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STUDYING USING A DIFFERENT TYPES OF EMULSIFIED ASPHALTS MATERIALS AS A BONDING BETWEEN PAVEMENT LAYERS

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ABSTRACT

Asphalt roadway is a complex structure usually consists of surface, the base and subbase courses on a subgrade. A complete bond between layers will made the pavement work as a single composite structure. A slippage is the one most common distress due to poor bonding among pavement layers which decrease the life of overlay pavement structure. A tackcoats was a use of an asphalt emulsion between a current bituminous surface and a newly constructed bituminous overlay and usage to raise the bond between bituminous layers (two layers). This study is a try to estimate bond strength at the interface among pavement layers by performing laboratory tests. FDOT test method use to evaluate the bond between bituminous layers, to carry these objective cylinder specimens with 101.6 mm diameter need set using normal Marshall Process firstly for the fundamental layer, follow in application of tackcoat and lastly overlay with the upper layer in the similar mould in a fitting manner. After the samples tested it is detected interface bond strength depend on tack coat type and rate.

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 **(Sutradhar, 2012).**

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 1310F (25 and 55℃). 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/cm^2. 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/m^2 at 25℃.

Mohammad et al. (2002) evaluated the bond strength of tack coat used in the interface of the bituminous paving layers by using the Superpave shear tester,which consists of a shear box set up for 150 mm (6 inch) diameter specimens. The specimens were compacted up to 50 mm and tack coat applied in five different application rates (0.0 to 0.9 L/m^2), the samples were allowed to cure and second lift is placed on top and compacted. The tack coat bond strength evaluated with two PG asphalt binders (PG 64-2P and PG 76-22M) and four emulsified asphalts (CRS-2P, CSS-1, SS-1 and SS-1h). The test was conducted on two test temperatures 25 and 55℃ (77 and 131F). They observed CRS-2P emulsion as the best performer and 25℃ (77F) test temperature gives five times more shear strength then 55℃(131F)

Sholar et al. (2002) was developed a simple direct shear test device to measure the shear strength of field cores at their interface. The test was performed at 25℃(77F), with a constant rate of loading 50.8 mm/min (2in/min).

The field cores were obtained from test sections with no tack, and with 0.091, 0.266 and 0.362 l/m^2 (0.02, 0.06, 0.08gal/yd^2) tack coat application rate.

The Layer-Parallel Direct Shear test device was an EMPA (Swiss Federal Laboratories for Materials Testing and Research) modified version of the device developed by **Leutner (1979)** in Germany. **Raab and Partl (2004)** were modified it and one part of the 150 mm diameter cylindrical specimen placed on a circular u-bearing and held with a well-defined clamp. The other part was suspended to allow for transferring the shear force, induced by a semicircular shear yoke with constant deformation rate of 50.8 mm/min. This modified device was easily fitted to an ordinary servo-hydraulic Marshall testing machine or any standard universal testing machine. The tests were conducted at a temperature of 20℃ by keeping the specimens in a climate chamber for 8 hours.

In Italy Univarsita Politecnica Delle Marche **Santagata et al. (1993)** design Florida Method of Test the ASTRA (Ancona Shear Testing research and Analysis apparatus) for observing the interlayer bond shear strength of bituminous paving layers. The system consist of a direct shear box to hold the cylindrical specimens of 100 mm diameter placed in two independent half-box and mounted on a movable table. A horizontal load is applied along the interface of double-layered specimens at a constant displacement rate of 2.5 mm/min until failure; in the meantime, a constant normal load is applied on top of the specimen. During the test process, the shear force, vertical displacement and the horizontal displacement were recorded. The study was conducted to observe the influence of tack coat type, temperature, and applied normal load, on the interlayer shear resistance. The study was concluded that the interface shear strength increased with an increase in normal stress for a given temperature and shear strength was found to increase with a decrease in temperature for a given normal stress. The square cross section of 100×100mm specimens was also tested on ASTRA.

OBJECTIVE AND SCOPE

The objective of this study was to explore the factors that impact the adhesive bond providing by the tack coats at the interface among pavement lifts; in order to facilitate the construction of roads with more guarantee of achieving the design requirements. In this research studying the effect of the following factors on the bond strength Asphaltic pavement layers:

1. The kinds of tack coat materials, 3 types of tack coat will be used.
2. Application rates of tack coat materials.
3. Using FDOT direct shear test for measuring bond strength between asphalt pavement layers.

MATERIAL USED IN THE EXPERIMENTAL WORK

Materials were estimated conferring to the ASTM standard specifications and compared with the SCRB (2003) [4] specification requirements.

Asphalt Cement

One type of asphalt cement (40-50) penetration graded is used in this work. It is gained from [Dourah Refinery], south-west of Baghdad. The physical properties of the asphalt cement are presented in Table. 1.

Table. 1 The Physical Properties of Asphalt Cement

Property	**Test Condition**	**Unit**	**ASTM Designation No.**	**Penetration Grade (40-50)**	**SCRB Specification 2003**
Penetration	25 ℃, 100 gm , 5sec	1/10 mm	D-5	44	40-50
Viscosity	135 165℃	Pas.sec	D-4402	0.525 0.137	----
Softening point	Ring &Ball	(℃)	D-36	49	----
Ductility	25 ℃, 5cm/min	cm	ASTM D-113	120	+100
Specific Gravity	25℃	-----	ASTM D-70	1.05	-----
Flash Point	Cleveland open Cup	(℃)	D-92	280	>232

After Thin Film Oven Test ASTM D 1754					
Penetration of Residue	25 Č, 100 gm, 5sec	1/10 mm	D-5	30	>55%
Ductility of Residue	25 ℃, 5cm/min	cm	D-113	84	>25%

Aggregate

The crushed quartz aggregates basis which is used to fix the specimens is Al-Nibaie quarry which is usually used in local asphalt paving. The outcomes of physical properties and chemical properties are presented in Tables. 2 and 3 respectively.

Table. 2 Physical Properties of Selected Aggregate

Laboratory Test	**Coarse Aggregate**	**Fine Aggregate**
Bulk Specific Gravity (ASTM C-127 and C128)	2.61	2.631
Apparent Specific Gravity (ASTM C127 and C128)	2.641	2.6802
Percent Water Absorption (ASTM C-127 and C128)	0.423	0.57
Percent Wear(Loss Angeles Abrasion) (ASTM C-131)	19.3%	----
Percent Sand equivalent D2419	-----	52
Angularity for Coarse aggregate ASTM D5821	97%	----
Percent flat and elongated particles D4791	Flat	2%
	Elongation	5%

Table. 3 Chemical Properties of Selected Aggregate*

Chemical Compound	**Content,%**
Silica, Sio2	83.53
Lime ,Cao	4.33
Magnesia, MgO	0.76
Sulfuric Anhydride,SO3	2.8
Alumina,Al2O3	0.50
Ferric Oxide, Fe2O3	0.63
Loss on Ignition	6.5
Total	99.05
Mineral Composition	
Quartz	81.3
Calcite	10.02

* Tests are carried out in cooperation with National Center for Construction and Laboratories.

Tack Coat Type

Emulsified asphalt

Emulsified asphalts are created by breaking asphalt cement, typically of 100 to 250 penetration range; into miniature particles and dispersing them in water with emulsifier. These minute elements have like-electrical charges and so do not coalesce. They stay in suspension in the liquid stage as long as the water does not vaporize or the emulsifier does not break. Emulsified asphalts hence involve of asphalt, which makes up about 55 to 70 percent by weight, water, and an emulsifying agent, this in some cases too may contain a stabilizer. Emulsions are categorized by their ionic charge. Emulsions cationic begin with a "C." If there is no C, the emulsion is usually an anionic. The charge is essential when designing an emulsion for compatibility with definite aggregates [8]. Two type of asphalt emulsion used in this study. The next physical tests for asphalt emulsion were used in present study Table.4, Table.5:

Table. 4 Physical Properties of Anionic Asphalt Emulsion according to ASTM

TEST	ASTM Designation D244	Test Result	ASTM SPECIFICATION MIN.	Max.
Particle Charge Test	D244	Negative	Negative	
Viscosity Saybolt Furol at 25 ℃(77)F	D244	24	20	100
Residue by Evaporation	D6933	59.4	50	70
Settlement Test 5day%	D6933	0.9	0	1
1Day storage Stability test %	D2397	0.4	0	1
Test on Residue				
Penetration	D5	121	100	250
Ductility 25 ℃ 77F cm/min	D113	41	……	……
Density (gm./liter)	D 6937	1014		

Table. 5 Physical Properties of Asphalt Emulsion Cationic Slow Setting Low Viscosity (Css-1).

Test	ASTM Designation	Test Result	ASTM Specification Min.	Max.
Particle Charge	D244	positive	positive	
Viscosity,Saybolt Furol at 25°C	D244	26	20	100
Residue by Distillation, %.	D6997	55.3	57	……
Residue By Evaporation	D6934	54.9	50	70
Sieve Test,%	D6933	0.02	……	0.10
Cement mixing test, %	D6935	0.732	……	2.0
Settlement Test,5day,%	D6930	0.1	0	1
1 Day Storage stability test, %	D6930	0.04	0	1
Tests on Residue				
Penetration,25°C (77°F), 100 g, 5 s	D5	133	100	250
Ductility, 25°C (77°F), 5cm/min,	D113	185	40	……
Density (gm./liter)	D 6937	994	……	……

Cut back Asphalt (Rc-70)

Cutback asphalts consist mainly of asphalt cement and a solvent. The speediness at which they cure is connected to the volatility of the solvent (diluent) used. Cutback made with greatly volatile solvents will treatment faster as the solvent will evaporate more quickly. In opposition, cutbacks made with less volatile solvents will cure slower as the solvent will evaporate slower. There are three types (SC, MC and RC) cutback asphalts; which designate the rate at which the solvent evaporates [12]. Table.6 shows the physical properties of cutback asphalt

*Table. 6 Physical Properties of Cutback Asphalt Rc-70**

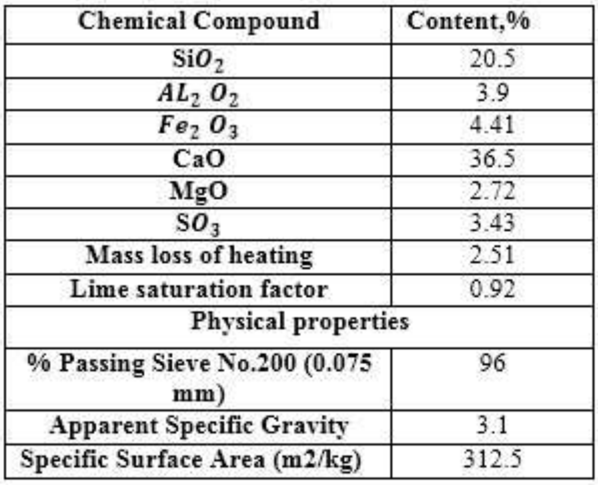
Properties	**ASTM Designation**	***Cutback* Asphalt***	**Specification Limits**	
			Min.	**Max.**
Density (gm./liter)	D 2028 D3142	1080	….	….
Water concentration (%)	D 95	10%	….	0.2%
Residual from evaporation	D 2028	85%	55%	….
Viscosity	D 2170	80	70	95

* Tests are carried out in cooperation with National Center for Construction and Laboratories.

Mineral Filler

Unique type of mineral filler which is Portland cement used. The biochemical compositions and physical properties are shown in Table.7.

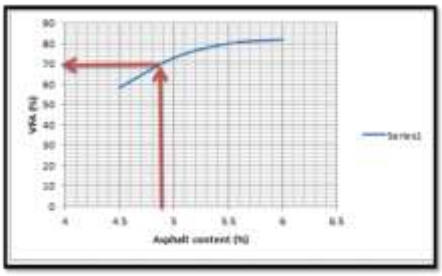
*Table.7 Physical Properties and Chemical Compositions of Portland cement filler**



Chemical Compound	Content,%
SiO_2	20.5
$AL_2\ O_2$	3.9
$Fe_2\ O_3$	4.41
CaO	36.5
MgO	2.72
SO_3	3.43
Mass loss of heating	2.51
Lime saturation factor	0.92
Physical properties	
% Passing Sieve No.200 (0.075 mm)	96
Apparent Specific Gravity	3.1
Specific Surface Area (m2/kg)	312.5

EXPERIMENTAL TESTING

The design of asphalt mix according to superpave gyratory compactor is included mixing the materials (aggregate, asphalt binder and mineral filler), later making sure it is in agreement with specifications, then preparation the specimen to the compaction procedures in the Superpave gyratory compactor (SGC) according to AASHTO T 312. The design bitumen binder content is recognized at 4.0% air voids as demonstrate in Fig.1.The optimum asphalt content was found to be (4.9%) by the total weight of mixture. Table.8 and Table.9 Result of different specific gravity and initial Asphalt content and mixture volumetric requirement respectively is.



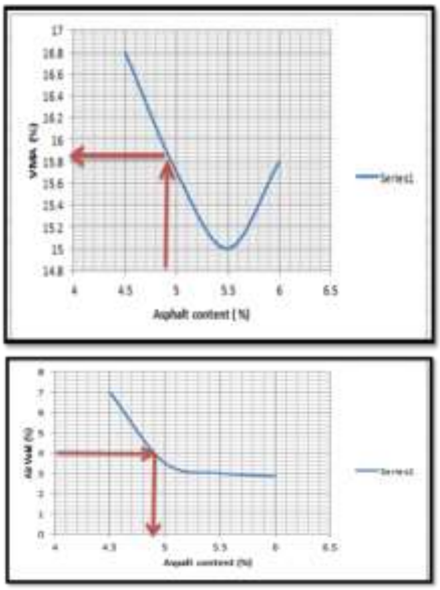


Fig. 1 Relation of air void, VMA% and VFA% versus asphalt content %

FDOT DIRECT SHEAR TEST

The mold for testing the bond strength shall be designed it can be used with the corresponding loading machine (hydraulic testing machine that can provide a vertical movement of 2.0 in. /min). This mold with 10.15cm (4in.) diameter, length 20cm, width 11.5cm, thickness 3cm, and height19cm.The gapis1/4 in. plate. 3 Cross-sectional views. [14]

Plate.3 Cross-sectional of manufacturing mold

SPECIMEN PREPARATION

The test for this study included one mix type, 3 tack coat types, and three temperatures. A total of 55 specimens were necessary for testing to study the effect of tack coat types and temperature on bonding strength. A testing specimen involved of two layers, upper and lowest, with a tack coat at the interface of these layers. The diameter of each specimen was 101.6 mm (4 in.). The loose mix is set at optimum asphalt content 4.9% and 12.5 mm nominal maximum aggregate size then left in oven for 2 hr aging at 135°C according to superpave specification. To facilitate using of manufacturing mold, adopt a Marshall mold dimension with the highest number of blows (75 blow) to compact the upper layer .This is conducted to simulate an HMA overlay of an in-place HMA pavement. 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.

THE TEST PROCEDURE

According to constant loading rate (50.8mm/min) of Marshall Apparatus, the interface bonding strength will be tested under this rate. The interface bonding strength was estimated by measuring the shear strength of the test samples at the interface. A simple shear test was conducted with the FDOT to determine interface bond strength. A shearing load was applied at a constant rate of 2 in/min (50.8mm/min) on the specimen until failure. The specimen is left in water path or a chamber for (2hr±15min) at testing temperature (15˚C, 30˚C and 45˚C) this temperature adopted according to many literature research to allow uniform distribution of temperature within the specimen .The sample is placed in the mold so that the direction of load on the specimen is parallel to the shear direction, the load applied on movable part of the mold until specimen failure plate.5. Load applied to specimen

Plate 5 Load applied to specimen

The interface bond shear strength was calculated by [2]

$$\mathbf{IBS} = \frac{P}{\frac{\pi D^2}{4}}$$

IBS = interlayer bond strength (psi)
P = Max. Load applied to specimen (lb.)
D = diameter of test specimen (in.)

Test result analysis and discussion

The results of various tests conducted to evaluate the interlayer bond strength in various types of combinations are presented below in Table.10

Table.10 the results of various tests conducted to evaluate the interlayer bond strength

Type of Tack Coat	Set Time	Application rate (l/m^2) of tack coat materials	Interface Bond strength at different test temperature (psi)		
			15℃	30℃	45℃
CSS-1	2 Hour	0.15	157.75	34.9	10.18
		0.25	349.36	52.47	14.23
		0.35	121.6	50.53	12.1
	4 Hour	0.15	173.54	33	11.6
		0.25	208.63	55.8	12.81
		0.35	191.26	50.88	10.63
		0.15	114.1	43.52	9.65

Anionic	2 Hour	0.25	136.87	51.41	13.5
		0.35	121.07	48.8	11.05
	4 Hour	0.15	155.8	56.85	10.53
		0.25	192.66	65.27	15.27
		0.35	175.3	39.48	11.93
Rc-70	2 Hour	0.3	135.11	54.39	7.36
		0.4	168.45	72.99	10.9
		0.5	116.7	47.2	7.72
	4 Hour	0.3	130.2	52.29	6.32
		0.4	186	68.1	8.4
		0.5	173.36	53	4.9
Without tack coat			159.5	113.7	12.1

SUMMARY AND CONCLUSIONS

The following are specific observations drawn from the test results:

- The maximum interface bond strength for Css-1 type and anionic at 0.25 l/m^2 application rate at all temperature test and setting time.
- The Css-1 tack coat type provided highest bond strength at all application rate 0.15 l/m^2, 0.25 l/m^2, 0.35 l/m^2 when temperature 15 ℃ at 2, 4 hour setting time compared to anionic and Rc-70.
- For the situation of interface layers without tack coat will give high bond strength at 30℃.
- The temperature has a significant effect on interface bond strength and decrease with increasing of temperature due to decreasing the emulsion viscosity with increasing of temperature.
- The optimum rate for emulsion (Css-1 and Anionic) is 0.25 l/m^2 and for Rc-70 is 0.4 l/m^2.
- At a test temperature 15℃, all types of tack coat used have been found maximum interlayer bond strength value as compared to other test temperatures.

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