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Influence of wax additives on the properties of porous asphalts

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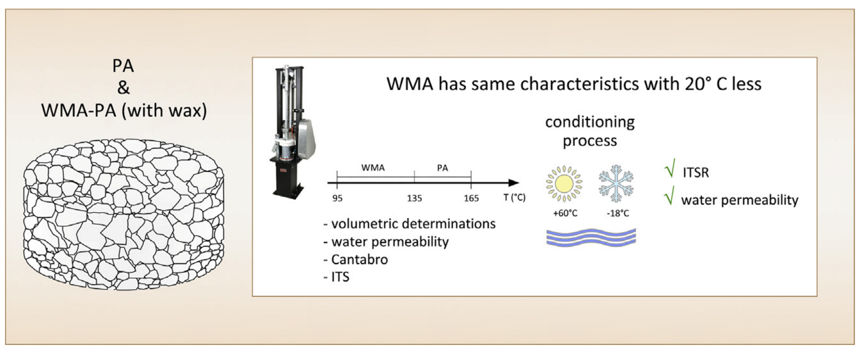
HIGHLIGHTS

- The WMA technology is applicable to porous asphalts in cold climates.
- WMA-PA samples have same density and voids than PA at −20 °C compaction temperature.
- With WMA, a given ITS_d level can be achieved with 25 °C lower compaction temperature.
- After conditioning, WMA-PA permeability decreases more than in traditional PA.
- ITSR is independent from preparation temperature; waxes worsen the ITSR results.

GRAPHICAL ABSTRACT



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ABSTRACT

An experimental work evaluating the application of Warm Mix Asphalt technologies to Porous Asphalts in severe cold climate is reported. Volumetric tests as well as water permeability, Cantabro and Indirect Tensile Strength tests were performed on samples of a selected porous asphalt, with and without the Sasobit wax. Mixing and compacting temperatures were varied during the tests. Permeability and ITS tests were repeated after a severe water/temperature conditioning process. In general, the results confirmed that WMA technology is applicable to porous asphalts in a cold climate, allowing the lowering of compaction temperatures by about of 20 °C without any significant decrease in performance.

1. Introduction

Modern Porous Asphalts (PA) are the result of more than 20 years of specific research aimed at increasing their drainage capability in order to increase traffic safety and environmental quality. Years and years of experience have shown their benefits including hydroplaning reduction, pollutant filtration, and excellent friction resistance [1]. Rolling noise is also significantly reduced [2]. All these benefits depend on the high void content (20% or greater) that characterizes these asphalts and on the void structure. As for the drainage, the larger the pores and the greater their connection, the higher the drainage capability [3]. To absorb noise at different frequencies, the voids must have variable dimensions [4]. To filter pollutants within the porous layer, the voids must be gradually reduced in the lower part [5]. To enhance skid resistance, the maximum grain size should be reduced so decreasing the void dimensions [6]. It is evident that many of these characteristics conflict with each other. All these factors provided the framework of needs that has led the research into these asphalts in recent years. Many porous asphalts have been produced in the

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recent past with the aim of balancing these various needs [7–9]. A specific porous asphalt was developed for this research in order to evaluate both the potential of draining rainfall and of noise absorption when combined with the use of Warm Mix Asphalt (WMA) technologies. This is a well known technology developed to deal with environmental and economic issues related to pavement construction.

This technique allows the production of asphalt mixes suitable for use at lower construction temperatures. WMA technologies improve mixture workability through the addition of organic, chemical, water-based, or hybrid additives [10–15]. These technologies work mainly by reducing the binder viscosity, which increases the ability to flow or pour the mixture. This allows the aggregates to be properly coated with asphalt binder at lower temperatures, thus reducing fuel consumption, lowering plant emissions and reducing energy costs by decreasing production temperatures by 30°–50° C in comparison to traditional hot mix asphalt (HMA). In addition, when applying WMA techniques in cold weather conditions, the increase in the workability of the material makes the drop of temperature with time less important as a result of the decrease in the viscosity of the binder. This also allows longer haulage distances, reduces the risk of compaction problems and requires less time to cool the laid material before opening it to traffic or laying the next layer [10].

The WMA technique also improves workability during construction by allowing the mixture to be properly transported, paved and compacted at lower temperatures, thus improving worker conditions through decreased smoke and odours [16].

The lower mixing temperatures may also reduce the aging of the binder leading to increased fatigue life [17]. Moreover, lower binder viscosities allow the use of higher percentages of reclaimed asphalt pavement (RAP) in WMA. This reduces the production of additional aggregate and binder [18].

The aim of this work is to evaluate how the advantages given by the use of this technique, in particular using the wax Sasobit, modify the physical and mechanical characteristics of the porous asphalt under study.

Many works on WMA technologies referring to the application of different types of additives have been published in the literature in recent years.

Zhao et al. [19] studied the effects of various warm additives on the rutting performance of traditional asphalt mixture with different binders and mixing temperature applications. Lowering mixing temperatures can increase the rutting susceptibility due to less aging occurring in the binder during mixing. The results indicated that the addition of warm wax additive can stiffen the binder and increase the mixture rutting resistance, while chemical additives do not soften the binder, nor do they stiffen the binder.

The study conducted by Capitão et al. [20] confirmed that resistance of WMA to cracking at low temperature is apparently generally good, but slightly lower than that observed for similar HMA. It appears that permanent deformation behaviour of WMA is highly dependent on how much the production temperature is lowered. For high levels of temperature reduction, WMA performance is consistently reduced. Sasobit wax additive seems to be the only one that does not follow this tendency, as the crystallisation of this wax improves resistance to deformation at high temperatures.

Several studies have also been conducted on porous asphalts. They mainly involved the investigation of mechanical properties of mixtures containing various additives. Almost all the works agree in suggesting that, due to the low mixing temperature, the mixtures are more prone to moisture damage. The moisture sensitivity of porous asphalt is of fundamental concern because the presence of water can affect both binder cohesion and adhesion between the bitumen and aggregate, causing accelerated stripping.

Hamzah et al. [21] investigated the stripping resistance of warm porous asphalt mixes by using a specially designed dynamic stripping machine. Porous asphalt specimens incorporating Sasobit wax additive were used and subjected to a strength test (indirect tensile strength ratio, ITSR) indicating that the dynamic action of water significantly reduces the resistance to stripping of porous asphalts.

Regarding the durability, abrasion resistance is also a parameter for investigating the moisture susceptibility. Hamzah et al. [22] used the Cantabro Particle Loss test as an indicator of cohesion for evaluating the stripping resistance of porous asphalt samples prepared with different additives and subjected to dynamic stripping machine conditioning.

Goh and You [23] (2012) characterized the mechanical properties of porous asphalt pavement mixtures containing reclaimed asphalt pavement (RAP) and a WMA additive. They found that WMA mixes containing RAP had ITS values significantly higher than mixes with RAP alone (without WMA additives). Recent studies have shown that using Warm Mix Recycled Asphalt (WMRA) it is possible to achieve good results with high RAP percentages [24], even up to 100% [25], without affecting the Superpave mix design [26].

Finally, Jamshidi et al. [27] report on the state of art on the performance of Warm Mix Asphalt containing Sasobit. They found that in order to optimize the performance of Sasobit-modified asphalt binders, careful selection of the binder type and source as well as Sasobit content are essential. Construction temperatures, aggregate type and source, aggregate gradation, filler type and anti-stripping agent type are also key points.

2. Research objectives and scope

An attempt was made to produce a PA with WMA technologies that would be suitable for climates with hot summer, cold winter and number of freeze-thaw cycles more than 100 per year (e.g. central Europe, Poland severe climate). Thus, the main objective of this paper is to evaluate the feasibility of the application of WMA technologies to Porous Asphalt for its use in climates that experience low temperatures. The study investigated the possibility of obtaining the required volumetric and mechanical characteristics at lower production temperatures than traditional PA, by evaluating:

- The differences in density and void content,
- The differences in Cantabro test results,
- The differences in ITS results, also before and after the severe water/temperature conditioning process required by the Polish standard PN-EN 12697-12:2008,
- The differences in hydraulic conductivity, also before and after the water/temperature conditioning process.

3. Experimental work

In order to achieve the results mentioned above, one PA mix was selected and prepared using both traditional and WMA technologies, with the Sasobit wax additive used in the latter. In the preparation of the samples, the aggregate temperature was varied based on the target production temperature, while the binder temperature was kept constant for both PA and WMA-PA mixtures.

3.1. Material selection

The gradation curve of the PA selected for the experiments is presented in Fig. 1. A polymer modified binder PmB 45/80-65 produced in Poland (by Lotos Group), was used for the preparation of all the specimens. In order to reduce the number of variables, the