Comparison of Stress States in the Interface Shear Fatigue Test with Field Conditions

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RESEARCH & DEVELOPMENT

Comparison of Stress States in the Interface Shear Fatigue Test with Field Conditions

FINAL REPORT

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16. Abstract

In unsponsored dissertation research that was conducted after the completion of the RP 2018-13 project, interlayer shear fatigue (ISF) tests were conducted to evaluate the effects of tack coat type and application rate on test specimens' resistance to interlayer shear failure under fatigue loading. The ISF test results delineated the shear performance of different tack coat materials and application rates, whereas the interface shear strength test could not.

The laboratory shear fatigue test is performed under much larger stress levels than what is expected at the asphalt layer interface in the field. These large stress levels are necessary to accelerate the test so that it can be completed within a reasonable time (normally less than a day). The objective of this research is to determine whether the difference in shear fatigue performance observed from the previous studies does matter in the field condition.

To accomplish this objective, the NCSU research team used FlexPAVE™, a three-dimensional viscoelastic finite element program that is capable of simulating the moving loads, to simulate the stress states at the bottom of asphalt overlays with varying thicknesses under various loading and temperature conditions. The results from this study indicate that the observed effects of tack coat material type and application rates on shear fatigue performance from the ISF test can be significant in the stress states of pavements in field conditions. The findings from this study suggest that the ISF test should be used in future studies to evaluate the effect of tack coats and provide solutions for debonding distress in North Carolina.

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INTRODUCTION

In unsponsored dissertation research that was conducted after the completion of the RP 2018-13 project, interlayer shear fatigue (ISF) tests were conducted to evaluate the effects of tack coat type and application rate on test specimens' resistance to interlayer shear failure under fatigue loading. The ISF test results delineated the shear performance of different tack coat materials and application rates.

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To accomplish this objective, the NCSU research team used FlexPAVE^{TM}, a three-dimensional viscoelastic finite element program that is capable of simulating the moving loads, to simulate the stress states at the bottom of asphalt overlays with varying thicknesses under various loading and temperature conditions. The simulation results are presented in the appendix and summarized in the next section, where the results are discussed.

DISCUSSION OF RESULTS

First, the research team ran a few simulations using two different mixtures, a North Carolina RS9.5B mixture and an SMA mixture obtained from Maryland (SMA-MD), to evaluate the sensitivity of shear stress levels for the type of mixture. The results of the simulations shown in Table 1. As can be seen, the shear stress levels did not change significantly between the two mixtures. Consequently, the research team decided to run the simulation matrix using the RS9.5B mixture only, as it exhibited a higher shear stress level. The selected simulations' conditions are shown in Table 2.

Table 1: Comparison of shear stress level for RS9.5B and SMA-MD asphalt mixtures.

<table>
<tr><th>Mixture</th><th>Temperature (F)</th><th>Speed (mph)</th><th>Load (kip)</th><th>Shear stress (psi)</th></tr>
<tr><td>RS9.5B</td><td rowspan="4">122</td><td rowspan="4">1</td><td rowspan="2">9</td><td>53</td></tr>
<tr><td>SMA-MD</td><td>48</td></tr>
<tr><td>RS9.5B</td><td rowspan="2">18</td><td>58</td></tr>
<tr><td>SMA-MD</td><td>54</td></tr>
</table>

Table 2: Simulation conditions.

Mixture ID	Temperature (F)	Thickness (in)	Speed (mph)	Load (kip)
RS9.5B	50	1.5	1	9
				18
			45	9
				18
		3	1	9
				18
			45	9
				18
	122	1.5	1	9
				18
			45	9
				18
		3	1	9
				18
			45	9
				18

The results of the simulations are presented in Figure 1. It can be seen that, for a given temperature, speed, and thickness, the shear stress level increases with an increase in traffic load. It is also noticeable that, for a given temperature, speed, and traffic load, the shear stress level increases as thickness decreases. Furthermore, the simulations showed that, for a given temperature, traffic load, and thickness, the shear stress level increases as traffic speed decreases. Additionally, the shear stress level increases with the temperature rise. The results also suggest that the impact of traffic load is more pronounced in higher-thickness structures compared to lower-thickness structures. Overall, the shear stress level ranged from 35 psi to 58 psi.

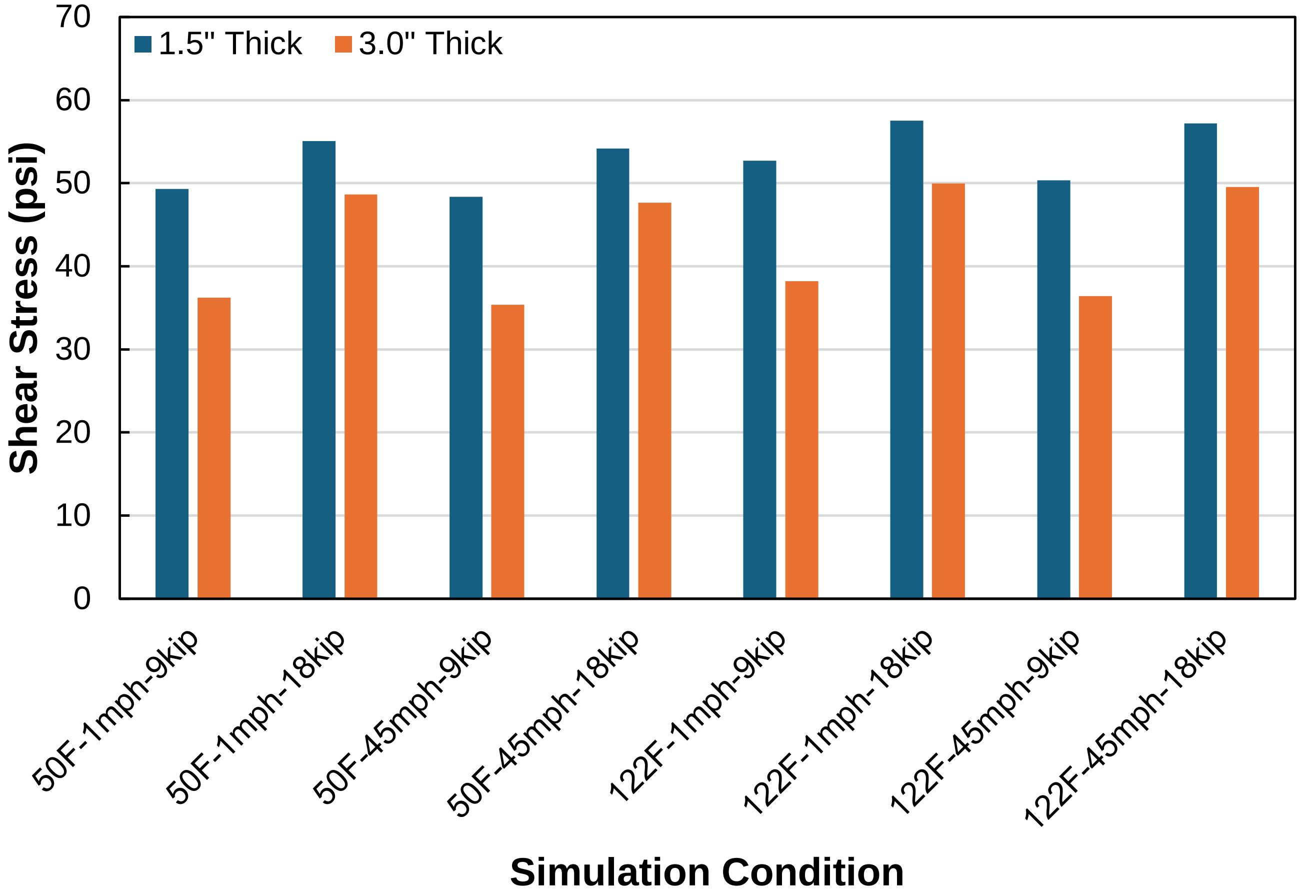

Figure 1: Simulation results.

The interface shear fatigue (ISF) test results from the RP 2018-13 project and NCAT field cores as well as the shear stress levels from FlexPAVE^{TM} simulations are presented in Figure 2. The results from the previous unsponsored dissertation research are extrapolated using a linear function in the log-log scale. The extrapolated results show that, at a shear stress level of 58 psi, the number of cycles to failure ranged from 4.8E+05 cycles to 3.5E+07 cycles, while it ranged from 1.7E+06 cycles to 5.3E+08 cycles at a shear stress level of 35 psi. The results from the previous research show less than a decade difference in fatigue life between different materials and application rates, whereas the fatigue life difference is more than two decades for the stress levels from the FlexPAVE simulations.

Note that the interface shear strength test could not detect the effects of tack coat material type and application rates on shear strength in the previous project. The results from this study indicate that the observed effects of tack coat material type and application rates on shear fatigue performance from the ISF test can be significant in the stress states of pavements in field conditions. The findings from this study suggest that the ISF test should be used in future studies to evaluate the effect of tack coats and provide solutions for debonding distress in North Carolina.

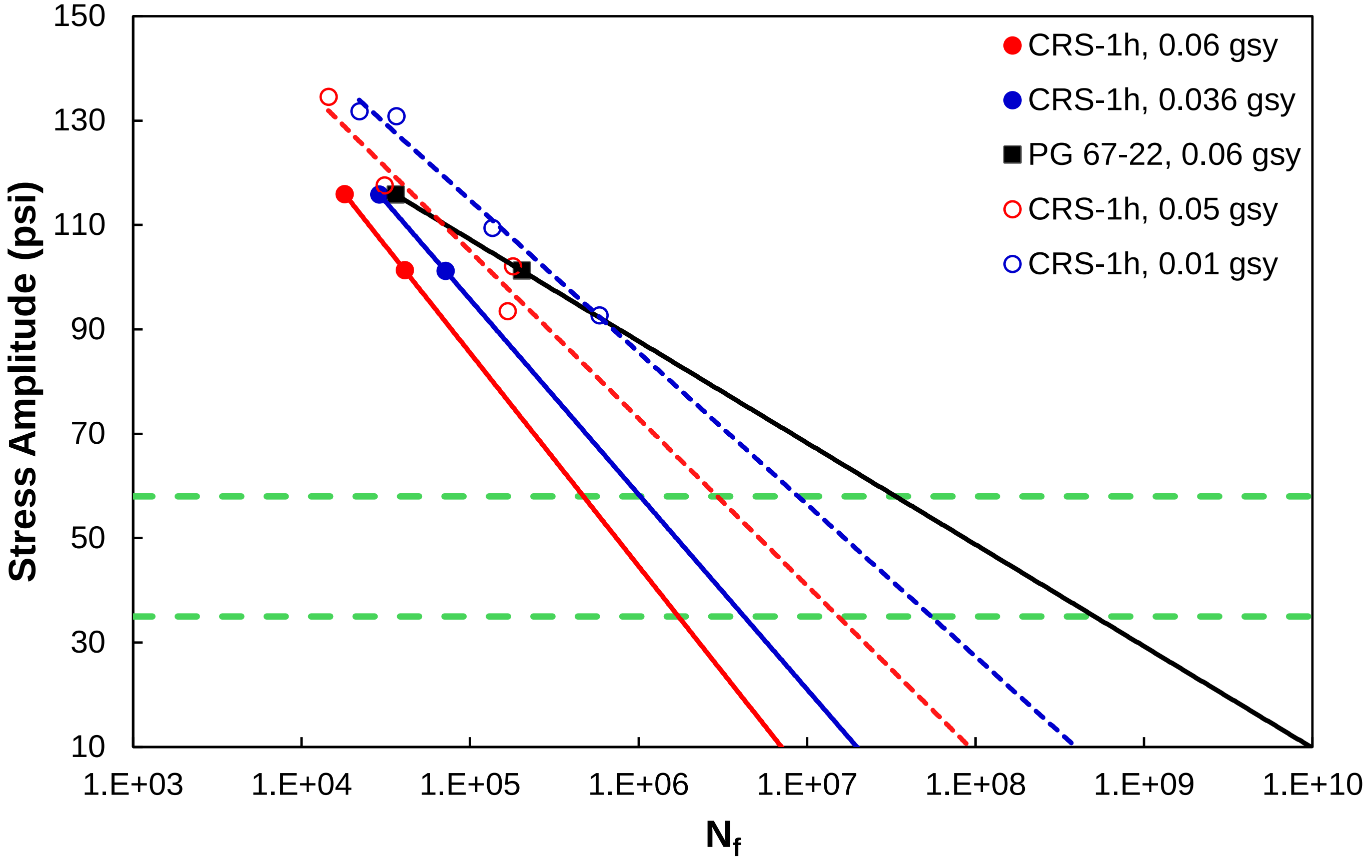

Figure 2: Interface shear fatigue test results from the RP 2018-13 project and NCAT field cores.

APPENDIX. NORMAL AND SHEAR STRESS AND STRAIN SIMULATION RESULTS

Table 3: Normal stress results.

Normal stress (psi)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	113	86
		18	117	101
	45	9	113	85
		18	117	100
122	1	9	112	86
		18	117	103
	45	9	110	81
		18	115	97

Table 4: Normal strain results right on top of the interface.

Normal strain right on top of the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	203	189
		18	171	191
	45	9	49	48
		18	30	43
122	1	9	6,600	5,900
		18	6,900	6,800
	45	9	1,600	1,400
		18	1,600	1,600

Table 5: Normal strain results at the interface.

Normal strain @ the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	203	189
		18	171	191
	45	9	49	48
		18	30	43
122	1	9	6,600	5,900
		18	6,900	6,800
	45	9	1,600	1,400
		18	1,600	1,600

Table 4: Normal strain results right below the interface.

Normal strain right below the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	70	77
		18	35	62
	45	9	22	27
		18	42	20
122	1	9	2,800	2,600
		18	2,800	3,000
	45	9	883	819
		18	810	914

Table 5: Shear stress results.

Shear stress (psi)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	49	36
		18	55	49
	45	9	48	35
		18	54	48
122	1	9	53	38
		18	58	50
	45	9	50	36
		18	57	50

Table 8: Shear strain results right on top of the interface.

Shear strain right on top of the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	357	250
		18	406	324
	45	9	99	69
		18	113	92
122	1	9	10,200	7,200
		18	12,100	9,700
	45	9	2,400	1,700
		18	2,800	2,200

Table 9: Shear strain results at the interface.

Shear strain @ the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	357	250
		18	406	324
	45	9	98	69
		18	113	92
122	1	9	10,200	7,200
		18	12,100	9,700
	45	9	2,400	1,700
		18	2,800	2,200

Table 6: Shear strain results right below the interface.

Shear strain right below the interface ($\mu\varepsilon$)				
Temperature (F)	Speed (mph)	Load (kip)	Thickness (in)	
			1.5	3
50	1	9	196	135
		18	228	181
	45	9	77	53
		18	90	73
122	1	9	5,000	3,400
		18	6,000	4,800
	45	9	1,500	1,100
		18	1,900	1,500