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Analysis On Bond Between Bituminous Paving Layers

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ABSTRACT:

The interlayer bonding of modern multi-layered pavement system plays an important role to achieve long term performance of a flexible pavement. It has been observed that poor bonding between bituminous pavement layers contributes to major pavement overlay distresses such as premature fatigue, top down cracking, potholes, and surface layer delaminating. One of the most common distresses due to poor bonding between bituminous layers is a slippage failure, which usually occurs where heavy vehicles are often accelerating, decelerating, or turning. To enhance the bonding between layers, a tack coat is sprayed in between the bituminous pavement layers. A tack coat is an application of a bituminous emulsion or bituminous binder between an existing bituminous / concrete surface and a newly constructed bituminous overlay. Normally, hot bituminous binders, cutback bitumens or bituminous emulsions are used as tack coat materials.

This study is aimed to evaluate the bond strength at the interface between pavement layers by performing laboratory tests. To carry out this objective, three special attachments are fabricated for use in Marshall Loading Frame for finding the performance of tack coat laid at the interface between Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) layers in the laboratory. In this study, the results of the specimens prepared with 100 mm and 150 mm diameter specimens using two types of normally used emulsions, namely CMS-2 and CRS-1 as tack coat at application rates varying at 0.20 kg/m , 0.25 kg/m and 0.30 kg/m made at 25 C temperature are presented.

1.INTRODUCTION

1.1 Problem Statement

The modern flexible pavement is generally designed and constructed in several layers for effective stress distribution across pavement layers under the heavy traffic loads. The interlayer bonding of the multi-layered pavement system plays an important role to achieve long term performance of pavement. Adequate bond between the layers must be ensured so that multiple layers perform as a monolithic structure. To achieve good bond strength, a tack coat is usually sprayed in between the bituminous pavement layers. As a result, the applied stresses are evenly distributed in the pavement system and subsequently, reduce structural damage to the pavements.

It has been observed that poor bonding between pavement layers contributes to major pavement overlay distresses. One of the most common distresses due to poor bonding between pavement layers is a slippage failure, which usually occurs where heavy vehicles are often accelerating, decelerating, or turning. The vehicle load creates dynamic normal and tangential stresses in the pavement interfaces from horizontal and vertical loads. With the vehicle load being transferred to each underlying bituminous layer, the interface between the layers is vital to the pavements integrity. Slippage failure develops when the pavement layers begin to slide on one another usually with the top layer separating from the lower layer. This is caused by a lack of bond and a high enough horizontal force to cause the two layers to begin to separate. Other pavement problems that have been linked to poor bond strength between pavement layers include premature fatigue, top down cracking, potholes, and surface layer delamination. One such result is the formation of cracks in the shape of a crescent as shown in figure 1.1.

Figure 1.1: Slippage Crack (http://www.surface-engineering.net)

1.2 Background on Tack Coat

A tack coat is an application of a bituminous emulsion or bituminous binder between an existing

bituminous / concrete surface and a newly constructed bituminous overlay. A tack coat is also known as bond coat as it is used to bond one pavement layer to another. A tack coat acts as an adhesive or glue so that combined pavement layers perform as a monolithic structure rather than individual sections. Typically, tack coats are emulsions consisting of bituminous binder particles, which have been dispersed in water with an emulsifying agent. Bituminous particles are kept in suspension in the water by the emulsifying agent and thus bitumen consistency is reduced at ambient temperature from a semi-solid to a liquid form. This liquefied bitumen is easier to distribute at ambient temperatures. When this liquid bitumen is applied on a clean surface, the water evaporates from the emulsion, leaving behind a thin layer of residual bituminous on the pavement surface. When the bituminous binder is used as a tack coat, it requires heating for application (Rahman, 2010).
Normally, hot bituminous binder, cutback bitumen or bituminous emulsions are used as tack coat materials. However, the use of bituminous emulsions as a tack coat material is escalating instead of cutback asphalt or hot bituminous binder because of the following advantages:

1. Bituminous emulsions can be applied at lower application temperatures compared to cutback bitumen or hot bituminous binder.

2. As bituminous emulsions do not contain harmful volatile chemicals, they are relatively pollution free.

3. As bituminous emulsions are water based, they have no flashpoint and are not flammable or explosive. Therefore, they are safer to use as they do not pose health risk to workers. (Patel, 2010)

2.LITERATURE REVIEW

2.1 Introduction

In this chapter, extensive literature survey on the various laboratory studies conducted for the evaluation of bond strength between bituminous pavement layers has been discussed.

2.2 Tests to Evaluate the Interface Bond Strength of Pavement

Numerous studies have been performed investigating adhesive properties of the interface between layers. These studies have typically developed a unique test method or instrument for analysis of the interface bond strength. Literature on bond strength clearly indicates that shear force is mainly responsible for interface bond failure.

Different organizations and different researchers have used various tests for evaluating the pavement interface bond strength including the following:

- Layer-Parallel Direct Shear (LPDS);
- Ancona Shear Testing Research and Analysis (ASTRA);
- Superpave Shear Tester (SST), which has been recently modified by the Louisiana

  Transportation Research Center by building a shear mold assembly;
- Leutner test, originally developed in Germany;
- FDOT Shear Tester;
- LCB shear test
- Modified Marshall Test developed by the Pennsylvania Department of

  Transportation;
- NCAT bond strength device developed by National Center for Asphalt Technology ;
- Shear-Testing Device developed at Mcasphalt Lab.

An overview of some of these commonly used test procedures is provided in the subsequent sections.

2.3 Layer-Parallel Direct Shear (LPDS)

The Swiss Federal Laboratories for Material Testing and Research developed a shear testing device known as Layer-Parallel Direct Shear (LPDS) which is a modified version of equipment developed in Germany by Leutner (1979). The modified LPDS test is used to test the 150 mm diameter cylindrical specimens using Marshall testing as reported by Raab and Partl (2002). The bottom layer of a double-layered specimen is placed on a u-bearing and the upper layer is moved with a constant displacement rate of 50.8 mm/min at a temperature of $20^{0}C$ by means of a yoke, allowing the application of a shear force at the interface as shown in figure 2.1. The shear force and the corresponding displacement are continuously recorded to find the maximum load. The nominal shear stress (τLPDS) is calculated as follows:

$$\tau_{LPDS} = F/A$$
$$= 4F/(d^2 \pi)$$

Where, F = maximal force;
A = nominal cross sectional area; and
d = specimen diameter.

The study was conducted to evaluate the influence of compaction (50 and 204 gyrations), surface texture (smooth and rough), moisture, heat and water on the interface shear bond of pavements by using 20 different types of tack coats. The study concluded that higher shear strengths were observed for the specimens with the smooth surface than the specimens with rough surface. The results clearly indicated the negative influence on adhesion due to the presence of moisture and absence of tack coat. The study also reported the improvement of shear adhesion up to 10% for a top-layer compaction at 240 gyrations by using a certain tack coat, while such improvement was not observed for 50 gyrations.

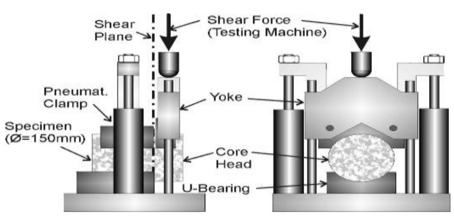

Figure 2.1: Schematic view of the LPDS (Layer-Parallel Direct Shear) test device (Raab

3.EXPERIMENTAL INVESTIGATIONS

3.1 Introduction

This chapter describes the experimental works carried out in this present investigation.

This chapter has been divided into two parts. First part deals with the experiments carried out on the materials (aggregates, bitumen, and emulsions), second part deals with the fabrication of the shear testing devices for evaluation of pavement interface bond strength.

3.2 Materials Used

3.2.1 Aggregates

For preparation of cylindrical samples composed of Dense Bituminous Macadam (DBM) and

Bituminous Concrete (BC), aggregates were as per grading of Manual for Construction and

Supervisions of Bituminous Works of Ministry of Road Transport and Highways

(MORT&H, 2001) as given in Table 3.1 and 3.2 respectively.

3.2.1.1 Coarse Aggregates

Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm

IS sieve size. Standard tests were conducted to determine their physical properties as summarized in Table 3.3.

3.2.1.2 Fine Aggregates

Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found to be 2.62.

3.2.1.3 Filler

Portland slag cement (Grade 43) collected from local market passing 0.075 mm IS sieve was

used as filler material. Its specific gravity was found to be 3.0.

4.CONCLUSION

This chapter summarizes the findings of the laboratory study to evaluate the bond strength between pavement layers. The scopes for the future research work are also recommended in this chapter.
4.2 Conclusions

A laboratory study was conducted to evaluate the bond strength between the Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) layers

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with tack coat sprayed at the interface. For this purpose three simple shear testing models were fabricated and experiments were conducted using the same in a Marshall Stability Apparatus. For shear testing model no 1, laboratory tests were conducted on 100 mm diameter cylindrical specimens at a temperature of 25 0 C by applying a shear force of constant deformation rate of 50.8 mm/min.

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