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The influence of aggregate, filler and bitumen on asphalt mixture moisture damage

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Abstract

Moisture damage in an asphalt mixture can be defined as the loss of strength, stiffness and durability due to the presence of moisture leading to adhesive failure at the binder–aggregate interface and/or cohesive failure within the binder or binder–filler mastic. Various test methods exist to identify the susceptibility of asphalt mixtures to moisture damage, such as the AASHTO T283 procedure. This paper describes a new combined ageing/moisture damage laboratory test known as the Saturation Ageing Tensile Stiffness (SATS) test that has been successfully used to quantify the moisture damage of a range of UK asphalt mixtures. The test consists of initial saturation prior to placing compacted asphalt mixture cylindrical specimens in a moist, high temperature and pressure environment for an extended period of time. The stiffness modulus measured after the test divided by the stiffness modulus measured before the test (retained stiffness modulus), and the specimen saturation after the test (retained saturation), are used as an indication of the sensitivity of the compacted mixture to moisture damage. In this paper, the sensitivity of the SATS test to different aggregates, fillers, binders and volumetric proportions as well as mixture types has been assessed. The results show that the SATS test is able to discriminate between different asphalt mixture combinations in terms of their moisture damage resistance. Compared to AASHTO T283, the SATS test was found to be a more aggressive conditioning protocol, although both tests ranked mixtures in a similar order with respect to moisture damage.

Keywords: Moisture damage; Asphalt mixtures; Aggregates; Fillers; Bitumen; Durability

1. Introduction

Moisture damage is an extremely complicated mode of asphalt mixture distress that leads to the loss of stiffness and structural strength of the bound pavement layers of a road and eventually the costly failure of the road structure. Essentially the damage is caused by a loss of adhesion between aggregate and bitumen and/or a loss of cohesion strength in the bitumen and/or bitumen–filler mastic due to the presence of moisture in the asphalt mixture. Various test methods have been developed in an attempt to identify the susceptibility of asphalt mixtures to moisture damage and can generally be divided into those conducted on loose coated aggregate and those conducted on compacted asphalt mixtures [1]. Tests on compacted mixtures generally use samples either prepared in the laboratory or cored from existing pavements. Typically, the samples are conditioned in water to simulate in-service conditions and assessment of moisture damage is made by dividing the conditioned stiffness modulus or strength by the unconditioned stiffness modulus or strength. Tests of this nature include the accelerated water conditioning and freeze–thaw AASHTO T283 procedure [2]. In addition, immersion wheel tracking tests, such as the Hamburg wheel tracking device [3], can be used to assess the moisture damage of asphalt mixtures.

However, none of these tests has been found to accurately predict the magnitude of moisture damage (strength and/or stiffness reduction) of different asphalt mixtures in

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the field. Researchers at the Nottingham Transportation Engineering Centre (NTEC) have therefore recently developed a combined ageing/moisture damage laboratory test that has been shown to correctly predict the performance of asphalt mixtures in the field and replicate the magnitude of this moisture damage distress [4]. The test, known as the Saturation Ageing Tensile Stiffness (SATS) test [5], consists of initial saturation under vacuum prior to placing compacted asphalt core samples in a high temperature and pressure environment in the presence of moisture for an extended period of time. The stiffness modulus measured after the test divided by the stiffness modulus measured before the test (retained stiffness modulus), and the specimen saturation after the test (retained saturation), are used as an indication of the sensitivity of the compacted mixture to the combined effects of ageing and moisture.

This paper investigates the sensitivity of the SATS test to assess the moisture damage performance of various asphalt mixtures incorporating different aggregates, fillers, binders and volumetric proportions as well as different mixture types. The results achieved with the SATS test have been compared to observed moisture damage field performance and the assessment of moisture damage possible with the AASHTO T283 procedure.

2. Test description and procedure

The SATS test is based around the principle of combining ageing with moisture conditioning by conditioning pre-saturated asphalt mixture specimens at an elevated temperature (85 °C) and pressure (2.1 MPa) in the presence of moisture for a duration of 65 h [5]. A pressure vessel is used to hold five nominally identical specimens (100 mm in diameter and 60 mm in thickness) in a custom-made specimen tray as shown in Fig. 1. The dimensions and specifications of the SATS testing equipment, including the size and spacing of the holes in the perforated trays are detailed in Clause 953 of Volume 1 of the UK Manual of Contract Documents for Highway Works, 2004 [6]. The test conditions used with the SATS test were selected in order to reproduce in the laboratory, the field observed 60% decrease in stiffness modulus for a high modulus base asphalt mixture as detailed by Airey et al. [7]. The SATS test procedure as specified in Clause 953 is as follows:

1. The unconditioned (initial) indirect tensile stiffness modulus of each asphalt mixture specimen is determined at 20 °C using the Nottingham Asphalt Tester (NAT) [8] in accordance with BS DD213 [9] (124 msec rise time, 5 μm peak transient horizontal diametral deformation).
2. The dry mass of each specimen is next determined by weighing.
3. The specimens are subsequently immersed in distilled water at 20 °C and saturated using a residual pressure of between 40 and 70 kPa for 30 min.
4. The wet mass of each specimen is next determined by weighing, and the percentage saturation of each specimen calculated, referred to as "initial saturation".
5. The SATS pressure vessel is partly filled with a predetermined amount of distilled water (water level between sample positions P4 and P6 in Fig. 2). The pressure vessel and water are maintained at the target temperature of 85 °C for at least 2 h prior to introducing the specimens.
6. The saturated asphalt specimens are then placed into the pressure vessel, the vessel is sealed and the air pressure is gradually raised to 2.1 MPa.
7. The specimens are maintained at the testing conditions, i.e., 2.1 MPa and 85 °C for 65 h.

Fig. 1. SATS pressure vessel and specimen tray.