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Asphalt mixture layers' interface bonding properties under monotonic and cyclic loading

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HIGHLIGHTS

- Monotonic shear test cannot reflect the research and practice experience in total.
- Shear strength can be used as a rough indicator for long term interface performance.
- Cyclic shear test can be successfully applied for interface long term evaluation.
- Cyclic shear test leads to better differentiating between particular bond materials.

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ABSTRACT

This paper focuses on investigating the interface shear bonding properties of asphalt pavement structures using both monotonic and cyclic direct shear tests. Several pavement structures were considered, differing in the asphalt mixture type and tack coat type, and laboratory preparation of the double-layered asphalt specimens. Based on the results on bond materials used in this research, it was found that the resulting shear strength from monotonic shear test can be used only as a rough indicator for long term interface bonding performance, because not all research and field experience could be reflected in the test results. The cyclic shear test employed in this study can be used for evaluating the interface fatigue performance. Additionally, differentiation between particular bond materials with respect to interface shear bonding properties is assured.

1. Introduction

Asphalt pavement structures are usually composed of at least two asphalt layers which are successively paved and commonly bonded using bituminous tack coat material. The prevailing interface bonding properties highly influence the long-term performance and durability of asphalt pavements [1].

Good bonding between asphalt layers ensures that the layers work as a composite structure in order to withstand traffic and environmental loading [2]. On the other hand, poor or missing bonding between asphalt layers can affect the redistribution of stresses and strains in the pavement structure, leading to premature failure [3]. This can result in a slippage cracking of the surface layer, or in loss of bearing capacity of the whole pavement structure.

Interface bonding characteristics in asphalt pavement structures are mostly evaluated using monotonic shear test methods, which number has been raised over the years [1,4–8]. Usually, the monotonic shear test consists of applying a constant shear displacement rate across the layers' interface, where shear strength is obtained at the peak shearing force. However, it is not clear if the so obtained shear strength can be used as an indicator for long-term interface shear performance, because the generated shear stress is not cyclic. Furthermore, the test results cannot be appropriately used for modeling or for mechanistic pavement design purposes.

In order to overcome disadvantages of monotonic shear testing some research effort has been put in the development of more complex cyclic shear tests, which are partially able to simulate the field conditions more realistically [1,3,9–15]. The difference between cyclic shear tests is mainly attributed to different interface loading conditions.

2. Objective and research approach

The objective of this work is to investigate if the shear strength obtained from monotonic shear tests can be used as an indicator

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for the long-term interface shear performance, as observed under cycling loading. For that purpose, direct monotonic shear test introduced by Leutner [4], and direct cyclic shear fatigue procedure introduced by Isailović et al. [14] were used. In order to determine the displacement amplitudes for shear fatigue tests, cyclic shear amplitude sweep tests were additionally performed. Several pavement structures (with different types of bonding) were considered, differing in the asphalt mixture type and tack coat type, and laboratory preparation of the double-layered asphalt specimens. Fig. 1 shows the selected research approach.

3. Experimental study

3.1. Material composition and specimen preparation

Double-layered asphalt specimens for both cyclic and monotonic tests were prepared using three different asphalt mixture types:

- asphalt concrete AC 22 T S with maximum grain size 22 mm, usually used as base course material on highly trafficked road pavements,
- asphalt concrete AC 16 B S with maximum grain size 16 mm, usually used as binder course material on highly trafficked road pavements, and
- stone mastic asphalt SMA 11 S with maximum grain size 11 mm, usually used as wearing course material on highly trafficked road pavements.

Fig. 2 and Table 1 represent the grain size distribution and composition of the used asphalt mixtures respectively.

From these materials double-layered asphalt slabs were fabricated in laboratory in three steps using segmented steel roller compaction method [16] (Fig. 3): (i) compaction of the lower slab layer, (ii) application of the tack coat, and (iii) compaction of the upper slab layer after breaking process of tack coat occurred. This compaction procedure is defined as “hot over cold” compaction.

Three types of bituminous interface tack coat materials were used:

- cationic polymer modified emulsion **C60**BP1-S with 60 mass% of bitumen content,
- cationic emulsion **U60K** with 60 mass% of bitumen content, and
- cationic emulsion **C40**BF1-S with 40 mass% of bitumen content.

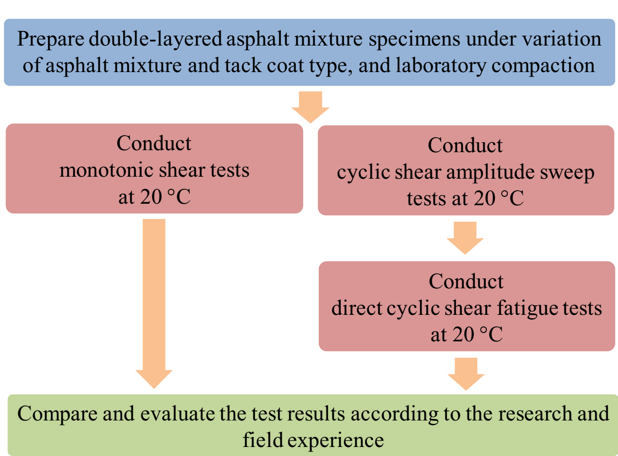

Fig. 1. Flow chart of the selected research approach.

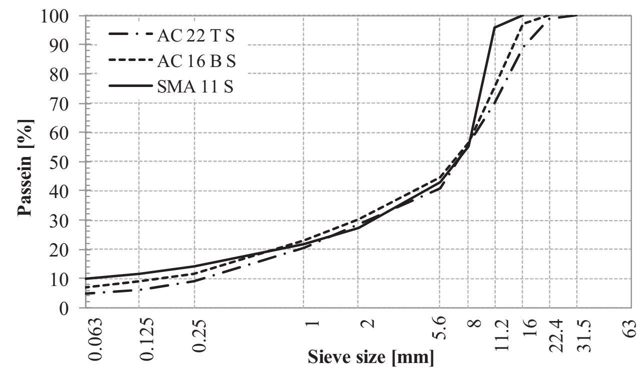

Fig. 2. Grain size distribution for asphalt mixtures: AC 22 T S, AC 16 B S, and SMA 11 S.

Table 1
Composition of asphalt mixtures.

Characteristic	Asphalt mixture type		
	AC 22 T S	AC 16 B S	SMA 11 S
Aggregate type	Limestone	Basalt	Basalt
RAP addition [%]	30	0	0
Binder type	50/70	25/55-55	25/55-55
Binder content [%]	4.1	4.7	6.0
Bulk density [g/cm^3]	2.374	2.475	2.461
Air voids content [%]	7.4	6.5	3.9

Additionally, “hot over hot” compaction was performed, where lower and upper asphalt layers were successively compacted in a short time, without tack coat application (Fig. 3). The lower slab layer was compacted in displacement controlled pre-compaction mode with low energy in order to avoid over-compaction. Consequently, additional compaction was provided by immediate compaction of the upper slab layer. For this method a better interlocking of the asphalt layers is guaranteed.

After slab compaction, double-layered samples were drilled from the slabs, with 99 mm diameter for cyclic tests and with 150 mm diameter for monotonic tests.

Based on various asphalt mixture and tack coat types, and laboratory preparation of the double-layered asphalt specimens, 10 different bond types were considered in total. Table 2 gives an overview of the applied layer-bond combinations and their composition.

3.2. Monotonic shear test

Monotonic shear test introduced by Leutner [4] relies on a simplified shear apparatus (see Fig. 4), where one layer of double-layered asphalt test sample is fixed during the test, and the other layer is loaded vertically in a displacement controlled mode. A constant shear displacement rate of 50 mm/min is applied across the layers’ interface until failure. The test is performed on a 150 mm diameter core specimen, and at fixed temperature of 20 °C.

During the whole test duration, displacement and shear force are continuously recorded using a data acquisition system. Shear strength is defined as peak of the shear force (cp. τ_{max}, Fig. 5).

Usually, two replicates per bond type are tested.

3.3. Cyclic shear fatigue test

Cyclic shear fatigue procedure used in this study [14] relies on a direct shear test, which is actually a cyclic version of the monotonic shear test introduced by Leutner [4].