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Modified Asphalt Binder with Natural Zeolite for Warm Mix Asphalt

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Abstract

In recent years, warm mix asphalt (WMA) is becoming more and more used in the asphalt industry. WMA provide a whole range of benefits, whether economic, environmental and ecological. Lower energy consumption and less pollution is the most advantages of this asphalt mixture. The paper deals with the addition of natural zeolite into the sub base asphalt layers, which is the essential constituent in the construction of the road. Measurement is focused on basic physic – mechanical properties declared according to the catalog data sheets. The aim of this article is to demonstrate the ability of addition the natural zeolite into the all asphalt layers of asphalt pavement. All asphalt mixtures were compared with reference asphalt mixture, which was prepared in reference temperature.

Key words: warm mix asphalt, natural zeolite, temperature.

1 Introduction

The first technology of warm mix asphalt (WMA) was developed in the late of nineties. The ingredients have been tested in Germany and Norway by WAM-Foam technology. Figure 1 shows how technology WMA fit into a wide range of technologies, from cold to hot asphalt.

Cold mixtures are produced by mixing cold aggregate with bitumen emulsion or foamed bitumen. Half-Warm mix asphalt is made by mixing the heated aggregate and asphalt in the approximate temperature range of 70 - 100 °C. Warm mix asphalt (WMA) is produced in the temperature range 100 - 140 °C. Hot mix asphalt (HMA) is produced at a temperature of about 140 - 190 °C. Industrial temperature of the asphalt mixture depends on the asphalt.

This article describes the basic technology of WMA that used, and which have a manufacturing asphalt temperature above 100 °C. These mixtures have the same physic-mechanical properties than conventional hot mix asphalt.

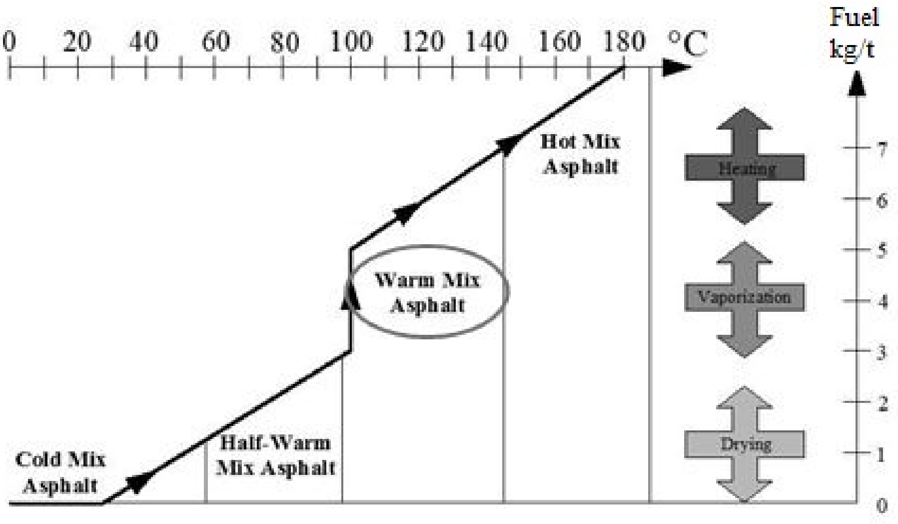


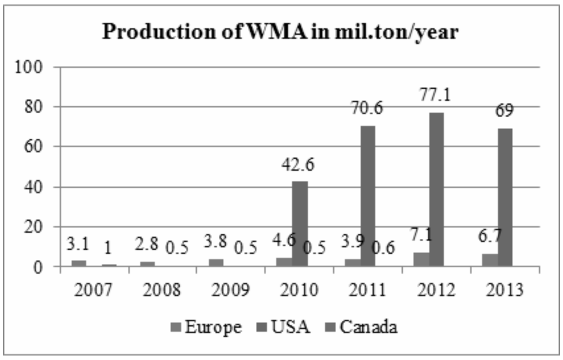
Figure 1: Classification by temperature range [1]

2 Technology of production of WMA

Technology of WMA cooperates at temperatures above 100 °C, so that the remaining quantity of water in the mixture is very low. To reduce of the effective viscosity of the binder are used different technologies to allow a complete coating and subsequent compactibility at lower temperatures. Most used technologies are based on:

- organic ingredients,
- chemical additives,
- foam processes [11].

Fig.2 presented graph of the development of production WMA in the world in recent years.



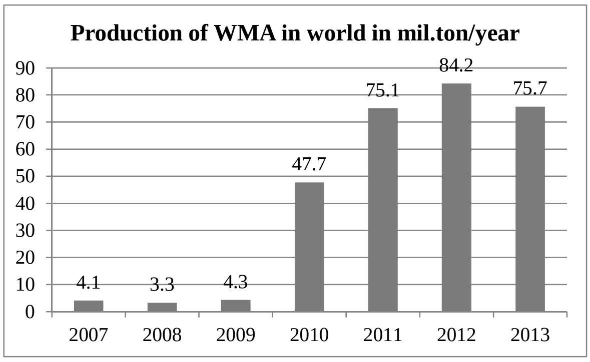


Figure 2: Production of WMA in world in recent years [2]

2.1 Technology based on foaming processes

This technology is based on the addition of a small amount of water to be injected either into the hot binder, or directly into the mixing chamber. If the water mixed with the hot asphalt, that the heat causes the water is evaporated. This creates a large amount of foam, which temporarily increases the volume and decreases the viscosity of the binder mixture. This effect is remarkably improved processability mixture, but its duration is limited. That is, the mixture has to be transported, compacted as soon after production. The amount of water should be just enough to occur foam effect, but not enough to cause problems for wrapping of aggregates. Although the basic process is the same for most of these products and technologies, the methods in which water is added to the production cycle can vary. That is, the foam process can be either water-based technology (technology direct method) or water containing (technology indirect method) [10].

Technology used in the world: Aspha-Min® a Advera® - both technologies work by a similar way. It is a finely powdered synthetic zeolite that has been hydrothermally crystallized. It contains approximately 20 % water of crystallization, that is released while the temperature above 85 °C. When the additive was added to the mixture at the same time as the binder, the water is released as water vapor and thus cause foaming of asphalt. The viscosity of the binder at high temperatures is reduced, thereby enabling reduction in production and laying temperature. These materials allegedly not affect the characteristics of the binder [3].

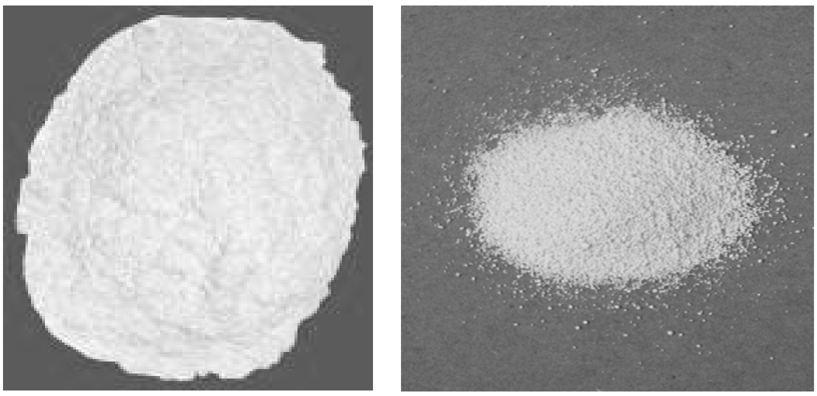


Figure 2: Synthetic zeolite fine powder and granulate

3 Natural zeolite

Zeolite is a crystalline hydrated aluminosilicate of alkali metals and alkaline earth metals. The uniqueness of the zeolite lies in the fact that the spatial arrangement of atoms creating channels and cavities of constant dimensions (see Figure 3). In these passages can be captured substances solid, liquid and gaseous.

The structure of clinoptilolite consists of three-dimensional grid which consists of silicate tetrahedrite $(SiO_4)_4$-. Each interconnected via oxygen atoms; the atoms of silicon is replaced by aluminum $(AlO_4)_5$-. It´s creating a characteristic spatial structure with a significant incidence of cavities, interconnected by channels, in which metal cations, or water molecules are stored. The total volume of these cavities is 24 to 32 %.

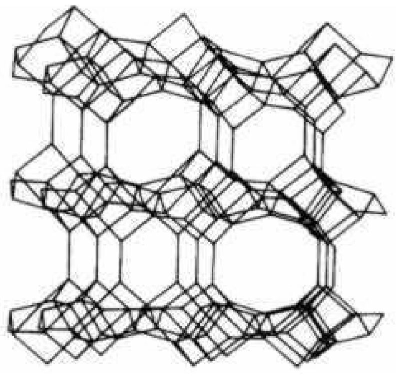


Figure 3: Structure of natural zeolite

The extensive uses of zeolites are mainly due to the specific physic-mechanical properties:

- high selectivity and ion exchange,
- reversible hydration and dehydration,
- high gas sorption capacity,
- high thermo stability,
- resistance to aggressive media [4].

For experimental measurements were used natural zeolites from site Nižný Hrabovec. A product of Zeocem 200 has the following chemical composition (see Table 1). Moisture adding zeolite was 6.3 % [12].

Table 1: Chemical properties of natural zeolite

Oxide	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O
Quantity (%)	66.97	10.61	0.24	1.72	0.03	2.90	0.73	2.96	0.68

4 Thermogravimetric test of natural zeolite

One of the basic methods of thermal analysis is thermogravimetry. According to EN ISO11358 thermogravimetry is called the process by which we measure the weight of the selected test sample as a function of time or temperature when the test sample is exposed to temperature program, which is under constant review. On heating, the test compound releases a gas component with the result that there is a weight loss of the sample. It may also occur a phenomenon which occurs on heating the substance to react with the gas and the sample weight is increased. The thermogravimetric analysis data are expressed as the percentage change in weight, or the resulting curve, which is dependent weight change as a function of temperature and the time. The mass and the temperature determine the thermogravimetric (TG) curve. Depending on how the sample is heated to divide thermogravimetry:

- isothermal (static) - in this method, the heating is performed at a constant temperature,
- non-isothermal (dynamic) - in this method, the sample is exposed to the continuously increasing or decreasing temperatures. Temperature is generally pushed up linearly with time.

Thermal stability kinetic method is most often used in the works to research the character, because this method allows you to very quickly get an overview of the cold substance and its overall temperature behavior. Curved line, which occurs in thermo gravimetric analysis reflects our weight changes depending on temperature. We also collect information on the composition of samples of products that we formed during decomposition of its thermal stability and also by thermal decomposition. The aim of thermogravimetric analysis (TGA) with a program increase of temperature is obtained curve that reflects our interdependence between weight gain or weight loss on temperature. Based on this curve, you can get a wealth of information and knowledge. It sets out the change in mass at constant pressure, constant temperature or linearly increasing temperature.

TGA analysis is used for diagnosis of:

- composition of the copolymers and blends - by TGA method we can believe in favorable conditions as those of the copolymer composition goes,
- analysis of the additive in the fibers and the polymer - physical and chemical properties of the fibers and the plastic is improved if added various additives,
- thermal stability of the polymers and their identification - for the same gas flow rate and the heating atmosphere, any polymer or fiber, and characteristics of their thermograph as possible the number of samples and the same geometry [5].

Natural zeolite sample area was exposed to TGA with a linear increase of temperature, and was exposed to 900 °C [6]. The loss in weight (Figure 4) recognizes that the zeolite contains in its crystalline structure, 8.52 % of water.

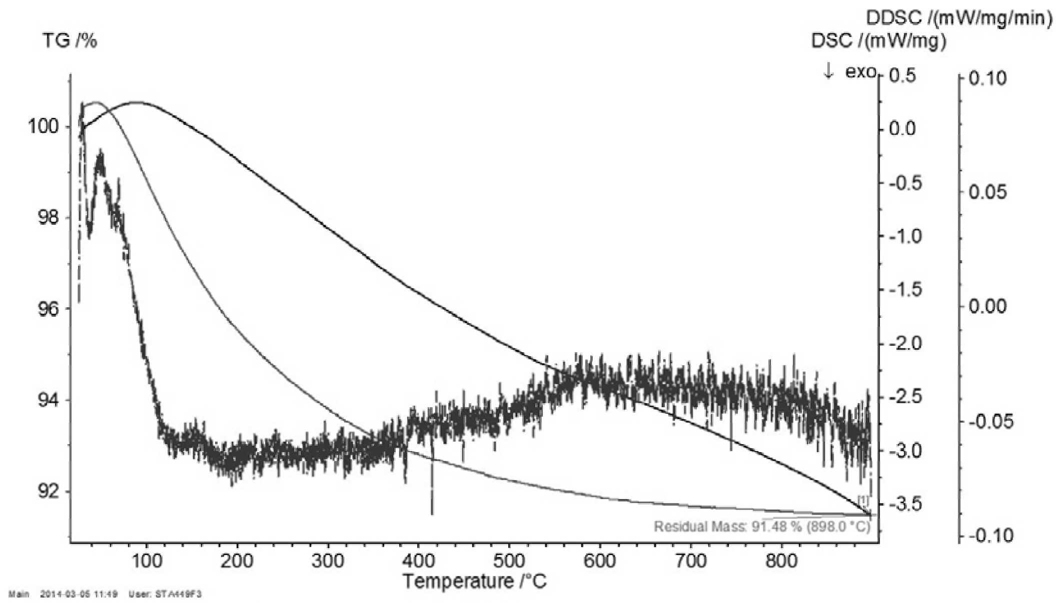


Figure 4: Thermogravimetric test of natural zeolite

By laboratory measurement has shown that the natural zeolite containing 6.3 % of water. The test was performed on three different batch size of zeolite. The test was performed in a laboratory. The samples were exposed to the zeolite at 100 °C to constant weight of the zeolite, after three successive measurements [7].

5 Natural zeolite as a low temperature additive in synergy with asphalt

Natural zeolite as an ingredient has been used product from the company Zeocem Bystré under the trade name ZeoCem 200.

The low temperature addition of natural zeolite was added to asphalt mixtures, together with a binder. To produce a foaming effect of asphalt was necessary to add zeolite with natural moisture [8].

For better declare the presence of zeolite in the asphalt mixture were carried out the tests necessary binding properties. Penetration test was conducted and the test binder softening point asphalt [9]. Were compared three different variants. The tests were performed on the reference CA 50/70 asphalt, and two variants with addition of natural zeolite. Zeolite was in a weight percentage of 0.3 % and 0.6 % of the total weight of the asphalt mixture.
In Figure 5 is displayed Penetration test binder.

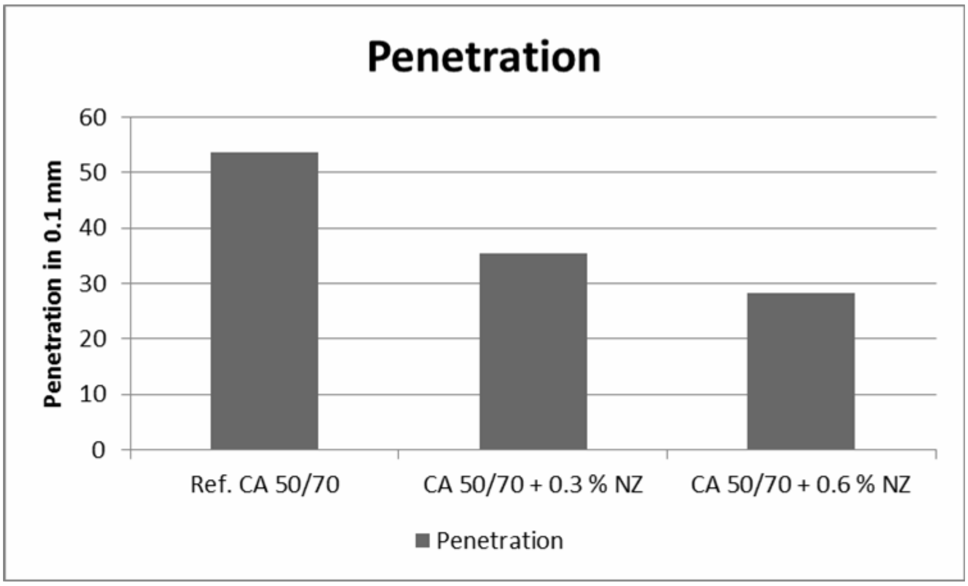


Figure 5: Penetration of asphalt binder

As appears from the measured values, the addition of natural zeolite in asphalt penetration of 50/70 CA decreases. With addition of 0.6 % of natural zeolite, the penetration is decreased below a 30 x 0.1 mm.

A second test was the test for determining the softening point ring and ball method. The test itself shows a very significant feature of bitumen. As in the first experiment were made to the same variations. In Figure 6 are shown the results of the test.

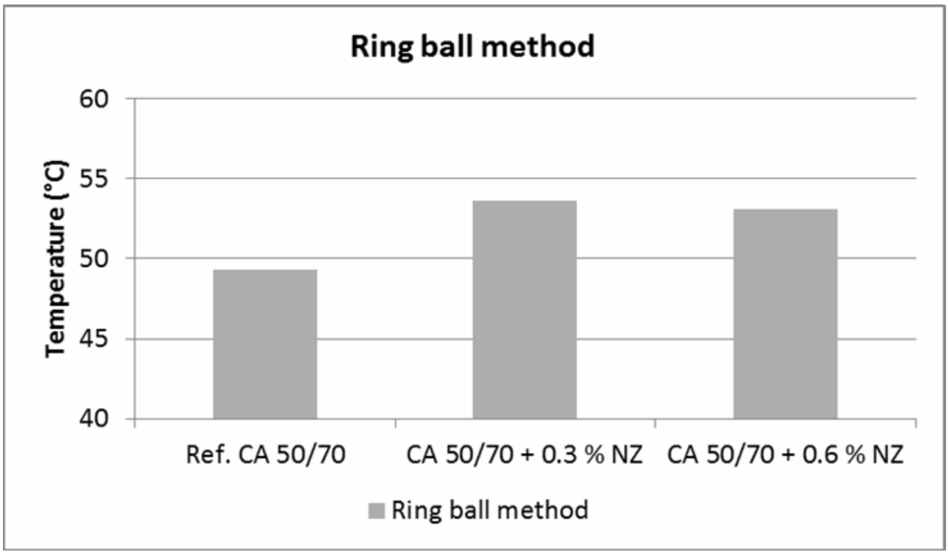


Figure 6: Determination of the softening point. Ring and Ball method

The results of this test suggest an improvement in asphalt properties with addition of natural zeolite. The values of the softening point are increased compared with the reference samples at 4 °C with the addition of 0.3 % of natural zeolite.

6 Conclusion

Warm mix asphalt is adequate substitute conventional hot mix asphalt. The results of laboratory measurements show that the asphalt mixture with the addition of 0.3 % of natural zeolite, has similar physical and mechanical properties as a hot mix asphalt compacted at elevated temperatures. Warm mix asphalt has a whole range of benefits, and it would be beneficial to put them into production. Further research should aim to determine more precisely the optimal value adding zeolite to asphalt mixture.

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