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Impact of asphalt ageing on the activity of adhesion promoters and the moisture susceptibility

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Abstract

Bitumen-aggregate adhesion is one of the crucial characteristics related to an asphalt mix. It affects the mix durability mainly in terms of its moisture susceptibility. Wide range of adhesion promoters is available to the market and can be used in regular practice, nevertheless usually only limited attention is paid to the long term activity (mainly the effective substances) and stability of the additives in the bitumen and the asphalt mix. Research done at the Czech Technical University in Prague is focused on studying the impact of differently aged asphalt mix using selected procedures defined in prEN 12697-52 as well as developing a self-defined procedure by applying the PAV equipment used since many years for long-term bitumen ageing. The results of aged mixtures were always compared to unaged control mixes. In parallel use of aged bitumen was assessed as well. The results were further compared to a simple adhesion test to get a more complex understanding of the activity of selected additives. In total more than 5 additives were selected and tested on one type of asphalt concrete with the application on a more hydrophilic aggregate type. Results gained during this experimental study are presented in the paper using as a criterion indirect tensile strength ratio determined either by EN 12697-12 or by modified procedure according to AASHTO T283.

In parallel because of elevated temperatures used during ageing suitable covering of cylindrical test specimens was analyzed as well to avoid unnecessary deformations or even disintegration of the tested specimens. For this reason two types of protective collar were chosen – PVC and thin steel mash – in both cases fixed by plastic belts. It is assumed that steel mash can better simulate the effect of ageing keeping the envelope partly free for direct contact with hot air and pressure. Results of this comparison are presented in this paper as well.

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1. Introduction

Prevalent part of the road infrastructure is built with asphalt mixes. However, similarly to any other built structure, also asphalt pavements change their properties and performance with time. Deterioration caused by moisture is seen as one of the key reasons of asphalt pavements deterioration, whereas for their maintenance and rehabilitation are European-wide yearly expended considerable financial means. The moisture can in general act on adhesion loss what is the starting point of many pavement failures. Therefore moisture susceptibility of asphalt mixes is a critical aspect which has to be always evaluated. The typical mechanism of deterioration caused by moisture is reduced adhesion because of water which transfused to the interface of bitumen film and aggregate particle. Then stripping effect of asphalt coating usually starts up to release of particular aggregate particles. The pace of this deterioration is significantly affected also by asphalt mix ageing. It is therefore important to reflect this natural process typical for bitumen if moisture susceptibility is assessed, especially if for reasons of improved adhesion various surfactants are used. To design asphalt mix resistant to water immersion and adhesion problems surfactants are usually added either to the bitumen or to the mix during its production. Their mission is to reduce the hydrophilic behavior of the aggregates. Nevertheless, long term effect of these additives is exactly not known and is subject to many expert discussions. It is further questionable if these additives always deliver the solution for issues induced by moisture in all materials and for all necessary construction processes.

Main objective of the experimental study done by CTU in Prague was the development of suitable procedures for laboratory assessments of asphalt mix durability including the obtaining of knowledge with long term behavior of asphalt mixes in terms of their durability studied by indirect tensile strength test. The effort was to develop a simple and suitable test protocol which would simulate ageing (caused by known factors like oxidation, elevated temperature and UV radiation) and impact of water and frost. At the same time it should simulate conditions of the real paved asphalt layer (compacted specimens with access of air and temperature). To forecast exactly the behavior and properties of aged pavement is as good as impossible because of enormous set of different variables. The study therefore compared suitable experimental methods for asphalt ageing simulation. Use of a suitable test protocol, which would in a best way simulate these conditions, would deliver corresponding experience for determining the asphalt mix durability. During the research stage of this study standardized test methods for either bitumen-aggregate adhesion or moisture susceptibility assessment were used. For ageing it should be stated that this phenomenon is today widely used for bituminous binders. In opposite to that ageing simulation for asphalt mixes is still an area with a lot of discussion and therefore with limited development of commonly acceptable test procedures – even if it is highly important to implement ageing if describing the functional characteristics and performance-based behavior of asphalt mixes.

2. Ageing

Over 30 methods of ageing for either bulk asphalt mix or compacted asphalt test specimens have been developed in the recent decades. For those, the material is usually stored under higher temperature (30 °C to 100 °C) for a stipulated number of hours, days or weeks which is intended to accelerate the oxidative processes caused by atmospheric oxygen. In some cases, pure oxygen or ozone is used as oxidising agent, while elsewhere additional overpressure is applied to speed up the reaction. The ageing methods allow simulating a condition of long-term ageing in several days, thus presenting a situation closely resembling the effect on the layer within the pavement structure after several years. So ageing occurs in two phases, on a short-term scale and, then, subsequently, as long-term ageing. Long-term ageing depends on the short-term ageing; therefore, mix preparation and paving must be performed as well as possible to render the mix less susceptible to ageing over the life-time. In the course of short-term ageing, lightweight compounds evaporate and oxidation occurs during construction. With long-term ageing, steric hardening occurs and the pavement oxidizes over its entire life. The oxidation effect is an irreversible chemical change. Steric hardening, contrastingly, is reversible as it involves a structural re-organization produced by thermal change impact.

In the presented study four types of long-term ageing laboratory procedures were compared, including following