International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Experimental Analysis of Bond Strength between Bituminous Paving Layers in Laboratory Settings

Rajendra Tigga [1] Durgesh Kumar Sahu[2]

M.Tech Scholar, Assistant Professor

Department of Civil Engineering Shri Rawatpura Sarkar University, Raipur

Abstract

The purpose of this research is to evaluate the bond strength between various combinations of bituminous layers in a laboratory setting. The bond between these layers is critical for the overall performance of pavement under traffic stresses. Bituminous tack coatings are widely used to improve interlayer adherence. This study examines two layer combinations: bituminous concrete (BC) on dense bituminous macadam (DBM) and semi-dense bituminous concrete (SDBC) on BM. A variety of tack coat materials are employed, 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 typical service temperatures (25°C, 30°C, 35°C, and 40°C) and various tack coat application rates. The testing procedure follows the standard Marshall Procedure, where the tack coat is applied, and the top layer is suitably covered 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 connected to the loading frame of the Modified Marshall Testing Apparatus.

The results indicate that interlayer bond strength is influenced by test temperature, with a reduction observed as temperature increases. The type of tack coat and the specific layer combination also affect binding strength. The required amount of tack coat varies depending on the tack coat type and layer combination.

Overall, this study provides insights into improving the bond between bituminous layers in pavements, thereby enhancing their performance and durability under traffic-induced stresses.

Keywords: Interlayer bond strength, Tack coat, Bituminous layer combination, Bond strength device.

1. Introduction

1.1 General

Highways are essential for a country's growth and development. Both developed and developing countries continuously work on sustaining, building, and improving road infrastructures to handle increased traffic. One common method is to strengthen existing pavements by overlaying them with additional material. Flexible pavements are designed in multiple layers to distribute stress effectively under heavy traffic loads. Their viscous nature allows these layers to sustain significant plastic deformation, but repeated heavy loading often leads to distress and failure. Good bonding between the layers is crucial for the pavement to function as a single structure. Poor adhesion can weaken the pavement and cause premature failures. To enhance bonding, bituminous tack coats are applied before overlaying. These emulsions are

commonly used, but opinions on their effectiveness vary among engineers. The tack coat, made of a thin bitumen layer, ensures adherence between layers. However, the quantity of bituminous emulsions must be precise; too much or too little can result in poor interface bonding.

1.4 Objectives

Based on the discussion above, the objectives of the present study are:

- **Development of Testing Equipment:** Fabricate a simple testing arrangement compatible with a conventional Modified Marshall test apparatus to directly measure the interlayer bond strength between two pavement layers.
- **Experimental Evaluation:** Conduct experiments using the fabricated device to assess various material combinations.
- **Sample Preparation:** Prepare samples under varying conditions, including temperature, percentage of emulsions, absence of tack coat, use of bitumen as a tack coat, and different setting times.

3 Expérimental Méthodologies

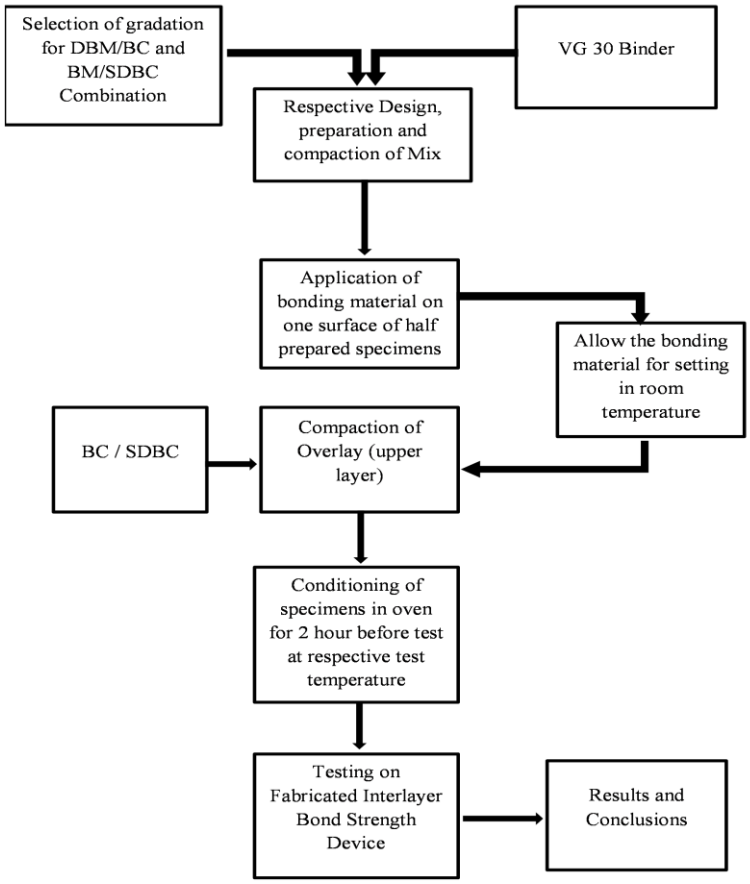

Figure 3.1 Methodology of the Experimental Work

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 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 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

4.2 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.

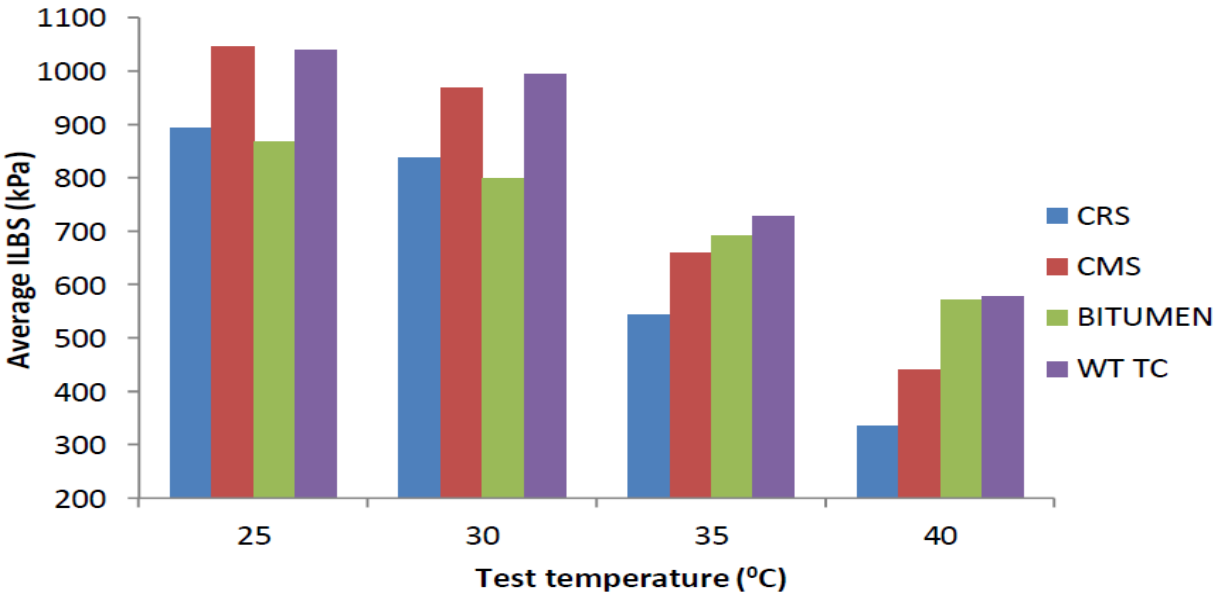

Figure 4.29 Comparisons of ILBS at Different Test Temperature Made

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.

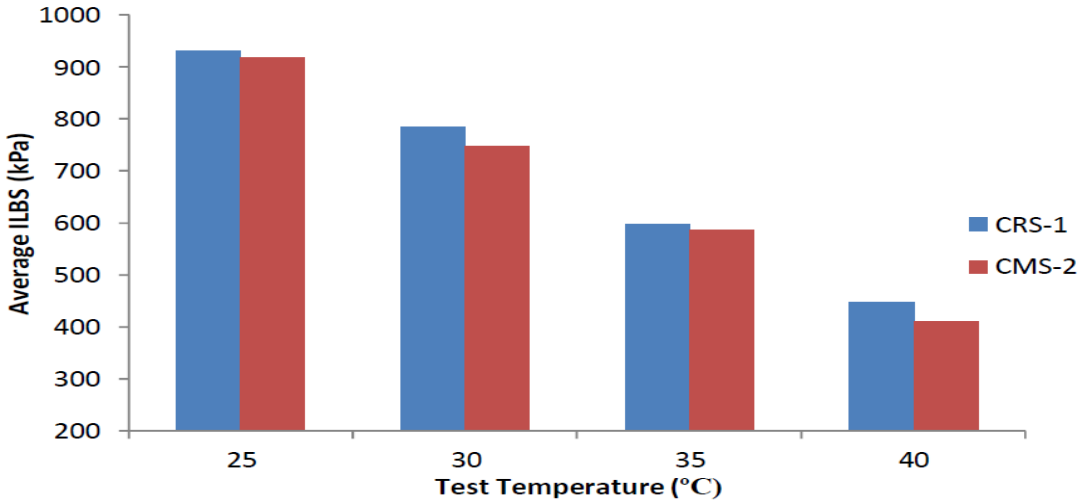

Figure 4.30 Comparisons of ILBS at Different Test Temperature Made

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

This study evaluated the interlayer bond strength of different tack coats using laboratory-prepared samples for DBM/BC and BM/SDBC layer combinations. A special device was designed and fabricated to fit the Modified Marshall Test apparatus for this purpose. Specimens were tested at four common temperatures: 25°C, 30°C, 35°C, and 40°C. Each specimen consisted of two bituminous layers bonded with either emulsion or bitumen, with the upper and lower layer combinations being DBM or BC and BM and SDBC, respectively. Various application rates and setting times were tested to identify the optimal conditions for bond strength. The following conclusions were drawn from the test results:

- Fabrication of Testing Device: Successfully designed and fabricated a device to measure interlayer bond strength.
- Temperature Variation: Tested specimens at four different temperatures relevant to the region.
- Layer Combinations: Evaluated bond strength for different layer combinations of DBM, BC, BM, and SDBC.
- Application Rates and Setting Times: Explored various emulsion application rates and setting times to determine optimal conditions.

5.2 Future Scope of Works

- Finite Element Analysis: Analyze bond strength using the finite element method and compare with laboratory results.

- Loading Combinations: Experiment with various loading combinations using the fabricated device.
- Comparison with Literature: Compare experimental results with existing literature and previous experiments.
- Field vs. Laboratory Samples: Test field core samples and compare their bond strength with laboratory-prepared samples.

Reference

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 ofPenetration", Bureau of Indian Standards, New Delhi.
12. IS: 1205 (1978), "Methods for Testing Tar and Bituminous Materials: Determination ofSoftening Point", Bureau of Indian Standards, New Delhi.
13. IS: 1208 (1978), "Methods for Testing Tar and Bituminous Materials: Determination of Ductility (First Revision)", Bureau of Indian Standards, New Delhi.
14. IS: 8887 (2004), "Bitumen Emulsion for Roads (Cationic Type) - Specification (Second Revision)", Bureau of Indian Standards, New Delhi.
15. Kucharek,T., Esenwa, M. and Davidson, J.K. (2011), "Determination of factors affecting shear testing performance of Bituminous emulsion tack coats." 7e congrès annuel de Bitume Québec, Saint-Hyacinthe, Canada.
16. Junior, M. S. M. (2009). "Evaluation of Bond Performance of an Ultra-rapid Setting Emulsion for Tack Coat Applications". (Doctoral dissertation, The Pennsylvania State University).
17. Ministry of Road Transport and Highways (2001), ''Manual for Construction and Supervision of Bituminous Works'', New Delhi.
18. Miro, R., Martínez, A., & Perez, F. (2006). "Evaluation of Effect of Heat-Adhesive Emulsions for Tack Coats with Shear Test: From the Road Research Laboratory of Barcelona." Transportation Research Record: Journal of the Transportation Research Board, 1970 (1), 64-70.
19. Mohammad, L.N., Raqib, M.A., and Huang, B. (2002), "Influence of Bituminous Tack Coat Materials on Interface Shear Strength," Transportation Research Record: Journal of the Transportation Research Board, No. 1789, pp. 56-65, Washington, D.C., Transportation Research Board of the National Academies.
20. Mohammad, L. N., Bae, A., Elseifi, M. A., Button, J., & Scherocman, J. A. (2009). "Evaluation of Bond Strength of Tack Coat Materials in Field". Transportation Research Record: Journal of the Transportation Research Board, 2126 (1), 1-11.
21. Molenaar A.A.A., Heerkens, J.C.P., and Veroeven, J.H.M. (1986) "Effects of Stress Absorbing Membrane Interlayer's." *Asphalt Paving Technology*, Vol.55, Proceedings of the Association of Asphalt Paving Technologies.
22. Paul, H. R., & Scherocman, J. A. (1998). "Friction testing of tack coat surfaces". Transportation Research Record: Journal of the Transportation Research Board, 1616 (1), 6-12.