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Evaluation of different test methods for bitumen adhesion properties

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Abstract

The adhesion between mineral aggregates and bitumen is an important criterion which describes the quality of the asphalt mixture, asphalt pavement performance and resistance to distress. The lack of bonding can lead to a significant asphalt pavement damage. For the evaluation of the adhesion behavior between bitumen and aggregates, used in road construction, many test methods are known. Therefore, it is important to assess the most appropriate test method for bitumen adhesion properties. In the European standard three testing methods are used to determine the affinity between bitumen and aggregate: Rolling-Bottle-Test, static water storage, detachment in boiling water. Whereas, in the Lithuanian standard – boiling water test method is used. The aim of this research is to determine an effective test method for bitumen and aggregates adhesion properties. Also, to investigate the validity of the test methods for the Lithuanian asphalt binders and to compare the adhesion test methods and parameters used in European standard. The materials used in the experiment research: 5 types of aggregates (granite, dolomite, crushed gravel, and quartz diorite), 6 types of asphalt binders used in Lithuania market (50/70, 70/100, and PMB 45/80-55) and 2 additives – Iterlene 400/IL, Antrocelbond. The test results showed a difference in bitumen adhesion according to test methods used in European and Lithuanian standards, since these methods differ in their methodology, preparation of the samples and results of the measurement unit. Based on the results of this research the conclusions and recommendations were made for determination of bitumen and aggregates adhesion in Lithuania.

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Keywords: Bitumen-aggregate adhesion; adhesion promoters; adhesion testing methods; moisture damage

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1. Introduction

The question of what test method to specify for the effective control of bitumen and aggregate adhesion properties is a difficult one to answer. Numerous research efforts, of which many started long ago, have been conducted to understand the conception of the adhesion and to find the most appropriate test method(s) to determine the affinity between bitumen and aggregate (Rice 1958; Terrel and Shute 1989; Curtis 1992; Robertson 2000; Cui et al. 2014; Liu et al. 2014).

Bitumen and aggregates are considered as the main constituents of an asphalt mixture and their physical and chemical properties have a direct influence on the performance of the mixture. The literature describes four primary theories that explains the concept of bitumen/aggregate interaction: chemical reaction, surface energy, molecular orientation, and mechanical adhesion. The theories explain the adhesive bond between bituminous binder and aggregate (Terrel and Shute 1989; Curtis 1992; Moraes et al. 2011).

A lack of compatibility between bitumen and aggregate is one of the main causes of moisture damage in an asphalt mixture. Moisture damage can manifest itself through various failure mechanisms such as rutting, raveling, potholes and fatigue cracking. For that reason many researches have been trying to define the bitumen-aggregate mechanism and to improve adhesion test methods (Renken et al. 2010; Copeland et. al. 2008; Grenfell et al. 2014; Moraes et al. 2011; Daučík et al. 2011; Liu et al. 2014).

In order to extend the service life of the pavement, several countries have implemented national requirements of mandatory addition of adhesion promoters in asphalt mixes, to secure and maintain the adhesion and durability of asphalt pavements over time. In general, adhesion between bitumen and aggregate depends on the chemical nature of the components and therefore the source of the bitumen and type of aggregate. Other aggregate properties such as surface texture, shape, porosity and absorption will also influence the adhesion. The use of appropriate adhesion additives is a vital importance to ensure the strong bond (adhesion) to the aggregate surface at the very beginning (Liu et al. 2014).

In Lithuanian technical document for asphalt mixes is pointed that the affinity between bitumen and aggregates should be ensured, but the test methods and limit values are not mentioned. Also, in Europe there is not common practice which method to use for determination of the affinity between bitumen and aggregates. Therefore, there are differences of particular methods and it makes a need to determine the appropriate test method for determination of adhesion and limit values.

The first objective of this study is to assess an effective test method for bitumen and aggregate adhesion properties. The second objective is to investigate the validity of the adhesion test methods for the Lithuanian bituminous binders and to recommend the adhesion limit values ensuring the compatibility between bitumen and aggregate.

The scope of this research is to compare different materials used in the experiment research: 5 types of aggregates (granite, dolomite, crushed gravel, and quartz diorite), 6 types of asphalt binders used in Lithuania market (50/70, 70/100, and PMB 45/80-55 from different producers) and 2 additives – Iterlene 400/IL, Adhezin.

The study focused on how to prove the most appropriate testing method effectiveness to asphalt adhesion properties and to recommend the adhesion limit values measured by one of test methods'.

2. Background

2.1. Theoretical review of adhesion

Adhesion between bitumen and aggregate is one of the most important criteria for a highly durable and water damage resistant asphalt pavement. The bitumen-aggregate bond is a surface phenomenon which depends on the contact between the two materials. Terrel and Shute (1989) describe four theories that are often used to explain the adhesion between asphalt and aggregate: chemical reaction, surface energy, molecular orientation, and mechanical adhesion. There are few factors by which these theories are affected: surface tension of the bitumen and aggregate, chemical composition of the bitumen and aggregate, bitumen viscosity, surface texture of the aggregate, aggregate porosity, aggregate cleanliness, aggregate moisture content and temperature at the time of mixing with bitumen (Terrel and Shute 1989, Bagampadde et al. 2004, Ramon-Torregrosa et al. 2008, Grenfell et al. 2014). Chemical reaction is based on the acidic and basic components of both bitumen and aggregate reaction. Robertson (2000)