DETERMINATION OF FACTORS AFFECTING SHEAR TESTING PERFORMANCE OF ASPHALT EMULSION TACK COATS

Tony Kucharek

Michael Esenwa

J. Keith Davidson

7e congrès annuel de
Bitume Québec

Saint-Hyacinthe, mars 2011

McAsphalt Depuis 1970

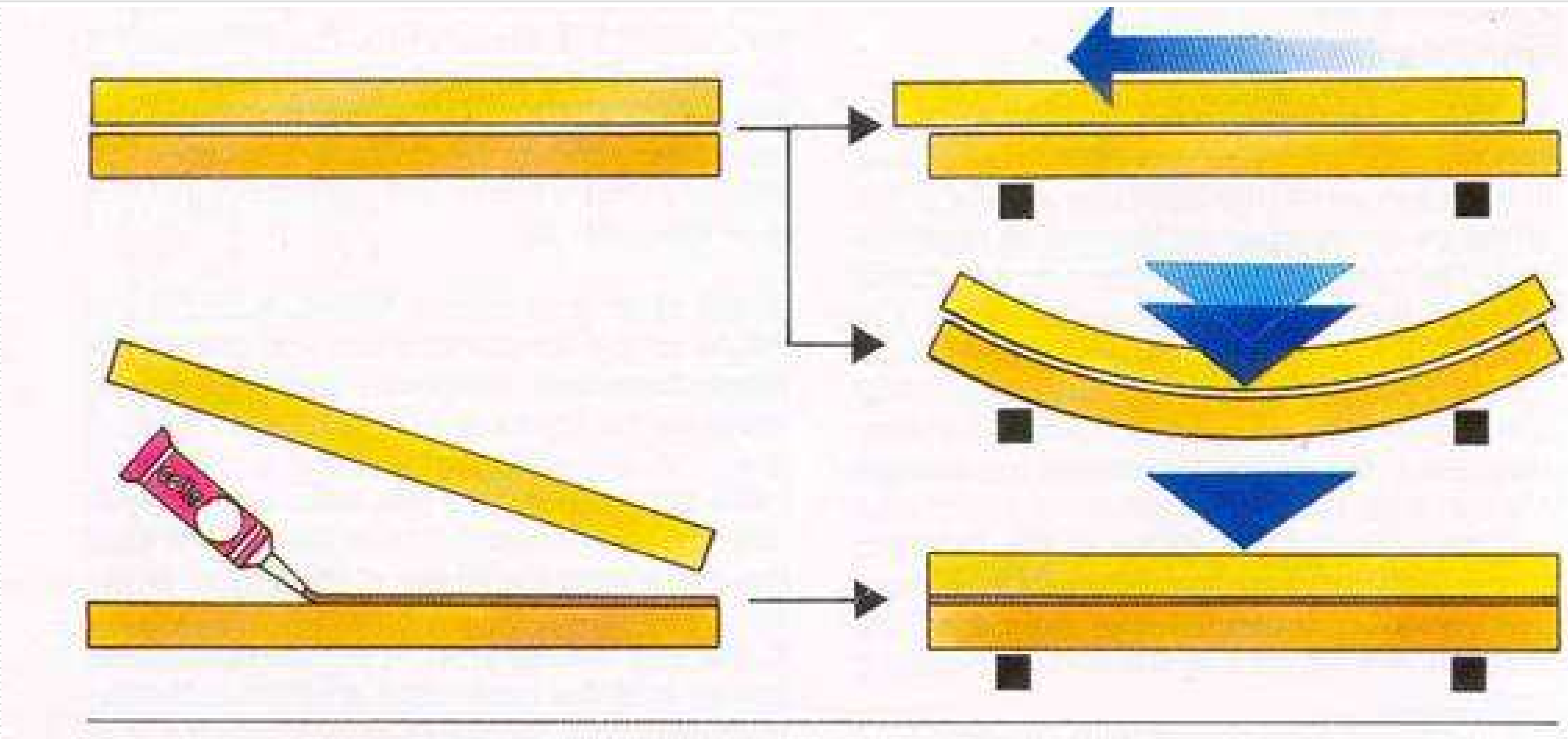
Presentation Outline

- Introduction
- Scope of Work
- Experimental Design
  - Material selection
  - Shear Testing Device
  - Testing Methodology
- Results and Discussion
- Conclusions

Introduction

- Tack coats (bond coats) are adhesive materials used to bond layers of flexible pavements
- Adhesive material is always an asphalt emulsion
- Tack coat applied by spraying during pavement construction on the exposed pavement layer
- The heat and compaction of the next HMA lift helps bond everything into one structure
- Absence of tack can lead to interfacial slippage
- Structural element for a multi-layered system

Tack Coat As Structural Element



Source: Bitumen Emulsions, SFERB, 2008

Tack Coat Application

Literature Review

- Many studies on tack coat performance testing are available
  - NCHRP 9-40, Louisiana Transportation Research Center
  - RILEM – tack coat performance study under Pavement Performance Prediction and Evaluation
- Bond strength measurement devices can be in tensile, shear or in torsion mode
  - Shear: ASTRA; SST; Florida DOT; Swiss LPDS; Al-Qadi
  - Tensile: AMAC; Instrotek

Scope Of Work

- A wide variety of specifications exist world wide
- Virtually all specified tack coating parameters are empirically selected
  - Emulsion types vary widely
    - Cationic or anionic
    - Rapid-set to slow-set
    - Diluted or non-diluted
  - Asphalt cements specified differently
    - From very hard (trackless tack) to soft
  - Application rates vary widely

Empirical Reasoning

- **Rapid Sets**: break and cure quickly, allow paving
- **Slow Sets**: allow good contact with fines and pores before breaking

- **Diluted**: low viscosity allows intimate wetting, easier to spray uniformly
- **Non-diluted**: less water to haul and spray, quicker drying and curing

- **Hard AC**: quick drying, no pick-up and no tracking
- **Soft AC**: ensure good adhesion even with warm mix, doesn't plug distributor nozzles

Experimental Work

- Designed to include a wide number of parameters
- Controlled environment and parameter variation
- Assessing the specific impact of every parameter independently
- Include non-tacked specimens

Material Selection

- Sixteen asphalt emulsion lab samples
  - RS-1; SS-1; CRS-1; CSS-1
- Four different asphalt cements
  - 20/30; 60/70; 120/150; 150/200 Pen
- Each emulsion type produced from each AC
  - 20/30 Pen – suffix HH (ex. CRS-1HH)
  - 60/70 Pen – suffix H (ex. SS-1H)
  - 120/150 Pen – no suffix (ex. RS-1)
  - 150/200 Pen – suffix S (ex. CSS-1S)

Emulsion Samples Characteristics

Emulsion	Asphalt Cement	Residue, %	SF Viscosity, 25°C, SFS	Particle Charge
RS-1HH	20/30 Pen	62.2	23.5	Negative
RS-1H	60/70 Pen	61.8	28.7	Negative
RS-1	120/150 Pen	62.3	27.0	Negative
RS-1S	150/200 Pen	62.2	27.8	Negative
SS-1HH	20/30 Pen	61.8	26.8	Negative
SS-1H	60/70 Pen	62.3	30.3	Negative
SS-1	120/150 Pen	61.5	31.2	Negative
SS-1S	150/200 Pen	61.6	28.8	Negative
CRS-1HH	20/30 Pen	65.1	30.1	Positive
CRS-1H	60/70 Pen	65.3	38.2	Positive
CRS-1	120/150 Pen	64.8	34.1	Positive
CRS-1S	150/200 Pen	65.3	36.5	Positive
CSS-1HH	20/30 Pen	62.1	28.1	Positive
CSS-1H	60/70 Pen	62.5	27.8	Positive
CSS-1	120/150 Pen	62.8	25.6	Positive
CSS-1S	150/200 Pen	62.8	27.0	Positive

HDBC Mix And RAP Samples

Job Mix Formula Blend	Materials	
	Source	Percentages (%)
19mm Clear Stone	Carden Quarry	25.5
9.5mmStone	Carden Quarry	23.5
Manufactured Sand	Carden Quarry	51.1
PG 64-28	McAsphalt	4.70
Physical Properties		
Parameter	**Selected**	**Specification**
Stability @ 60 ^{o}C (N)	14,250	12,000 min
Flow Index (0.25mm)	11.5	8.0 min
Air Voids (%)	4.5	3.5 – 4.5%
VMA (%)	14.3	13.0% min
BRD (kg/m3)	2.390	-
MRD (kg/m3)	2.502	

- RAP originates from Miller Paving, Richmond Hill
- 3.7 % AC content; recovered Pen of 20 dmm

Specimen Preparation

- Specimens gyrated in molds using Pine gyratory
- First lift (1000 g); 100 gyrations; cooling in mold
- Tack coat application using a paint brush, over the exposed surface
  - Tack application rate controlled on a balance
- Allow tack to cure under fan (2 hours or less)
- Introduce second lift (1000 g) in mold and gyrate for 50 gyrations; de-mold
- Two specimens prepared per test point

Specimen Preparation

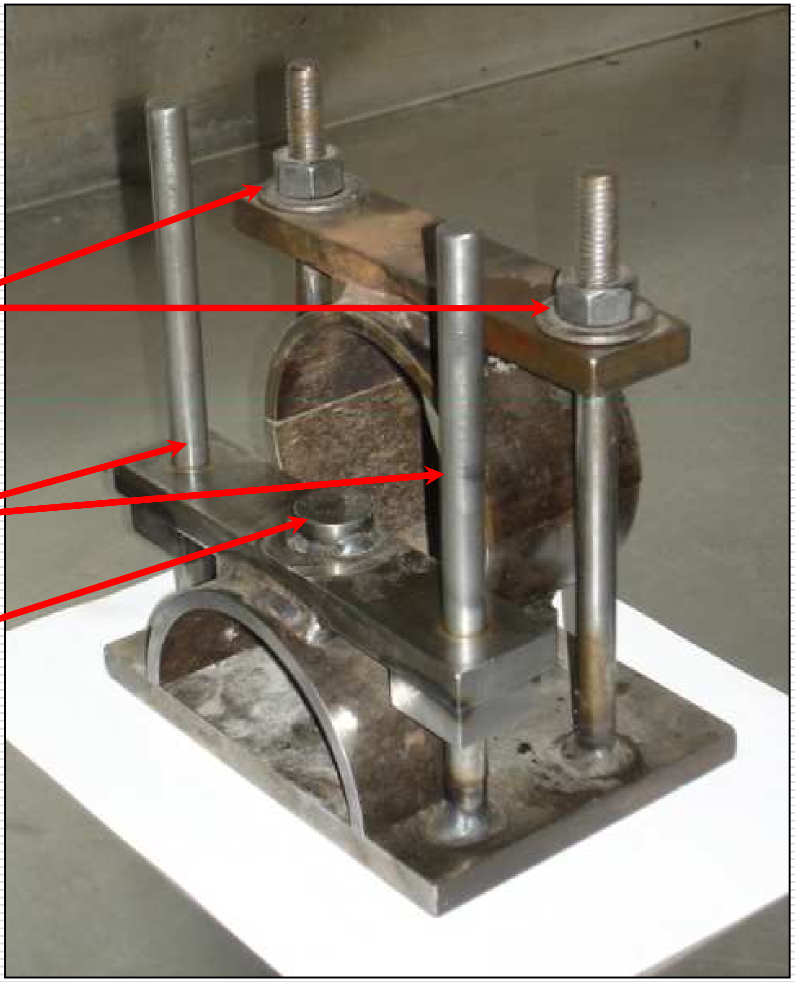
- Each 16 emulsions applied in 3 application rates
  - 0.05; 0.1 and 0.15 kg.m^2 of residual asphalt
  - This translates in approx 0.075; 0.15 and 0.225 l/m^2 of undiluted emulsion
  - Control specimens with no tack coat also prepared
- Two sets of test samples
  - First using the HDBC HMA as substrate and top coat
    - Simulates overlaying fresh HMA
  - Second used RAP as substrate and HDBC as top coat
    - Simulates overlaying old pavement
- A total of 196 specimens prepared in total

Specimen Preparation

- Because a reduced number of gyrations and cold mold, the second lift has lower density
- Overcompaction can lead to reduced testing resolution
  - Targeting testing conditions that will allow noticeable difference

Shear Testing Device

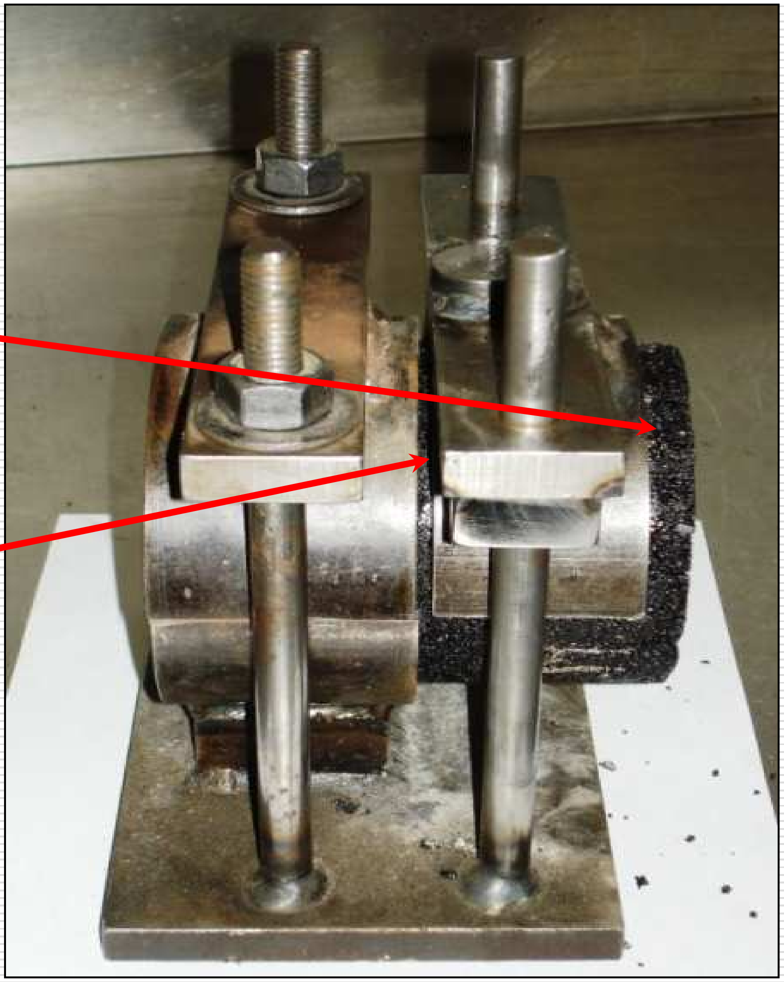
- Developed at McAsphalt lab
- Modified Marshall stability mold
- One part of the mold designed to fasten and tighten one end of the specimen
- Semi-circular shear sleeve travels on a set of guiding rods
- Shear is applied at the top of the shear sleeve, adjacent to the interface



Assembled Mold and Specimen

Mounted specimen

Shear plane



Testing Equipment And Procedure

- Specimen is aligned with the interface at the plane of shear
- Shear is applied using a Marshall Stability machine
- Loading speed is 50.8 mm/min
- Load vs. displacement graph is recorded
- The peak shear stress represents the shear strength of the bonded interface
- Method is also suitable for field specimens

Testing Principle

- The peak shear stress of a pavement interface can be expressed as a sum of different stresses

$$\tau_{peak} = \tau_{res} + \tau_{ic} + \tau_{res} + \tau_{a} = F/S$$

τ_{res} = residual friction

τ_{ic} = inner cohesive friction

τ_{d} = dilatancy effects

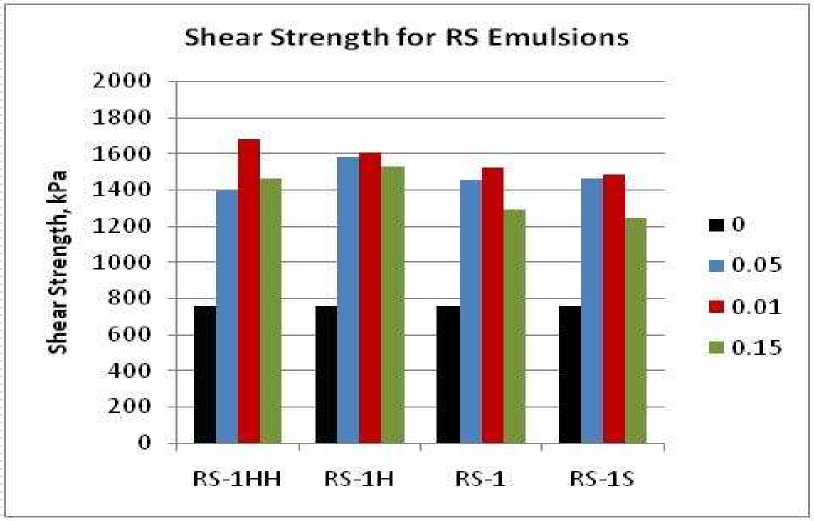
τ_{a} = adhesion friction given by the tack coat; zero in the absence of tack coat

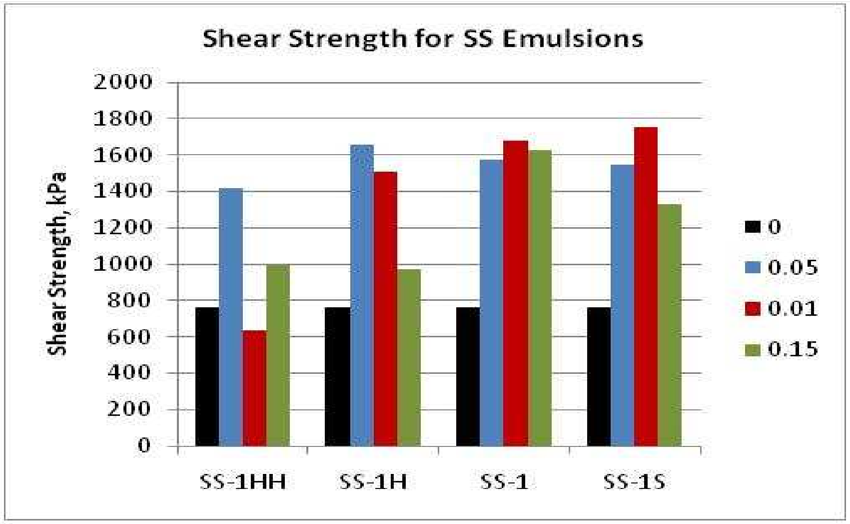
- We would like to prove that τ_{a} has a sizable contribution
  - Assess the influence of emulsion and AC type, application rate, etc.

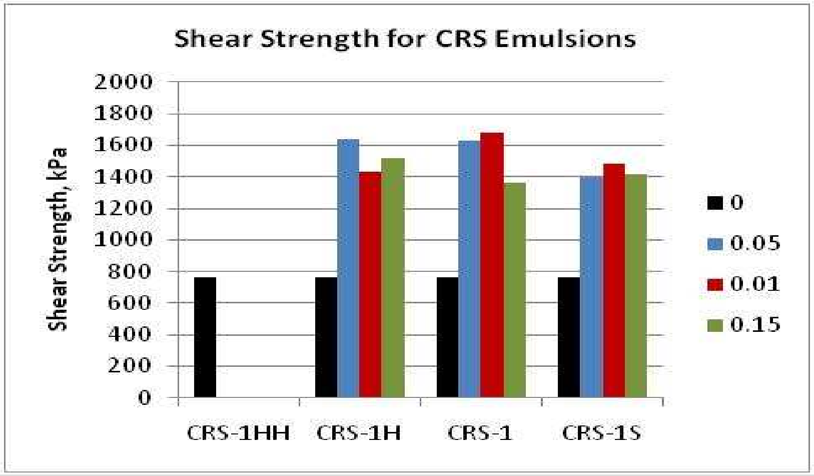
Virgin Mix Substrate Results

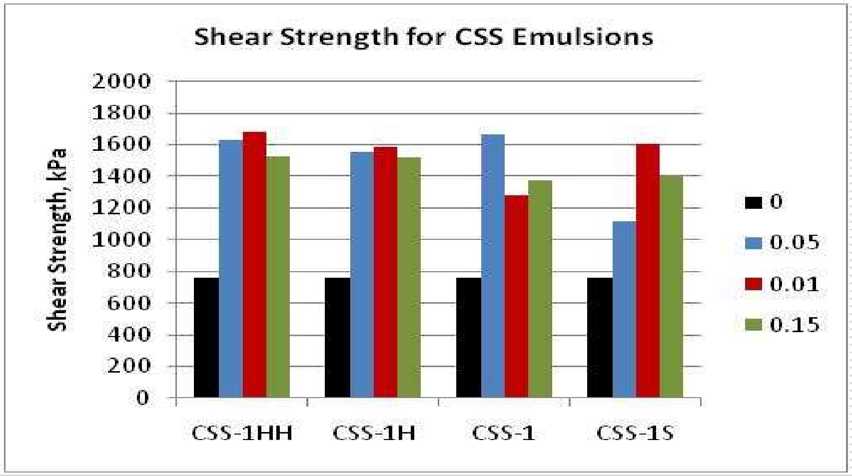
Application Rate, kg/m²	RS-1HH, kPa	RS-1H, kPa	RS-1, kPa	RS-1S, kPa
0	759			
0.05	1395	1587	1456	1465
0.01	1679	1606	1523	1487
0.15	1465	1530	1289	1247
Application Rate, kg/m²	**SS-1HH, kPa**	**SS-1H, kPa**	**SS-1, kPa**	**SS-1S, kPa**
0	759			
0.05	1417	1657	1572	1544
0.01	637	1509	1679	1757
0.15	997	969	1629	1326
Application Rate, kg/m²	**CRS-1HH, kPa**	**CRS-1H, kPa**	**CRS-1, kPa**	**CRS-1S, kPa**
0	759			
0.05	N/A	1635	1626	1397
0.01	N/A	1431	1686	1487
0.15	N/A	1519	1360	1417
Application Rate, kg/m²	**CSS-1HH, kPa**	**CSS-1H, kPa**	**CSS-1, kPa**	**CSS-1S, kPa**
0	759			
0.05	1629	1555	1660	1116
0.01	1680	1589	1283	1601
0.15	1530	1516	1374	1398

Virgin Mix Substrate Results









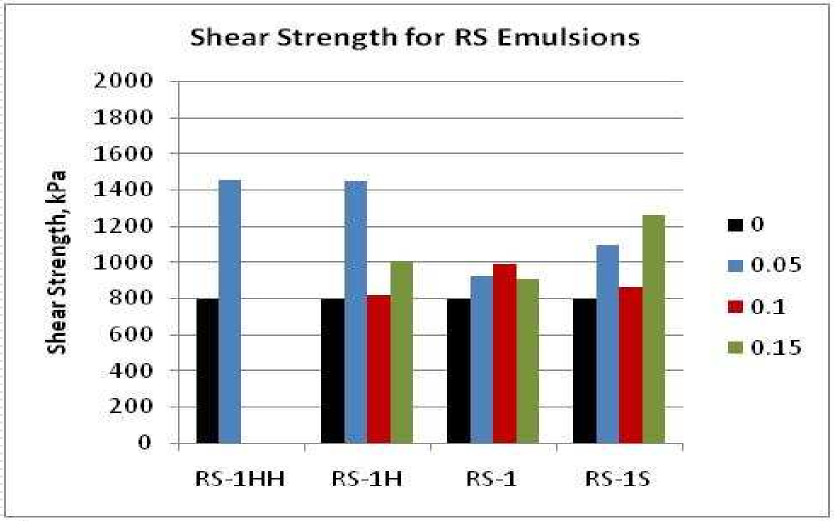
Observations on HMA Substrate

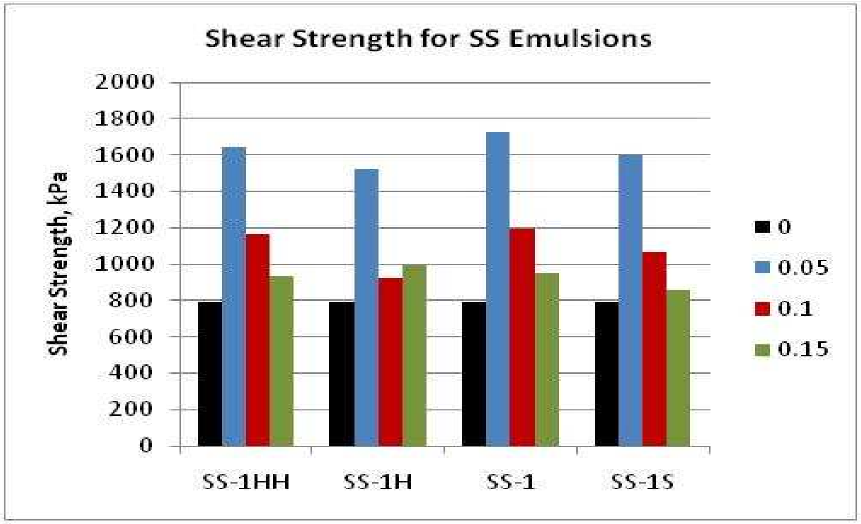
- All tacked samples have interface bond strength about double than the non-tacked
- No clear trend is visible related to the hardness of the residual asphalt cement
- Emulsion type has little or no impact on the bond strength
- Higher tack application rates do not automatically translate in higher bond strengths
- 0.1 kg/m^2 application rate gives the highest strength overall

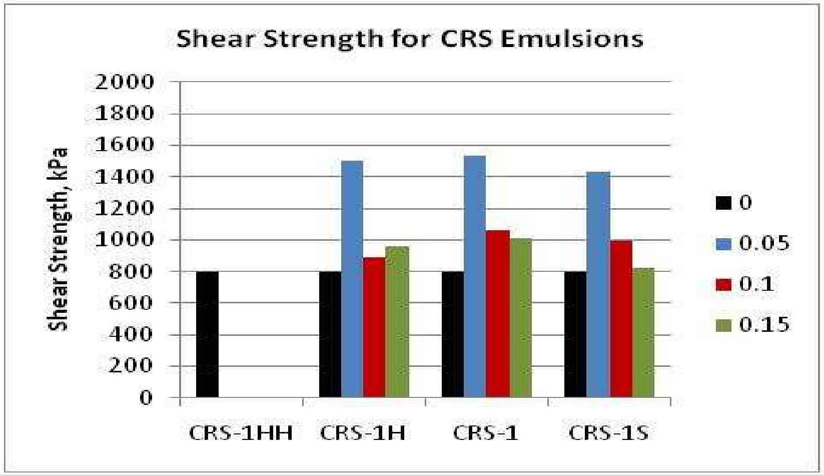
RAP Mix Substrate Results

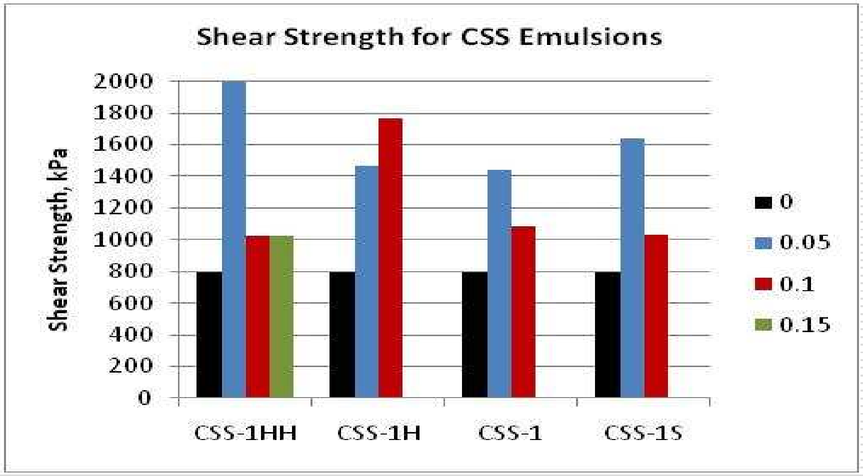
Application Rate, kg/m²	RS-1HH, kPa	RS-1H, kPa	RS-1, kPa	RS-1S, kPa
0	793			
0.05	1456	1445	926	1096
0.01	N/A	816	992	864
0.15	N/A	1009	907	1261
Application Rate, kg/m²	**SS-1HH, kPa**	**SS-1H, kPa**	**SS-1, kPa**	**SS-1S, kPa**
0	793			
0.05	1643	1521	1725	1601
0.01	1162	926	1194	1068
0.15	934	992	949	856
Application Rate, kg/m²	**CRS-1HH, kPa**	**CRS-1H, kPa**	**CRS-1, kPa**	**CRS-1S, kPa**
0	793			
0.05	N/A	1502	1534	1434
0.01	N/A	890	1062	992
0.15	N/A	992	1014	827
Application Rate, kg/m²	**CSS-1HH, kPa**	**CSS-1H, kPa**	**CSS-1, kPa**	**CSS-1S, kPa**
0	793			
0.05	2029	1468	1439	1638
0.01	1026	1771	1082	1034
0.15	1024	N/A	N/A	N/A

RAP Mix Substrate results









Observations on RAP Substrate

- Generally lower strength values than the HMA
- “More not better” trend more obvious
- Highest values obtained at 0.05 kg/m^2 rates
- However, even lowest tacked bond strength are higher than the non-tacked
- RAP substrate is smoother and denser than HMA
  - Too high application rates can create slippage plane
  - Smoother mix surface will increase film thickness, as less emulsion will be absorbed in pores and voids

General Discussion

- Overall higher bond strengths for the HMA vs. the RAP substrates can be because its higher surface roughness
- Variations in strength due to application rates smaller for HMA substrate; RAP shows narrower optimum
  - Coarser texture might be able to accommodate a wider tack coat application rates while maintaining good performance
  - Smoother textures show narrower optimum application rates
- Other substrate types will be studied
  - PCC
  - Milled HMA surface

Conclusions

- Little or no impact of asphalt emulsion type observed
- Little or no impact of AC hardness was noticed
- Tack coat application rate has an optimum value
  - Too little will lead to not enough adhesion
  - Too much can create slippage plane and weaken the bond
- Interface strength and optimum tack coat application rate depend on substrate characteristics
  - Rougher substrates have higher strengths and can tolerate higher variability of tack application rate
  - Smoother surfaces require more precise tack coat dosage

Conclusions

- Tacked interfaces show higher bond strengths overall
  - Adhesion friction τ_a contribution is real and positive
  - Experimental data shows it is highly unlikely to weaken the interface bond strength by selecting the wrong emulsion type or the wrong application rate
  - Any tack still better than no tack
- Future research will concentrate on
  - Expanding substrate types (milled surfaces, PCC)
  - Field validation of observed trends and conclusions

Merci pour votre attention

Questions?