reduction and on the amount of the mixture which is aimed to be produced. Technologies of warm asphalt mixtures [1], [2] can be divided into technologies using:

- Technologies using waxes and organic additives – technology are based on viscosity reduction by wax warming above the melting point with the ensured mixing of mixture and by enabling the suitable laying. Melting point shall be higher than assumed service temperatures (permanent deformations) and shall minimize brittleness of asphalt by low temperatures. Waxes can increase the strength of asphalt; have lower penetration, higher resistance against high and low temperatures. Batching of wax depends on particular input materials of mixture and on road class where the mixture shall be used.
- Addition of chemical additives and agents – by use of chemical additives there is no change in viscosity of asphalt binder. In this technology ability of surface-active additives to thoroughly coat the aggregate with asphalt binder is utilized by lower temperatures. The additive reduces and regulates frictional force on the edge of binder and aggregate by temperatures between 140 °C and 85 °C. Temperature reduction necessary for production and compaction of asphalt will decrease on 20 °C to 30 °C depending of the type of additive.
- Water addition – technology is based on water addition to asphalt binder in the aim to foam it and by this to reduce the viscosity. The assumption is that added volume will change by

atmospheric pressure into steam, by which the volume of binder will increase and its viscosity will reduce during short time when the mixture is cooling. Consequently, the foaming will vanish and asphalt binder acts like binder without modification. Foaming of binder is done directly or indirectly. By direct foaming small amount of water is injected into warm asphalt binder by faming jets to achieve temporal increase of binder volume. Reduction of temperature is between 20 °C to 30 °C. Indirect foaming is done by the use of synthetic zeolits or moist aggregate. Zeolit is crystallised hydrated alum-silicate containing approximately 20 % crystalic water released by temperatures over 100 °C. Such released water causes foaming of binder and during 6 to 7 hours, if the temperature does not decrease below 100 °C, shall ensure required workability of mixture. Reduction of temperature necessary for production and compaction of mixture is approximately 30 °C.

2 Experimental verifying of characteristics

Experimental part of this research was focused on laboratory verifying of asphalt mixtures characteristics determined for sub-base layers of pavement, asphalt mixtures where the asphalt binder is modified by FT additive. Concretely it is mixture AC 22 P; I, used additive was road asphalt 50/70 modified by FT additive Sasobit. Monitored was the influence of various amount of additive on binder characteristics and influence of additive on mixture resistance toward permanent deformations, resistance to fatigue and stiffness modulus of mixture.

2.1 Influence of additive on asphalt binder characteristics

Realised laboratory testing were softening point [5], breaking point [9], penetration [4] and force ductility [10]. In all tests was investigated dependence between increasing amount of FT additive (1, 2 and 3 %) and comparative value (50/70).

From the results of penetration test (0,1 mm) and softening point (Ring and Ball test) (°C) is evident positive influence of FT additive on these asphalt characteristics. With the increasing portion of Sasobit there was consistent decrease of penetration approximately on 25 %, from the value 61,6 (0,1mm) to 46,2 (0,1mm). In the case of asphalt binder resistance against high temperatures the value of softening point is increasing from 52 °C to 74 °C, which means increase on 22 °C. In the case of asphalt binder resistance against low temperatures the additive has hardly any influence, but also it has no negative influence on this characteristic. In all cases the value of breaking point (Fraass method) is round -11 °C. Basic tests results of asphalt binder are in table No. 1.

Characteristics of asphalt binder Tab.No.1

Binder	FT additive (%)	Penetration 25 °C (0,1 mm)	Softening point (°C)	Breaking point (°C)
50/70	0	61,6	52	-11
	1	52,6	57	-10
	2	49,6	63	-11
	3	46,2	74	-11

Force ductility test serves for strain strength determination of asphalt binder. On the basis of experience, the initial temperature 15 °C was selected. Testing specimens were in this test prolong to prescribed value 40 cm, in no case was the testing specimens trimmed. Resulting values of cohesive energy are in table No. 2.

Resulting values of force ductility, 15 °C Tab.No.2

FT additive (%)	15 °C				
	E'_s (J)	E'_{20} (J)	E'_{40} (J)	E'_r (J)	E'_{20-40} (J)
0	0,133	0,803	0,932		0,122
1	0,102	1,596	1,878		0,281
2	0,142	1,862	2,129		0,267
3	0,163	2,251	2,792		0,541

2.2 Influence of additive on asphalt mixture characteristics

From the results of experimental verifying of interesting results came from resistance against permanent deformations and fatigue and determination of stiffness modulus.

2.2.1 Resistance against the permanent deformations

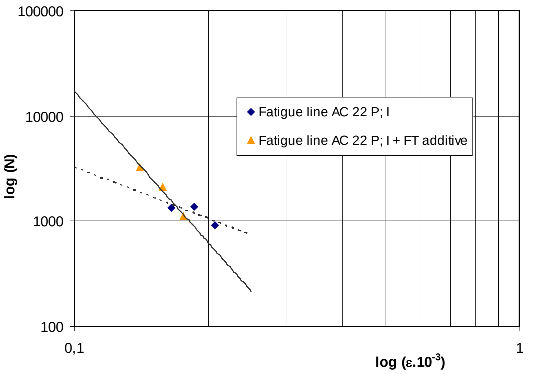
The resistance of asphalt mixture against the permanent deformation was determined with wheel tracking test, where the passage of vehicle on pavement is simulated. For this test was necessary to produce slab testing specimens. In the test was used small testing device and test was realised according correspondent standard, method B [6]. From the test were determined values of depth of tracked rut RD_{AIR} (mm), comparative depth of tracked rut PRD_{AIR} (%) and the slope of tracked rut WTS_{AIR} (mm/10^3 loading cycles). First assumption was that after addition of FT additive there will be continuous increase or decrease of temperatures. In the case of depth of tracked rut of mixture AC 22 P; I is the course of values decreasing. In the comparison with reference mixture the values of RD_{AIR} are decreasing from 3,5 to 1,8 mm. The same course is also by values of relative depth of tracked rut PRD_{AIR} (%). Standard states its maximal value as 5 %. This condition was fulfilled by all mixtures except reference mixture with PRD_{AIR} = 5,6 %. In the case of slope of tracked rut the satisfactorily were only mixtures AC 22 P; I with 3 % FT additive with the value 0,07 mm/10^3 loading cycles. According KLAZ [11] is maximal value for mixtures AC 22 P; I WTS_{AIR} = 0,10 mm/10^3 loading cycles.

Resistance against the permanent deformations Tab.No.3

Mix	Binder	RD_{AIR} (mm)	PRD_{AIR} (mm)	WTS_{AIR} (mm/10^3 l.c.)
AC 22 P	50/70	3,5	5,6	0,16
	50/70 + 1% FT	2,5	3,9	0,11
	50/70 + 2% FT	2,3	3,5	0,11
	50/70 + 3% FT	1,8	2,8	0,07

2.2.2 Resistance to fatigue

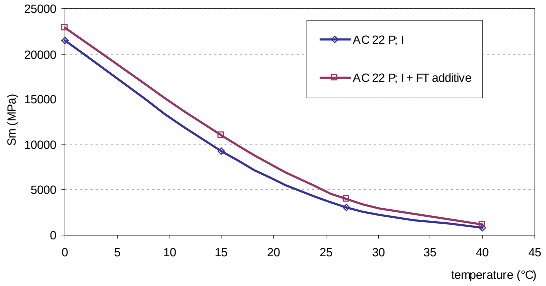
Fatigue can be defined as the loss of strength of asphalt mixture as result of repeated stress against the strength from single load. The test principle is in the repeated loading of test specimens by compression stress in the shape of sinusoids that causes the deformation [7]. This test was realised with the mixtures AC 22 P; I and AC 22 P; I + 3 % FT additive. Each mixture was subject of at least there levels of loading. From obtained values of loading impulses and developed vertical deformation were determined fatigue serviceabilities of mixture. Calculates values of horizontal tensile deformation served for drawing the fatigue envelopes and for determination of regression equations from which where material constants k and n determined. From the development of fatigue lines it can be stated that the longer serviceability can be assumed in the mixture AC 22 P; I + 3 % FT additive. This comes from the fact the steeper fatigue line the more cycles are needed for achieving certain value of strain. Development of fatigue lines are shown on picture No. 3.



Pic.No.3 - Fatigue resistance of WMA

2.2.3 Stiffness of asphalt mixtures

The value of stiffness modulus can be determined as the change of rheological characteristics of asphalt mixture by short time load. With the increasing value of stiffness modulus the resistance of mixture against affecting load is also increasing. Resistance against affecting load depends on stress and relative strain. Test was realised on roller testing specimens, by the test of indirect pull (IT-CY) [8]. This test was done on mixtures AC 22 P; I and AC 22 P; I + 3 % FT additive. As testing temperature were chosen 0, 15, 27 and 40 °C. With increasing temperature the values of stiffness modules of stated mixture decrease. The growth of stiffness modulus in mixture with FT additive is for example by 0 °C on 6,5 %, by 40 °C increase on almost 35 %. Resulting values of stiffness modules with the percentage formulation of increase of stiffness modulus in comparison with reference mixture are shown in table No. 4. Dependence between stiffness modulus and temperature is shown in picture No. 4.



Pic.No.4 - Stiffness modulus (MPa)

Stiffness modulus (MPa) Tab.No.4

Mix	Temperature (°)	Sm (MPa)	Increase of Sm (%)
AC 22 P; I AC 22 P; I + 3% FT	0	21499 22894	0 6,5
AC 22 P; I AC 22 P; I + 3% FT	15	9318 10978	0 17,8
AC 22 P; I AC 22 P; I + 3% FT	27	3049 3957	0 29,8
AC 22 P; I AC 22 P; I + 3% FT	40	865 1167	0 34,9

Conclusion

Rising and more and more recognizable production and use technologies of asphalt mixtures by lower temperatures represent the future in the field of production and use of asphalt mixtures. Technologies with lower energetic demands bringing many ecological advantages need to be recognised. Results of various experimental verifying show improvements of characteristics of binders modified with various additives and parameters of asphalt mixtures with these binders.

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