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ASSESSMENT OF BOND STRENGTH BETWEEN BITUMINOUS PAVING LAYERS: LABORATORY EVALUATION

Arun Kumar Aditya [1] Akhand Pratap Singh[2]

M.Tech Scholar, Assistant Professor

Department of Civil Engineering Shri Rawatpura Sarkar University, Raipur

Abstract

The purpose of this research is to assess the interface binding strength between various combinations of bituminous layers in a laboratory setting. The link between these layers is critical for the overall function of the pavement under traffic stresses. Bituminous tack coatings are widely used to improve layer adherence. The study looks at two layer combinations: bituminous concrete (BC) on dense bituminous macadam (DBM) and semi-dense bituminous concrete (SDBC) on BM. The study employs a variety of tack coat materials, including bitumen, Cationic Rapid Setting with low viscosity (CRS-1) and Cationic Medium Setting with high viscosity (CMS-2) emulsions. Bond strength is tested on cylindrical specimens at various usual service temperatures (250, 300, 350, and 400°C) and tack coat application rates.

The testing procedure entails following the standard Marshall Procedure, applying the tack coat, and suitably covering the top layer in the same mould. The bond strength between layers is then evaluated using a specially designed attachment known as the "bond strength device," which is attached to the loading frame of the Modified Marshall Testing Apparatus.

The results show that the interlayer bond strength is affected by the test temperature, with a reduction as the temperature rises. The binding strength is also affected by the type of tack coat used and the precise layer mix. The amount of tack coat required varies based on the type of tack coat and layer mix.

Overall, this study sheds light on how to strengthen the link between bituminous layers in pavements, hence improving their performance and longevity under traffic-induced stresses.

Key words: *Interlayer Bond strength, Tack coat, bituminous layer combination, Bond strength device.*

1. Introduction

1.1 General

Highways are considered to be the backbone of a country's growth and development. All developed as well as developing countries normally have a continuous program of sustaining and building road infrastructures or developing the existing road. To improve the existing road infrastructure in view of increased traffic is to strengthen the existing pavement layer by overlaying with another layer of appropriate material composition and thickness. The flexible pavement is generally designed and constructed in several layers for effective stress distribution across the pavement layers under the varying heavy traffic loads. The viscous nature of the flexible pavement, allows its different layers to sustain significant plastic deformation, although distresses due to repeated heavy loading over time which is the most common failure mechanism. The flexible pavement works as a single structure due to good bonding between the different layers interface of it. It is generally believed that, the pavement stress distribution is extremely influenced by the adhesion conditions at the layer interface. Poor adhesion at layer interface may cause adverse effects on the structural strength of the pavement system and form numbers of premature failures. To increase bonding between layers, bituminous tack coats are applied prior to overlay. Bituminous emulsions are normally used as tack coats. In spite of their extensive application, the thoughts among pavement engineers differ regarding the effectiveness of tack coat in enhancing the adhesion between the two layers. This tack coat also made of a thin layer of bitumen residue and its objective is to provide adequate adherence between the layers. If the quantity of bituminous emulsions used is in excess or less than the required one, the interfacebonding will not be satisfactory.

1.2 Failures Arise due to Inadequate Bond

A Number of premature pavement failures can be attributed due to loss of bond between two layers of hot mix asphalt (HMA). It has been generally observed that poor adhesion between pavements layers contributes to major pavement overlay distresses and numbers of premature failures. Such are Slippage failure and Surface layer Delamination.

Slippage failure grows when the pavement layers begin to slide on one another and generally the top layer separating from the lower layer. This type of failure develops due to lack of bond between two top important pavement layers and it's mainly seen at high horizontal force at points where traffic is accelerating or decelerating, such as at traffic signals and within horizontalcurves.

Figure 1.1 Slippage Failure [www.pavementinteractive.org]

Delamination is a section of a surface layer that has come loose from the pavement. The causes of this type of failure are slippage between layers and poor interlayer bond between the pavement layers. Other pavement problems that have been linked to poorer bond strengthbetween pavement layers shape of a crescent are shown in figure.

Figure 1.2 Surface Layer Delamination [www.roadscience.net]

1.4 Objectives

Based on the discussions as mentioned above, the objectives of the present study have been identified as follows

- Fabrication of a simple testing arrangement to be used in a conventional Modified Marshall test apparatus to determine directly the interlayer bond strength between two layers.
- Experimentation using the fabricated device in respect of various material combinations.
- Preparation of samples under varying conditions, such are temperature, percentage of emulsions, with no tack coat use, by using bitumen as tack coat and setting time.

3 Experimental Methodology

3.1 Introduction

This chapter describes the experimental works carried out for this study of interlayer bond strength between two bituminous paving layers. This chapter has been divided into two parts. First part discusses the collection of materials which are used for preparing the composite cylindrical specimens (aggregates, bitumen, and emulsions) and second part described by the testing of the specimens by using a fabricated simple attachment which has been easily mounted on Modified Marshall Apparatus. For the study two different types of bituminous layer specimens were prepared with 100 mm total height and 101 mm in diameter. The specimens were prepared with varying different types of tack coat, bitumen as a tack coat also without using any tack coat. This investigation also observed dissimilarities in bond strength due to variations in their setting time and duration of compaction between two layers.

3.2 Methodology

The experimental methodology adopted in the study consisted of evaluating the maximum interlayer bond strength of the two types of bituminous layer combinations (DBM/BC and BM/SDBC). In this experimental method, the specimens were subjected to direct shear force applied at a constant rate of displacement of 50.8 mm/min until the failure of the specimens. A customized simple device referred to the modified Marshall test apparatus was fabricated for the testing of the double layer composite bituminous samples for evaluation of interlayer bond strength. The methodology adopted for this project is shown in figure 3.1.

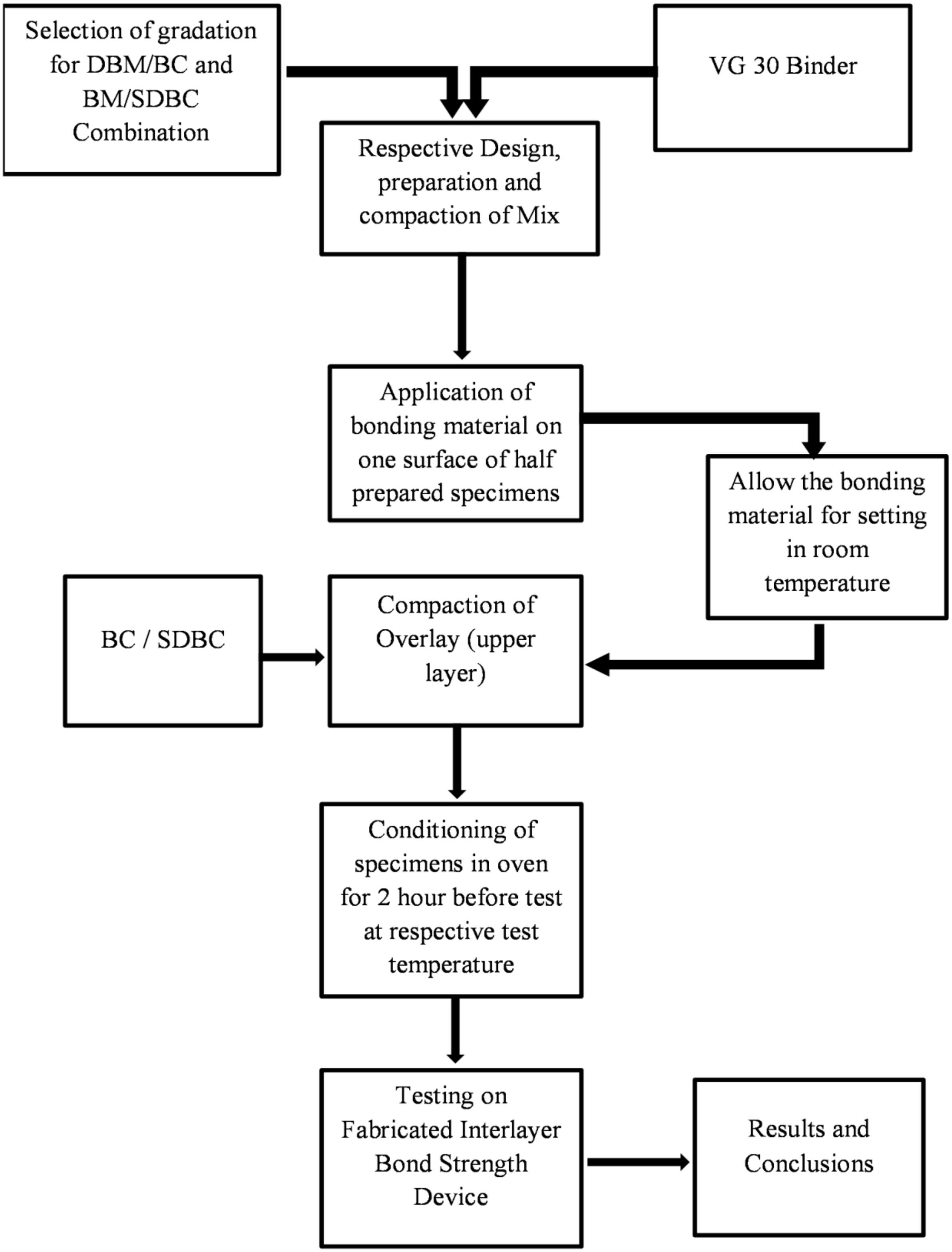

Figure 3.1 Methodology of the Experimental Work

4. Results and Discussions

4.1 Introduction

The experimental test was conducted for observing the interface bond strength between two types of bituminous paving layers carried out in the cylindrical laboratory prepared specimens having 100 mm diameter and 100 mm total height which was tested on a fabricated attachment fitted to the Marshall Loading frame. The results were obtained at four different test temperature 25^0, 30^0, 35^0, and 40^0C with two type tack coat CMS-2 and CRS-1 varying with different application rate. Also the bond strength was evaluated by using bitumen as a tack coat with various application rates and without using any tack coat. The CMS-2 type emulsion was observed considering three setting time 6, 9 and 12 hours and in CRS-1 type 0.5, 1 and 1.5 hours.The curing time for bitumen used in place of tack coat, before applying the overlay taken as no curing time, half an hour and one hour. In the study shear strength was evaluated at the interface between bituminous macadam (BM) and semi dense bituminous concrete (SDBM) type flexible paving layers considered with CMS-2 and CRS-1 bitumen emulsions.

4.2 Laboratory Test Results

The results of various tests conducted to evaluate the interlayer bond strength in various types of combinations are presented below.

4.2.1 Interlayer Bond Strength for Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) Combination

4.2.1.1 Variation of ILBS with Rate of Application for CRS-1 Type Tack Coat at Various Setting Times

The test results of bond strength with various application rates in case of CRS-I type tack coat cured at different setting times are presented in the following paragraphs.

In Table 4.1 present the average interlayer bond strength when setting time is 0.5 hours. The highest bond strength values are observed at application rate of 0.25 Kg/m^2 at all test temperatures for te CRS-1 type of tack coat.

Table 4.1 ILBS of CRS-1 Type Tack Coat (Considering 0.5 Hour Setting Time)

Type of Tack Coat	**Application Rate (Kg/m^2)**	**Average ILBS at Different Test Temperature (kPa)**			
		25^0C	**30^0C**	**35^0C**	**40^0C**
CRS-1	0.2	691.37	530.09	411.26	286.90
	0.25	716.83	635.35	460.49	323.83
	0.3	609.88	511.42	332.31	249.55

4.3 Overall Performance of Inter Layer Bond Strength

4.3.1 ILBS Comparisons between Two Types of Tack Coat, Bitumen as Tack Coat and With No Tack Coat at Different Test Temperature for the Interface of DBM and BC Type of Combination.

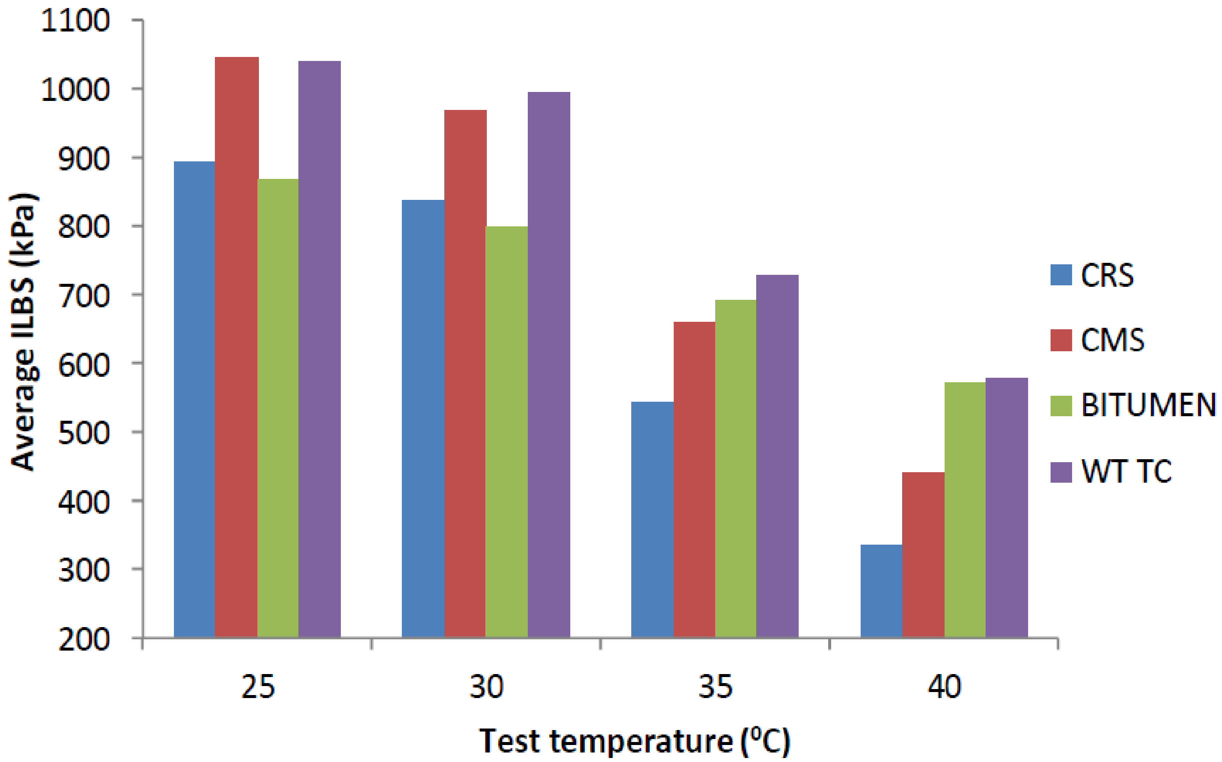

Figure 4.29 Comparisons of ILBS at Different Test Temperature Made

From the figure 4.29, the maximum bond strength was found at 25^0C among all others three cases considered as bonding materials for DBM and BC type of combination of the bituminous paving layer. When the bituminous concrete (BC) considered as upper layer placed immediately over the freshly compacted dense bitumen macadam (DBM) layer was given maximum interlayer bond strength as compared to all others. The interlayer strength decreased when the test temperatures, rate of applications and time interval between successive laying increased.

4.3.2 ILBS Comparisons between Two Types of Tack Coat at Different Test Temperature for Interface of BM and SDBC Type of Combination.

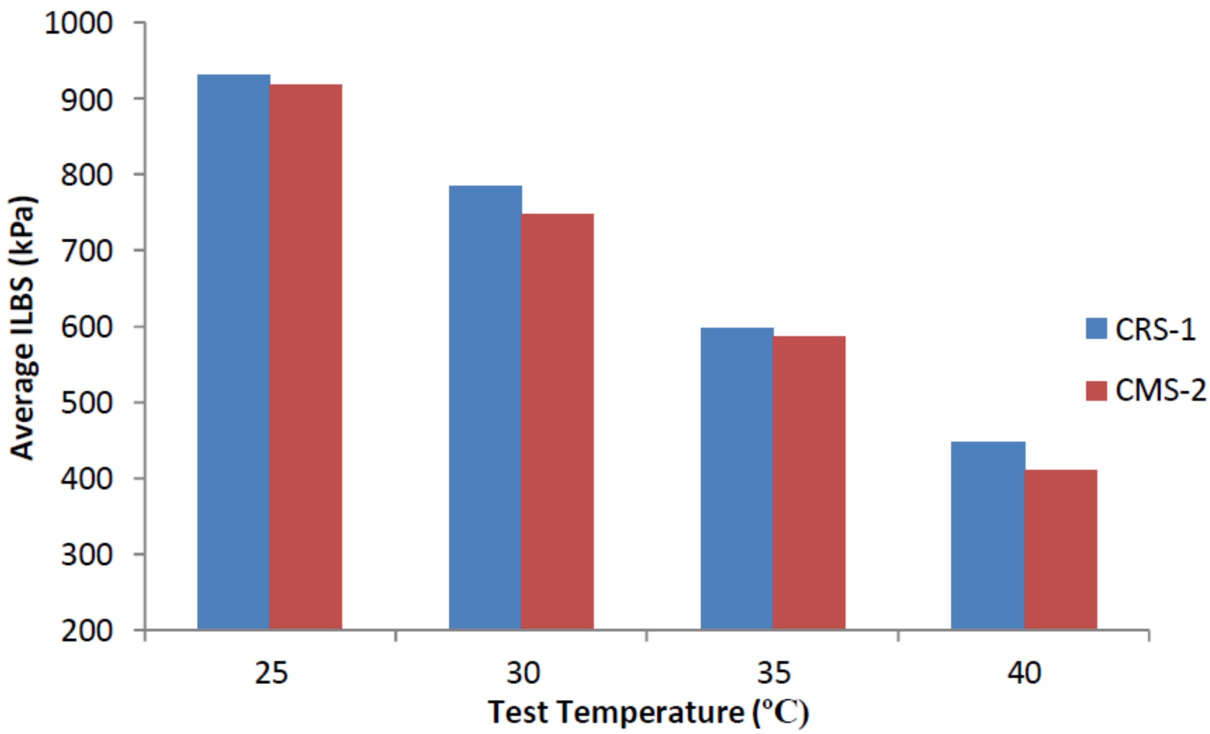

Figure 4.30 Comparisons of ILBS at Different Test Temperature Made

From the figure 4.30, the maximum mean interlayer bond strength was found at 25^0C among all other three test temperatures considered for the BM and SDBC type of combination for the bituminous paving layer. In all cases the CRS-1 type emulsion results more as compared to CMS-2 type of tack coat. The interlayer strength decreased when the test temperatures, rate of applications and durations of compaction increased.

5. Conclusions and Future Scope

5.1 Conclusions

A study has been made in this project to evaluate the interlayer bond strength in the laboratory for different types of tack coat using laboratory prepared samples for DBM/BC and BM/SDBC layer combinations. A special device has been designed and fabricated, which can be fitted to the loading frame of the Modified Marshall Test apparatus to determine the interlayer bond strength of two-layered bituminous specimens. The specimens have been tested at four different test temperatures, namely 25^0, 30^0, 35^0 and 40^0C, which are very common in our country. A specimen basically consists of two bituminous layers, bonded together by emulsion or bitumen. The upper and lower layer combination is either DBM or BC or BM and SDBC respectively. Various application rates have been tried and in case of emulsion, different setting times have been tried. All such variations in materials and sample casting methods have been attempted to explore the optimum condition for appropriate bond strength in a particular situation. The following conclusions are drawn from the results of the tests conducted.

DBM/BC Combination

- It is observed that for CRS-1, maximum interlayer bond strength results at 0.25 Kg/m^2 application rate in all test temperature conditions used and for CMS-2, at 0.15 Kg/m^2 application rate irrespective of different test temperatures. These optimum application rates are also found for all setting times considered for both types of emulsions.
- In the cationic medium setting type of emulsion used as tack coat, the maximum interlayer bond strength was found when setting time was at 9 hours and in the cationic rapid setting type of emulsion, maximum interlayer strength was observed when setting was at 1 an hour.
- When conventional VG 30 bitumen is used as a tack coat, the maximum interlayer bond strength is observed at 0.2 Kg/m^2 application rate when setting time was at 0.5 hours in all test temperatures used.
- When no tack coat is used, maximum bond strength at the interface available when the upper layer mix is laid and compacted immediately after the lower layer compaction was completed. If the duration of compaction increased between two layers, the interlayer bond strength decreased.
- At a test temperature 25^{0}C, all types of tack coat used and other considerations taken for observing the interlayer bond strength have been found maximum value as comparedto other test temperatures.

BM/SDBC Combination

- It is determined that for CRS-1, maximum interlayer bond strength results at a 0.15 Kg/m^2 application rate in all test temperature conditions used and for CMS-2, at the 0.15 Kg/m^2 application rate irrespective of different test temperatures.
- The interlayer bond strength is decreased when the test temperature increased for both types of tack coat used. The maximum bond strength has been found out at 25^{0}C for both types of tack coat used.

5.3 Future Scope of Works

- Analysis the bond strength using finite element method and comparison of laboratoryresults with theoretical work.
- Experimentation using the fabricated device in respect of various loading combinations.
- Comparison of the experimental results with that given in the literature and experiments conducted earlier.
- Testing of field core samples and comparison with laboratory prepared ones.

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