

# Evaluation of bond between Bituminous Pavement 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 delamination. 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<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> made at 25<sup>o</sup>C temperature are presented. It is observed that CRS-1 as tack coat provides higher interface bond strength value compared to CMS-2. Similarly, irrespective of the types of emulsions used as tack coat, the optimum rate of application is found to be 0.25 kg/m<sup>2</sup> as recommended in MORT&H's specifications.

**KEYWORDS:** Interlayer, bond strength, shear strength, tack coat, performance

## I. INTRODUCTION

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.

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Vol. 6, Issue 4, April 2017

Different organizations and different researchers as mentioned in the preceding paragraphs have developed and studied on various devices and determined the bond strengths of the interlayer of the bituminous pavement. While some have used complicated devices, it has been decided to go for simpler devices by fabricating simpler setups and using the same in existing Marshall Stability Apparatus then saving the time and cost aspects.

## II. OBJECTIVE OF THE WORK

The present study is aimed at the study evaluation of bond between bituminous pavement layers. The objectives of the present study are: The primary objective of this study is to fabricate a few simple testing devices for the evaluation of the bond strength offered by the tack coats at the interface between bituminous pavement layers in the laboratory scale by performing several laboratory tests with different tack coat application rates. The ideal design will be that the standard setup which produces consistent results comparable to others. A secondary goal of this study is to provide helpful information for the selection of the best type of tack coat materials and optimum application rate.

## III. MATERIALS AND METHODOLOGY

Following are the materials which are used in the present study:

### Physical Properties of Tack Coat:

Property	Test Method	Emulsion type	Test Results
Viscosity by Saybolt Furol viscometer, seconds: At 500 C	ASTM D 6934	CRS-1	37
		CMS-2	114
Density in g/cm <sup>3</sup>	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 250 C/100 g/5 sec	IS : 1203-1978	CRS-1	86.7
		CMS-2	106.7
Residue Ductility 270 C cm	IS : 1208-1978	CRS-1	100+
		CMS-2	79

## PREPARATION OF SAMPLES

The mixes were prepared according to the Marshall procedure specified in ASTM D1559. Laboratory specimens prepared to determine interface bond strength were generally 100 mm and 150 mm in diameter and 100 mm in total height. Each specimen consisted of two layers with tack coat applied at the interface. Test variables included 100 mm and 150 mm diameter specimen and two conventional emulsions namely CMS-2 and CRS-1 as tack coats with application rates varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup>. The bottom layer consisted of a Dense Bituminous Macadam (DBM) with a VG 30 binder; the top layer was a Bituminous Concrete (BC) with a VG 30 binder. For the preparation of bottom layer, first the loose mix was compacted by giving 75 blows using Marshall Hammer and then it was allowed to cool down at room temperature.

Next, the amount of tack to be applied on the specimen surface was calculated by multiplying the tack coat application rate by the surface area of a specimen. The rate of application of tack coat was selected as per MORT&H Specification which is given in the Table.

# International Journal of Innovative Research in Science, Engineering and Technology

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Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

### Rate of application of Tack Coat as per MORT&H Specification

Type of Surface	Quantity in kg per m <sup>2</sup> 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)	0.25 to 0.30
Cement Concrete pavement	0.30 to 0.35

The calculated amount of tack coat was then sprayed onto one face of the sample. Once the specimens had been tacked, they were allowed to cure until setting completed in a dust-free environment. The minimum setting period of emulsions is generally estimated by visual observation. Emulsions are mostly brown in color, and they become black as they set due to the evaporation of water from the emulsions. The water in an emulsion evaporates during or after its application to aggregates. This process is called setting of emulsions. Rapid setting emulsions set very fast, normally less than half an hour. Slow setting emulsions take longer to set. Once the application and curing of the tack coat was complete, the top layer of the specimen was compacted by placing the bottom layer in a compaction mould and compacting loose mix on top of the tack-coated bottom half by giving the same no of blows. All prepared specimens were allowed to cure at room temperature for few days before testing.

## IV. RESULTS AND DISCUSSION

The interface bond strength results obtained from the three shear test models conducted at a temperature of 25<sup>0</sup>C on 100 mm and 150 mm diameter specimens with CMS-2 and CRS-1 as tack coats at application rate varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup>.

### Shear testing model no. 1

The test was conducted on 100 mm diameter cylindrical specimens with CRS-1 and CMS-2 as tack coats applied at application rate varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> at a temperature of 25<sup>0</sup>C. As seen in table, the specimen with CRS-1 as tack coat exhibited higher shear strength as compared to CMS-2 for all application rates.

### Results of the shear strength of 100 mm diameter specimens using Shear testing model no. 1 at 25<sup>0</sup>C

Tack Coat Type	Application rate(kg/m <sup>3</sup> )	Load (kN)	Shear Strength (kPa)	Average Shear Strength (kPa)
CMS-2	0.20	3.228	411.001	429.590
CMS-2	0.20	3.374	429.590	
CMS-2	0.20	3.52	448.179	
CMS-2	0.25	4.397	559.842	572.277
CMS-2	0.25	4.397	559.842	
CMS-2	0.25	4.690	597.148	
CMS-2	0.30	4.032	513.369	538.155
CMS-2	0.30	4.251	541.253	
CMS-2	0.30	4.397	559.842	
CRS-1	0.20	3.812	485.358	460.615
CRS-1	0.20	3.667	466.896	
CRS-1	0.20	3.374	429.590	
CRS-1	0.25	4.543	578.431	597.106
CRS-1	0.25	4.690	597.148	
CRS-1	0.25	4.836	615.737	
CRS-1	0.30	4.543	578.431	575.376
CRS-1	0.30	4.397	559.842	
CRS-1	0.30	4.617	587.853	

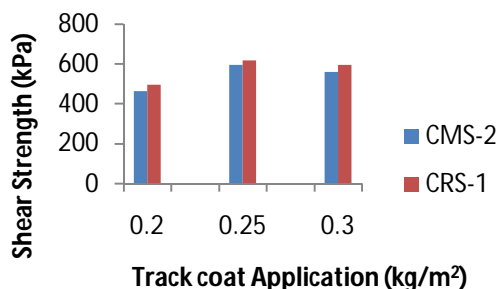
# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 4, April 2017

As shown in figure , the optimum rate of application was found to be 0.25 kg/m<sup>2</sup> for both CMS-2 and CRS-1 as tack coat.



**Figure : Plot of Shear Strength v/s Tack Coat application rates for 100 mm diameter specimens using Shear testing model no. 1.**

### Shear testing model no. 2

The test was conducted on 150 mm diameter cylindrical specimens with CRS-1 and CMS- as tack coats applied at application rate varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> at a temperature of 250C. As seen in table and figure the specimen with CRS-1 as tack coat exhibited slightly higher shear strength than CMS-2 for all tack coat application rates.

**Results of the shear strength of 150 mm diameter specimens using Shear testing model no. 2 at 25<sup>o</sup>C**

Tack Coat Type	Application rate(kg/m <sup>3</sup> )	Load (kN)	Shear Strength (kPa)	Average Shear Strength (kPa)
CMS-2	0.20	7.417	419.715	419.583
CMS-2	0.20	7.117	402.739	
CMS-2	0.20	7.710	436.296	
CMS-2	0.25	9.193	520.216	531.421
CMS-2	0.25	9.490	537.023	
CMS-2	0.25	9.490	537.023	
CMS-2	0.30	9.193	520.216	503.428
CMS-2	0.30	8.896	503.409	
CMS-2	0.30	8.600	486.659	
CRS-1	0.20	8.007	453.102	453.084
CRS-1	0.20	7.710	436.296	
CRS-1	0.20	8.303	469.853	
CRS-1	0.25	9.490	537.023	553.735
CRS-1	0.25	10.080	570.410	
CRS-1	0.25	9.786	553.773	
CRS-1	0.30	9.638	545.398	535.193
CRS-1	0.30	9.341	528.591	
CRS-1	0.30	9.394	531.590	

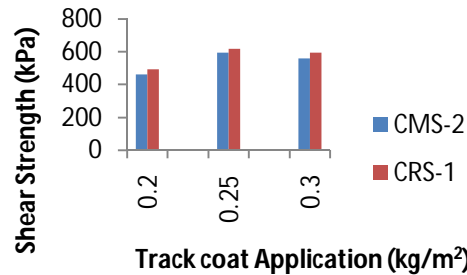
As shown in figure, the optimum rate of application was found to be 0.25 kg/m<sup>2</sup> for both CMS-2 and CRS-1 as tack coat.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017



**Figure: Plot of Shear Strength v/s Tack Coat application rates for 150 mm diameter specimens using Shear testing model no. 2.**

### Shear testing model no. 3

The test was conducted on 150 mm diameter cylindrical specimens with CRS-1 and CMS-2 as tack coats applied at application rate varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> at a temperature of 250C. As seen in table and figure the specimen with CRS-1 as tack coat exhibited slightly higher shear strength than CMS-2 at an application rate.

#### Results of the shear strength of 150 mm diameter specimens using Shear testing model no. 3 at 25<sup>o</sup>C

Tack Coat Type	Application rate(kg/m <sup>3</sup> )	Load (kN)	Shear Strength (kPa)	Average Shear Strength (kPa)
CMS-2	0.20	9.193	520.216	537.004
CMS-2	0.20	9.786	553.773	
CMS-2	0.20	9.490	537.023	
CMS-2	0.25	11.560	654.161	676.607
CMS-2	0.25	12.450	704.524	
CMS-2	0.25	11.860	671.137	
CMS-2	0.30	11.414	645.899	634.732
CMS-2	0.30	10.970	620.774	
CMS-2	0.30	11.266	637.524	
CRS-1	0.20	9.786	553.773	570.523
CRS-1	0.20	10.082	570.523	
CRS-1	0.20	10.378	587.273	
CRS-1	0.25	12.450	704.524	704.430
CRS-1	0.25	12.150	687.548	
CRS-1	0.25	12.745	721.218	
CRS-1	0.30	11.710	662.649	668.195
CRS-1	0.30	11.857	670.967	
CRS-1	0.30	11.857	670.967	

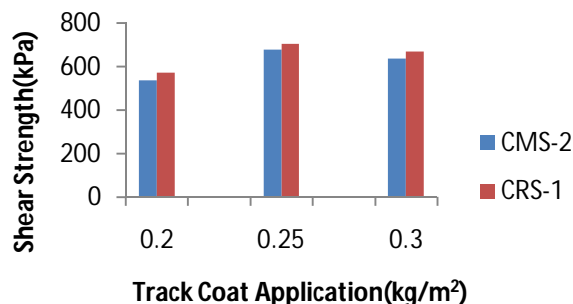
As shown in figure , the optimum rate of application was found to be 0.25 kg/m<sup>2</sup> for both CMS-2 and CRS-1 as tack coat.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017



**Figure: Plot of Shear Strength v/s Tack Coat application rates for 150 mm diameter specimens using Shear testing model no. 3.**

### Overall Performance of tack coat

The average shear strength of the specimens with both types of emulsions, namely CMS-2 and CRS-1 as tack coat at application rates varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> considering all three models together, are calculated as shown in tables.

### Results of the average shear strength using CMS-2 as tack coat for all three models at 25<sup>o</sup>C

Model No	Rate of Application (kg/m <sup>2</sup> )	Specimen No	Shear Strength (kPa)	Average Shear Strength (kPa)
1	0.20	1	485.358	494.740
		2	466.896	
		3	429.590	
2	0.20	1	453.102	
		2	436.296	
		3	469.853	
3	0.20	1	553.773	
		2	570.523	
		3	587.273	
1	0.25	1	578.431	618.424
		2	597.148	
		3	615.737	
2	0.25	1	537.023	
		2	570.410	
		3	553.773	
3	0.25	1	704.524	
		2	687.548	
		3	721.218	
1	0.30	1	578.431	545.398
		2	559.842	
		3	587.853	
	0.30	1	545.398	

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

2	0.30	2	528.591	592.921
	0.30	3	531.590	
3	0.30	1	662.649	
	0.30	2	670.967	
	0.30	3	670.967	
	0.30	3	670.967	

### Results of the average shear strength using CRS-1 as tack coat for all three models at 25°C

Model No	Rate of Application (kg/m <sup>2</sup> )	Specimen No	Shear Strength (kPa)	Average Shear Strength (kPa)
1	0.20	1	485.358	494.740
	0.20	2	466.896	
	0.20	3	429.590	
2	0.20	1	453.102	
	0.20	2	436.296	
	0.20	3	469.853	
3	0.20	1	553.773	
	0.20	2	570.523	
	0.20	3	587.273	
1	0.25	1	578.431	618.424
	0.25	2	597.148	
	0.25	3	615.737	
2	0.25	1	537.023	
	0.25	2	570.410	
	0.25	3	553.773	
3	0.25	1	704.524	
	0.25	2	687.548	
	0.25	3	721.218	
1	0.30	1	578.431	592.921
	0.30	2	559.842	
	0.30	3	587.483	
2	0.30	1	545.398	
	0.30	2	528.591	
	0.30	3	531.590	
3	0.30	1	662.649	
	0.30	2	670.967	
	0.30	3	670.967	

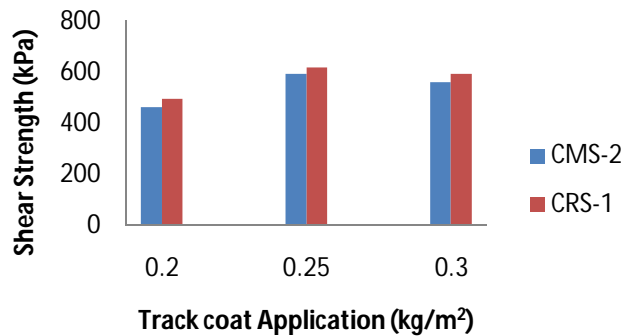


## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017



**Figure : Average Shear Strength v/s Application rates for the three models.**

The average maximum shear strength was observed on specimens with CRS-1 as tack coat at an application rate of 0.25 kg/m<sup>2</sup> while the specimens with CMS-2 at an application rate of 0.20 kg/m<sup>2</sup> showed the average minimum shear strength as shown in figure 4.5. Using CMS- 2 as tack coat the average shear strength values were obtained as 462.059, 593.435 and 558.772 kPa at application rates of 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> respectively. Similarly using CRS-1 as tack coat at application rates of 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> the average shear strength values obtained were 494.740, 618.424 and 592.921 kPa respectively.

### V. CONCLUSIONS

The below conclusions are drawn from the experimental investigated:

A laboratory study was conducted to evaluate the bond strength between the Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) layers 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 250 C by applying a shear force of constant deformation rate of 50.8 mm/min. While the shear testing model no. 2 and 3 were fabricated to evaluate the bond strength of 150 mm diameter cylindrical specimens. The samples were prepared in laboratory by applying CMS-2 and CRS-1 as tack coat at interface at application rates varying at 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup>. The following are specific observations drawn from the test results.

- The test results concluded the application rate of 0.25 kg/m<sup>2</sup> as the optimum one for all the tack coats.
- Generally, CRS-1 as tack coat provided the highest shear strength at all application rates, 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> as compared to CMS-2.49
- The shear strength values obtained from shear testing model no. 3 were higher than those obtained from model no.1 and 2 for all types of tack coat at all application rates. This might be due to eccentricity as the shear load was applied near the interface therefore; the shear strength values obtained were lower than those obtained from model no. 3 where a concentric shear load was applied.
- Considering all models together, average shear strength values were found to be as 462.059, 593.435 and 558.772 kPa using CMS-2 as tack coat at application rates of 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> respectively while using CRS-1 as tack coat at application rates of 0.20 kg/m<sup>2</sup>, 0.25 kg/m<sup>2</sup> and 0.30 kg/m<sup>2</sup> the average shear strength values obtained were 494.740, 618.424 and 592.921 KPa respectively.

### REFERENCES

- [1] "Bituminous Tack Coat." Unified Facilities Guide Specification (UFGS) 02744N.
- [2] Cross, S. A. and P. P. Shrestha (2004). "Guidelines for Using Prime and Tack Coats." Report No. FHWA-CFL-04-001, Central Federal Lands Highway Division, FHWA, Lackwood, CO.
- [3] 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 Bitumen Québec*, Saint-Hyacinthe, Canada.



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(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

- [4] 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
- [5] Paul, H. R. and Scherocman, J. A. (1998). "Friction Testing of Tack Coat Surfaces," *Transportation Research Record 1616*, Transportation Research Board, National Research Council, Washington, DC; pp. 6-12.