

Effect of Tack Coat Type and Application Rate on Bond Strength of Flexible Pavement Layers

¹Arpana Chaurpagar, ²Akhand Pratap Singh, ³Prof. R.R.L. Birali

¹M.Tech. Scholar, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India

²Assistant Professor, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India

³Professor, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India

Abstract - This research investigates the influence of tack coat type and application rate on the interlayer bond strength between flexible bituminous pavement layers. A strong bond at the interface is essential to ensure structural integrity and long-term performance under repeated traffic loads. Two layer combinations are considered in this study: bituminous concrete (BC) over dense bituminous macadam (DBM) and semi-dense bituminous concrete (SDBC) over bituminous macadam (BM) representing commonly used pavement configurations in practice. To assess the bonding behavior, three types of tack coat materials were utilized: VG-30 paving-grade bitumen, Cationic Rapid Setting (CRS-1) emulsion, and Cationic Medium Setting (CMS-2) emulsion. The specimens were subjected to testing at service temperatures of 25°C, 30°C, 35°C, and 40°C, with varying tack coat application rates. A custom-fabricated bond strength testing device, integrated into a Modified Marshall Stability Apparatus, was employed to evaluate the interlayer shear strength of laboratory-prepared cylindrical specimens. Experimental findings reveal that interlayer bond strength declines with increasing temperature due to reduced material stiffness. The performance of tack coats varied with both emulsion type and dosage, with optimal bond strengths achieved at specific application rates depending on the material properties and mix combinations. Notably, CRS-1 emulsions demonstrated superior performance at lower temperatures, while VG-30 bitumen showed improved bonding at intermediate application rates.

This study provides critical insights into the selection and application of tack coat materials, contributing to enhanced pavement durability, minimized surface distress, and overall improved structural response under traffic loading.

Keywords: Interlayer Bond Strength, Tack Coat, Application Rate, Bituminous Pavements, Modified Marshall Apparatus, Emulsified Asphalt, Pavement Layer Interface.

I. INTRODUCTION

1.1 General

Highways are vital for a country's development and are often improved by adding new layers over existing roads. These flexible pavements are built in multiple layers to handle heavy traffic loads effectively. For the pavement to work well as one strong unit, good bonding between layers is essential. To improve this bonding, bituminous tack coats are applied between layers. These are thin layers of sticky material, often made from bitumen emulsions like CRS-1 and CMS-2. However, if the tack coat is applied in the wrong amount too much or too little it can lead to poor bonding, causing pavement failures like slippage or layer separation. This study focuses on how the type of tack coat and its application rate affect the bond strength between layers. It aims to help improve pavement performance and increase road life by finding the most effective tack coat practices.

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.



Figure 1.1: Slippage Failure

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 horizontal curves.

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 strength between pavement layers shape of a crescent are shown in figure.



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

1.3 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 as temperature, percentage of emulsions, with no tack coat use, by using bitumen as tack coat and setting time.

Hot bituminous binders, obtained through the distillation of crude oil, are also used as tack coat materials. Unlike emulsions, these binders do not carry any electrical charge. While any bitumen grade may be used, it is generally preferred to use the same grade as that used in the Hot Mix Asphalt (HMA) to ensure compatibility and effective bonding (CPB 03-1, Tack Coat Guidelines, 2003).

II. LITERATURE REVIEW

2.1 Past Studies on Evaluation of Pavement Interlayer Bond Strength

Bituminous pavements are generally constructed in several layers and proper bonding between adjacent layers is required to ensure good performance. But, this is not always

achieved and a number of premature pavement failures have been developed due to poor bonding condition. The interface bond failure paving layers is due to mainly shear force only. In the recent past, interlayer shear performance has been broadly investigated. These studies have typically developed a unique test method or instrument for analysis of the interface bond strength. Various organizations and numbers of researchers have used various test methods for observing the pavement interlayer bond strength performance.

Uzan et al. (1978) used a direct shear test device to test with a 60-70 penetration asphalt binder as a tack coat at five different application rates. The tests were conducted in two different temperature 77 and 131^oF (25 and 55^oC). The tack coat was applied on the bottom layer and 3cm (1.8inch) of mix compacted on top. The direct shear device was developed considering the specimen size with a constant displacement rate of 2.5 mm/min (0.098 in/min). The shear strength was evaluated at five different normal loading pressures of 0.05, 0.5, 1.0, 2.5 and 5 Kg/cm². The shear strength increased when the test temperature decreases and the normal pressure increases. The observed optimum tack coat application rate for this studied was 1.0 Kg/m² at 25^oC.

Molenaar et al. (1986) used a shear test device to determine the shear resistance of the tack coat at the interface of the asphalt layers. The device was mounted on a standard Marshall Stability loading press for applied a load at a rate of 0.85 mm/Sec. This device held bottom part of the compacted cylindrical specimens and shear load was applied perpendicular to the axis of the specimens of the top layer.

Mrawira and Damude (1999) observed the bond strength of the interface by direct shear test. The specimens were collected as field cores from in-service pavements. Cores were assembled in six subsets varying with pavement age. All specimens were the same type of mix and the same type of materials used. The cores were trimmed to a height of 8cm (3.15 inch) and at the top surface of the layer 0.2 to 0.3 L/m² of SS1 emulsion was applied with set times left less than one hour. When the tack coat cured, 16mm nominal maximum aggregate size compacted on the core in two lifts with 75 Marshall blows per lift as a overlays. The specimen were left to cure for two weeks at room temperature, then cut into rectangular size and placed in a water bath at 22^oC (75^oF) for thirty minutes. The specimens were sheared on a guillotine style machine at a constant displacement rate of 1 mm/min.

III. EXPERIMENTAL METHODOLOGY

3.1 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.

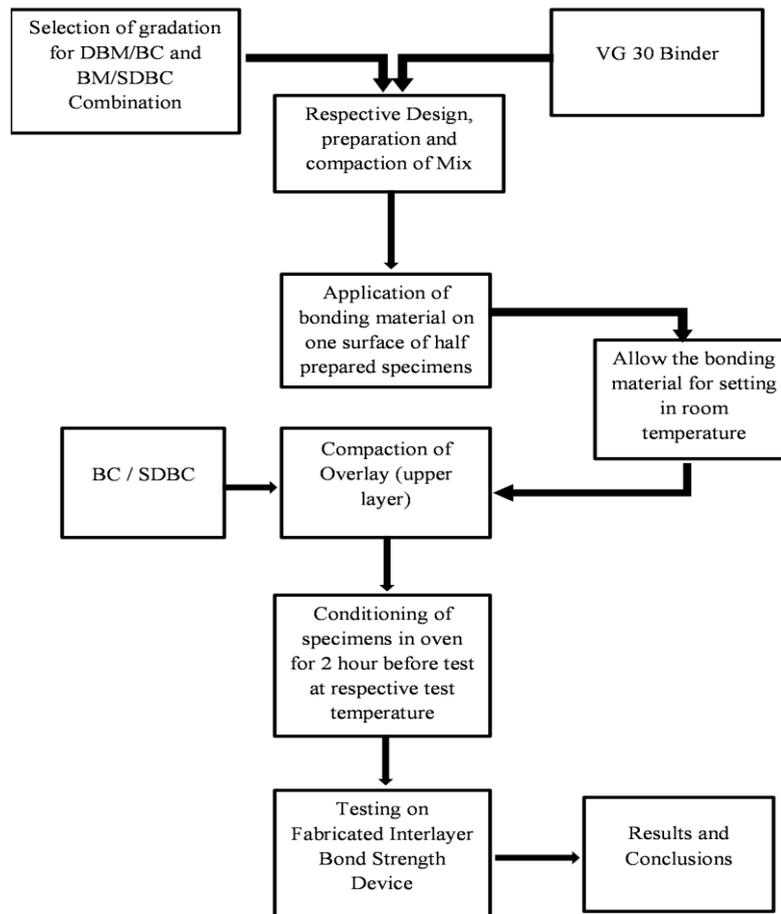


Figure 3.1: Methodology of the Experimental Work

Table 3.1: 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

Table 3.2: 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 3.3: Physical Properties of Tack Coats

Property	Test Method	Emulsion Type	Test Results
Viscosity by Saybolt Furol Viscometer, seconds: At 50 ⁰ 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 ⁰ C/100 g/5 Sec	IS : 1203-1978	CRS-1	86.7
		CMS-2	106.7
Residue Ductility 27 ⁰ C cm	IS : 1208-1978	CRS-1	100+
		CMS-2	79

3.2 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 coats 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 1600C 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 sticky 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.3.8.

Table 3.4: 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



Figure 3.2: Photographic Views of the Fabricated Interlayer Bond Strength Device

IV. RESULT AND DISCUSSIONS

4.1 Introduction

An experimental study was conducted to evaluate the interlayer bond strength between two types of bituminous layers using laboratory-prepared cylindrical specimens (100 mm diameter × 100 mm height). Testing was performed using a custom attachment on a Marshall loading frame at four temperatures: 25°C, 30°C, 35°C, and 40°C.

The study examined the effect of two tack coat emulsions (CRS-1 and CMS-2) at varying application rates. CRS-1 was tested with setting times of 0.5, 1, and 1.5 hours, while CMS-2 was evaluated at 6, 9, and 12 hours. VG-30 bitumen was also used as a tack coat with curing times of 0, 0.5, and 1 hour. Additionally, specimens without tack coat were tested.

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°C	30°C	35°C	40°C
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

4.2 Variation of ILBS with Rate of Application for CMS-2 Type Tack Coat at Various Setting Times

In Table 4.4 present the average interlayer bond strength when setting time is 6 hours. The highest bond strength values are observed at application rate of 0.15 Kg/m² at all test temperatures for the CMS-2 type of tack coat.

Table 4.2: ILBS of CMS-2 Type Tack Coat (Considering 6 Hour Setting Time)

Type of Tack Coat	Application Rate (Kg/m ²)	Average ILBS At Different Test Temperature (Kpa)			
		25°C	30°C	35°C	40°C
CMS-2	0.1	962.57	691.37	479.16	318.01
	0.15	1013.50	704.10	535.16	342.93
	0.2	918.43	697.73	497.84	311.94
	0.25	887.45	672.27	423.56	255.92
	0.3	729.14	616.67	392.58	230.88

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

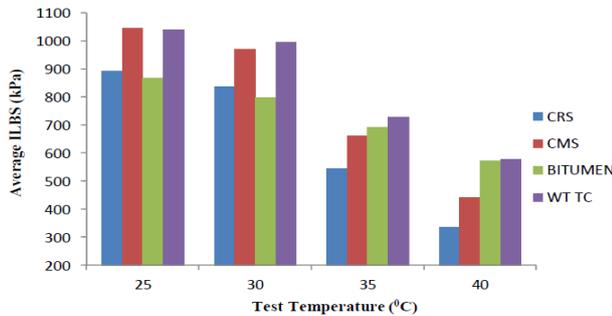


Figure 4.1: Comparisons of ILBS at Different Test Temperature Made

From the figure 4.29, the maximum bond strength was found at 25⁰C 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

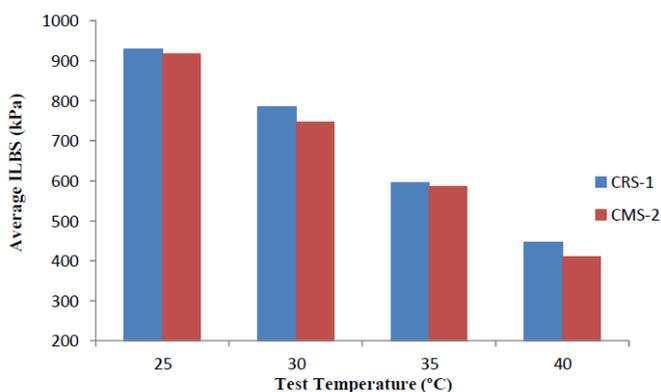


Figure 4.2: Comparisons of ILBS at Different Test Temperature Made

From the figure 4.2, the maximum mean interlayer bond strength was found at 25⁰C 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.

V. CONCLUSION AND FUTURE SCOPE

5.1 Conclusions

This study evaluated the interlayer bond strength between two types of bituminous layer combinations DBM/BC and BM/SDBC using different tack coat materials, application rates, setting times, and test temperatures. A custom attachment was used with the Modified Marshall Test Apparatus to perform shear testing.

For DBM/BC:

- **CRS-1** showed the highest bond strength at **0.25 kg/m²**, and **CMS-2** at **0.15 kg/m²**, across all temperatures.
- Best performance was observed at a **setting time of 1 hour** for CRS-1 and **9 hours** for CMS-2.
- **VG-30 bitumen** performed best at **0.2 kg/m²** with a setting time of **0.5 hours**.
- Without tack coat, maximum strength was observed when layers were compacted **immediately** after each other.
- The **highest bond strength** occurred at **25°C**, with strength decreasing at higher temperatures.

For BM/SDBC:

- Both **CRS-1** and **CMS-2** showed best results at **0.15 kg/m²** across all temperatures.
- Similar to DBM/BC, bond strength **decreased with temperature**, with the **maximum at 25°C**.

5.2 Future Scope of Work

- Use **finite element analysis** to simulate and compare bond strength results with lab findings.
- Test the fabricated device under **different loading conditions**.
- Compare current results with **existing literature and past studies**.
- Evaluate **field core samples** and compare them with laboratory-prepared specimens.

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.
- [7] Giri, J. P., Panda, M. and Chattaraj, U. (2013). "Inter-Layer Strength of Bituminous Paving Layers– A Laboratory Case Study." 2nd workshop on Indian water management in 21st century & symposium on sustainable infrastructure development (IWMSID-2013), IIT Bhubaneswar, Odisha
- [8] IS: 2386 (1963), "Methods of Test for Aggregates for Concrete (Part- I): Particle Size and Shape", Bureau of Indian Standards, New Delhi.
- [9] IS: 2386 (1963), "Methods of Test for Aggregates for Concrete (Part-III): Specific Gravity, Density, Voids, Absorption, Bulking", Bureau of Indian Standards, New Delhi.
- [10] IS: 2386 (1963), "Methods of Test for Aggregates for Concrete (Part-IV): Mechanical Properties", Bureau of Indian Standards, New Delhi.
- [11] IS: 1203 (1978), "Methods for Testing Tar and Bituminous Materials: Determination of Penetration", Bureau of Indian Standards, New Delhi.

Citation of this Article:

Arpana Chaurpagar, Akhand Pratap Singh, & Prof. R.R.L. Birali. (2025). Effect of Tack Coat Type and Application Rate on Bond Strength of Flexible Pavement Layers. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 9(6), 205-211. Article DOI <https://doi.org/10.47001/IRJIET/2025.906027>
