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Evaluation of Bond between Bituminous Paving Layers in Laboratory

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***Abstract*: This study is an attempt to evaluate the interface bond strength between two types of bituminous layer combinations in the laboratory. The cylindrical specimens have been tested for bond strength at four normal service temperatures, namely 25, 30, 35 and 40 degree C by applying different types of tack coat at varying application rates. The specimens have been prepared using normal Marshall Procedure first for the underlying layer, followed by application of tack coat and finally overlaying with the top layer in the same mould in an appropriate manner. Two types of layer combinations have been tried, namely (i) Bituminous Concrete (BC) layer on Dense Bituminous Macadam (DBM) samples and (ii) Semi Dense Bituminous Concrete (SDBC) layer on Bituminous Macadam (BM) samples. Similarly, different types of tack coat materials namely bitumen, Cationic Rapid Setting with low viscosity (CRS-1) and Cationic Medium Setting with high viscosity (CMS-2) emulsions have been used for the interface bond between the said bituminous layers. The samples thus prepared have then been tested on a specially fabricated attachment (named bond strength device) fixed to the loading frame of the Modified Marshall Testing Apparatus. It is observed that the interlayer bond strength depends on the test temperature and this decreases with increase in test temperature. It is also observed that the bond strength depends on the type of tack coat used and conditions of the type of combinations. The optimum amount of tack coat has been found to vary for tack coat type and layer combination type.**

***Keywords*: Interlayer Bond strength, Tack coat, bituminous layer combination, Bond strength**

1. Introduction

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 [1]. 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 [2]. 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 [3]. 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 [4]. To increase bonding between layers, bituminous tack coats are applied prior to overlay. Bituminous emulsions are normally used as tack coats [5]. 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 [6]. If the quantity of bituminous emulsions used is in excess or less than the required one, the interface bonding will not be satisfactory. The main objectives of this work are to fabricate a simple device that can be used in a laboratory to assess the interlayer bond strength between two bituminous layers joined by a tack coat and also, explore the best conditions for developing the bond between two specific bituminous layers in form of rate of application of emulsions.

2. Demonstrated work

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.

A. Aggregates

This laboratory case study consists of two type's bituminous layer of cylindrical specimens. One has been prepared with composite of, lower layer as dense bituminous macadam (DBM) and upper one bituminous concrete (BC). Another type has been prepared with bituminous macadam (BM) as a base course (lower layer) with semi dense bituminous concrete (SDBC) as an overlay. For preparing two bituminous composed layers aggregates were graded as per Ministry of Road Transport and Highways (2001) given in Table 1, Table 2, Table 3 and Table.4 respectively.

Table 1
MORTH gradation for DBM (NMAS 25 mm)

BIS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
37.5	100	-
26.5	90-100	95
19.0	71-95	83
13.2	56-80	68
4.75	38-54	46
2.36	28-42	35
0.300	7-21	14
0.075	2-8	4
Binder Content % by weight	Min. 4.5	5

Table 2
MORTH gradation for BC (NMAS 13 mm)

BIS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
19.0	100	-
13.2	79-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.600	26-38	32
0.300	18-28	23
0.150	12-20	16
0.075	4-10	7
Binder Content % by weight	5-7	7

Table 3
MORTH gradations for BM (NMAS 19 mm)

BIS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
19.0	100	-
13.2	90-100	95
9.5	70-90	80
4.75	35-51	43
2.36	24-39	31.5
1.18	15-30	22.5
0.300	9-19	14
0.075	3-8	5.5
Binder Content % by weight	Min. 4.5	5

The DBM and BM mixes, which use relatively larger size aggregate, are not only stiff or stable but also are economical because they use relatively lower bitumen contents and need less breaking and crushing energy or effort. BC and SDBC mix with smaller aggregate in the other way having relatively higher bitumen contents, which not only impart high flexibility but also increase their durability. The aggregates shall be clean, hard, durable, cubical shape, free from dust and friable matter, organic or other deleterious matter. The coarse aggregates are crushed gravel hard material must be retained on 4.75 mm sieve and fine aggregates must be passed in 4.75 mm sieve and retained on a 75 micron sieve. MORT&H recommended 25 mm nominal maximum aggregate size (NMAS) for DBM Base Course and 13 mm NMAS for BC Binder Course. It also recommended 19 mm NMAS for BM base course and 13 mm NMAS for SDBC course. The specific gravity of aggregates used for preparing the specimens in the laboratory has been found 2.80. The physical properties of the aggregates which found in laboratory were given in below Table 5.

Table 4
MORTH gradations for SDBC (NMAS 13 mm)

BIS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
26.5	100	-
19.0	90-100	95
13.2	56-88	72
4.75	16-36	26
2.36	4-19	11.5
0.300	2-10	6
0.075	0-8	4
Binder Content % by weight	3.3-3.5	3.5

Table 5
Physical properties of aggregates

Property	Test Method	Test Result
Aggregate Impact Value (%)	IS: 2386 (Part-IV)	14.28
Aggregate Crushing Value (%)	IS: 2386 (Part-IV)	13.02
Los Angeles Abrasion Value (%)	IS: 2386 (Part-IV)	18
Flakiness Index (%)	IS: 2386 (Part-I)	18.83
Elongation Index (%)		21.50
Specific Gravity	IS: 2386 (Part-III)	2.75
Water Absorption (%)	IS: 2386 (Part-III)	0.13

B. *Filler*

Portland slag cement (Grade 43) collected from local market passing 0.075 mm IS sieve was used as filler material to increase the binding property between the aggregates in the preparation of specimens. Its specific gravity has been found in laboratory 3.0.

C. *Binder*

During this investigation VG 30 bitumen collected from local source used as binder for preparing the specimens. Some common types of tests were performed to determine the important physical properties of these binders. The physical properties thus obtained are summarized in Table 3.6

D. *Tack Coat*

The tack coat materials selected for this study include two emulsions CMS-2 and CRS-1. Standardized tests were conducted to determine their physical properties as summarized.

E. *Preparation of Samples*

The specimens were prepared to evaluate the interlayer bond strength between the bituminous paving layers either be made in the laboratories or collect from the field as a core. The laboratories prepared samples were mixed according to the Marshall procedure specified in ASTM D1559 and follows MORT&H grading of coarse and fine aggregate for both two types of composite specimens. The specimens are prepared for evaluation of bond strength having 101 mm diameter and total height of 100 mm with the help of a special fabricated mold. These samples were compacted into two layers; DBM and BM have 60mm as base course and top layer as BC and SDBC of 40mm height respectively. In between these two layers a layer of tack coat has applied. VG-30 binder has used for mixing of the base and surface courses in 0.075mm passing cement was used as filler to increase the binding property. The specimens consisted of two layers and the tack coat are applied between them. The study also carried out with bitumen used as tack coat material and with no tack coat used in between the two bituminous layers. Graded aggregates were sampled and kept them in an oven at 160 C for at least two hours before mix with a binder to form a design mix. The lower half of the specimen called as base course was prepared by compacted the design mix to a required height of 60 mm giving 75 blows with Marshall Hammer. Once the lower layer compacted by the same number of blows on both sides; it allowed to cool at room temperature for a few days. Then a layer of stiky material (tack coat and bitumen) has been applied at one surface of the previously compacted specimen. The amount of emulsions was calculated multiplying the application rates with the surface area of the specimen. The rate of application of tack coat was selected as per MORT&H (2001) specified as given in Table.8. When the specimens have been tacked, they were allowed to cure until setting/breaking completed in a dust-free environment. The minimum setting period of emulsions is generally estimated by visual observation. Normally tack coat was brown in color, but when the water evaporates from it; its color became deep black. This process is called setting of emulsion. After setting of emulsions, it left a thin layer of bitumen residue which work as a glue between two layers as result good bond was formed. In the study two types of emulsions have been used, CRS-1 and CMS-2. CRS means cationic rapid setting and CMS means cationic medium setting emulsion. Normally rapid setting emulsion set very fast, less than half an hour. When bitumen used as sticky material in the place of tack coat, application rates consider as per MORTH specification and setting of its normally varied from half an hour to one hour maximum for creating a better bonding between two layers. Once the application and curing of the tack coat was completed on one surface of the lower layer of specimens, the loose design mix for top layer was placed over it. Total required height for the samples was deserved by compacted the loose mix with the help of Marshall Hammer applied 100 numbers of blows. All prepared specimens were allowed to cure at room temperature for a few days before testing. The specimens prepared without any tack coat, the top layer was compacted as soon as possible after the lower layer compaction. For observing the variation in bond strength without using any tack coat some time gap may be maintained between compaction of two layers. After a few days of curing at room temperature specimens have been fully prepared for the test. Before the testing procedure was carried out these specimens were cured in an oven at different temperature (25, 30, 35 and 40 C) for two hours. The specimens were tested on fabricated bond strength attachment mounted on a modified Marshall Test apparatus.

Table 6
Physical properties of VG 30 bitumen binder

Property	Test Method	Test Result
Penetration at 25°C	IS: 1203-1978	67.7
Softening Point (R&B), °C	IS: 1205-1978	48.5
Viscosity (Brookfield) At 160°C, CP	ASTM D 4402	200

Table 7
Physical properties of Tack Coats

Property	Test Method	Emulsion Type	Test Results
Viscosity by Saybolt Furol Viscometer, seconds At 50°C	ASTM D 6934	CRS-1	37
		CMS-2	114
Density in g/cm^3	As per Chehab et al. (2008)	CRS-1	0.986
		CMS-2	0.986
Residue by evaporation, percent	ASTM D 244	CRS-1	61.33
		CMS-2	67.59
Residue Penetration 25° C/100 g/5 Sec	IS: 1203-1978	CRS-1	86.7
		CMS-2	106.7
Residue Ductility 27°C cm	IS: 1208-1978	CRS-1	100+
		CMS-2	79

Table 8
Rate of application of Tack Coat as per MORT&H Specification

Type of Surface	Quantity in Kg/m^2 area
Normal bituminous surface	0.20 to 0.25
Dry and hungry bituminous surface	0.25 to 0.30
Granular surface treated with primer	0.25 to 0.30
Non bituminous surface	-
Granular base (not primed)	0.35 to 0.40
Cement Concrete pavement	0.30 to 0.35

F. Fabrication of simple attachment to measure the Interlayer Bond Strength

In the study, the laboratory prepared specimens were tested by using a fabricated attachment fitted to modify Marshall Apparatus. This device was designed based on the shearing apparatus at McAsphalt Lab (Kucharek,T et. al.,2011). The device was designed for 101 mm diameter field core or laboratory prepared samples. The device consisted of two parts for holding the specimen's at upper and lower. One was a U-shape for hold the upper part (40 mm) could move freely with minimum friction along with two guiding rods fixed on the top of the base plate and another one clamping the lower half of the specimen. The schematic diagrams of the fabricated Interlayer Bond Strength device has shown in the figure 3.2 and the photographic views shown in figure 3.3. The vertical load was transferred to the U shape plate for shear the specimens at a constant rate of 50.8 mm/min (2 in/min).

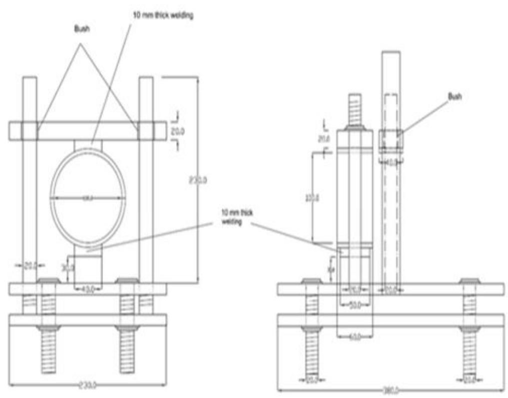

Fig. 1. Schematic diagrams of the fabricated Interlayer Bond Strength device

Fig. 2. Photographic views of the fabricated Interlayer Bond Strength device

3. Results and discussion

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, 30, 35, and 40 C 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. 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. From the figure 3, the maximum bond strength was found at 25 C 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.

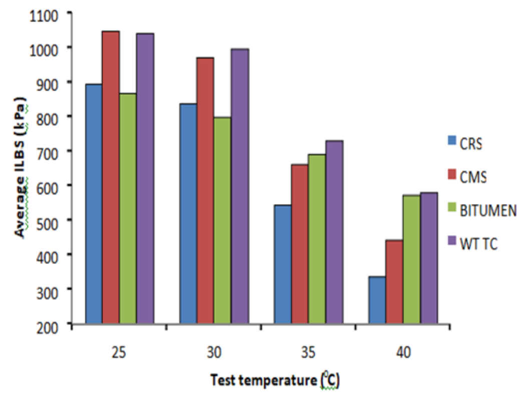

Fig. 3. Comparisons of ILBS at different test temperature made

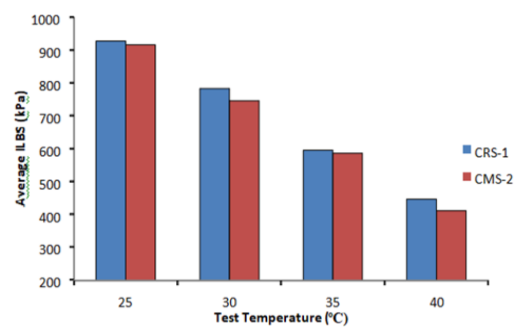

Fig. 3. Comparisons of ILBS at different test temperature made

Figure 4 From the Figure 4, the maximum mean interlayer bond strength was found at 25 degree C 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 increase.

4. Conclusion

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. 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 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 degree C, all types of tack coat used and other considerations taken for observing the interlayer bond strength have been found maximum value as compared to 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 degree C for both types of tack coat used.

References

[1] ASTM D 88 (1994). "Standard Test Method for Saybolt Viscosity". American Society for Testing and Materials, Philadelphia, USA.
[2] ASTM D244 (2004). "Standard Test Method for Residue by Evaporation of Emulsified Asphalt". American Society for Testing and Materials, Philadelphia, USA.
[3] ASTM D 4402 (2006). "Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer". American Society for Testing and Materials, Philadelphia, USA.
[4] Buchanan, M. S. and Woods, M. E. (2004). Mississippi Transportation Research Center.
[5] Chehab, G., Medeiros, M., and Solaimanian, M. (2008). "Evaluation of bond performance of Fast Tack Emulsion for Tack Coat applications." Pennsylvania Department Of Transportation, Report No. FHWA-PA-2008-017-PSU021, Pennsylvania Transportation Institute.
[6] CPB 03-1 Paint Binder (Tack Coat) Guidelines (2003), California Department of Transportation, Construction Procedure Bulletin.