Abridgment

Influence of Construction-Induced Cracks on Asphalt Concrete Resistance to Moisture Damage

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Present stripping mechanisms fail to specify the source of water necessary for stripping to start and progress with time. Finding the water source and route to the pavement interior is of great significance to efforts seeking a preventive measure against stripping. Investigation of the influence of contruction-induced cracks, referred to as checking, on pavement resistance to stripping is reported. A new field-compaction technique was used to produce a crack-free asphalt concrete surface that offered a much higher resistance to stripping than conventionally compacted surfaces. Cores recovered from field-compacted pavements were used throughout the investigation. The results of the experimental investigation indicated that compaction technique has a significant influence on the mix resistance to stripping. Vacuum saturation, used as part of the moisture-conditioning procedure, has in the past obscured the influence of construction-induced cracks on stripping susceptibility.

Virtually all investigators agree that stripping is caused by water displacing the asphalt from the aggregate surface (*1*,*2*). However, the existing stripping mechanisms cannot explain how water manages to reach locations close to the aggregate-asphalt interface. Air voids have been suggested as the cause of water penetration, circulation, and accumulation inside the asphalt concrete layer. As a result, many agencies, such as the Ministry of Transportation of Ontario (MTO), specified air void percentage as low as 2 percent. In Ontario, water still finds its way inside the pavement despite low air void percentage (*1*).

Surface cracks that exist at an early stage in the pavement life—that is, during and after construction—can constitute a path for surface water to penetrate the asphalt concrete layer where any of the suggested stripping mechanisms may start functioning. In the presence of such cracks, surface water is the source of water supply necessary for stripping to start and continue during the life of the pavement. Halim used a new analytical approach to prove that construction cracks are associated with the present compaction equipment (*3*). Laboratory investigations using models of the conventional and a new compactor, called the asphalt multi-integrated roller (AMIR), proved the outcome of the theoretical approach. The new compactor has a flat geometry coupled with a rubber mat at the interface of the asphalt surface and roller (*4*). The surface produced by the new compactor is crack-free as observed during the construction of field trials.

The concern of this study is to examine the role these cracks created by compaction play in the phenomenon of asphalt stripping. In the past when field tests were carried out to evaluate the effect of construction on a given problem related to pavements, the finished asphalt pavement always had the same cracking characteristic. Therefore, the influence of these cracks was common across most of the investigated projects and, as a result, masked the actual influence of such cracks. The presence of cracks also resulted in poor correlation between test results of laboratory-prepared samples and cores recovered from the field since such cracks were not always present in laboratory-prepared samples.

EXPERIMENTAL INVESTIGATION

The experimental program was designed and carried out to verify the hypothesized influence of construction-induced cracks on stripping. A field-compacted section was prepared on the campus of the National Research Council (NRC) of Canada in Ottawa. The conventional and the AMIR prototype rollers were used to compact a standard MTO HL-4 asphalt concrete mixture. Cores 3.7 in. in diameter were recovered from each section for laboratory conditioning and testing. No laboratory-prepared samples were used in this investigation to avoid the limitations imposed on compacted mixes by laboratory compaction procedures that influence their performance.

Simple Soaking

This type of conditioning included vacuum saturation of cores using 14 in. of mercury. Cores were then left in the water bath for 2 days at a specified temperature. The −20°F group was conditioned by storing in an environmental chamber in which the temperature remained controlled at −20°F. The

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cores were wrapped in a plastic sheet immediately after vacuum saturation and before storage in the temperature-controlled chamber. Following the 2-day conditioning period, all cores were soaked in a water bath at room temperature (75°F) for 2 hr and then tested for indirect tensile strength. A loading rate of 2 in./min was used throughout the investigation.

Soaking After Sealing

Other groups from the steel roller– and AMIR-compacted sections were treated differently so that the effect of surface cracks by sealing the sides and bottom of the cores before soaking could be studied. No vacuum pressure was used. Water can enter the core only through the surface. Cores were left in the water bath for 7 days. Three water bath temperatures were investigated (35, 65, and 110°F). A higher temperature was not possible because it would cause the plastic sealing to melt. A temperature below freezing was also not possible because the water would freeze before saturation water penetrates the core. Cores were removed from the temperature-conditioning water bath to a water bath at room temperature for 2 hr before loading.

Test Results and Analysis

Simple Soaking

Test results of cores soaked in water for 2 days are presented in Table 1. Figure 1 shows the relationship between soaking temperature and indirect tensile strength for both compaction techniques. The average indirect tensile strength of AMIR compacted cores increased from 101 to 113 psi after exposure to −20°F. The strength of AMIR compacted cores soaked at 110°F decreased by 17 percent. Similarly, the strength of the 140°F group decreased by 23 percent.

From Figure 1, the soaking temperature–strength curve shows relatively no change in the strength of steel roller–compacted cores after their exposure to temperatures ranging from −20 to 65°F. Above 75°F, the relationship indicated a sharp decrease in strength caused by stripping observed at the failure surfaces of tested cores. The strength drop was 41.8 percent due to 140°F exposure and 19.7 percent due to 110°F exposure. AMIR-compacted cores offered higher resistance to stripping than conventionally compacted cores after being exposed to warm-water soaking above 75°F. Construction cracks must have allowed warm water to circulate, thereby reducing the resistance of steel-compacted cores to stripping damage.

TABLE 1 Indirect Tensile Strength Results (Simple Soaking)

Conditioning Temperature (°F)	Type of Compaction	Bulk Specific Gravity	Permeable Voids %	Indirect Tensile Strength (psi)	Average Strength (psi)
-20	VSR/PR*	2.380	3-4	92	93
		2.401	2-3	85	
		2.414	2-3	104	
	AMIR	2.460	1-2	114	112
		2.366	3-4	96	
		2.421	2-3	127	
35	VSR/PR*	2.383	4-5	84	93
		2.399	4-5	101	
	AMIR	2.434	3-4	95	101
		2.450	2-3	109	
		2.366	4-5	100	
65	VSR/PR*	2.418	2-3	95	92
		2.381	3-4	89	
	AMIR	2.463	1-0	104	94
		2.413	1-2	96	
		2.377	3-4	82	
110	VSR/PR*	2.394	3-4	84	75
		2.395	2-3	66	
	AMIR	2.435	1-2	88	83
		2.438	1-2	70	
		2.376	3-4	82	
140	VSR/PR*	2.383	4-5	37	54
		2.412	2-3	71	
	AMIR	2.456	1-2	89	77
		2.358	-	-	
		2.429	2-3	66	
		Control Group – Tested Dry			
NA	VSR/PR*	2.389	4-5	85	93
		2.395	2-3	101	
	AMIR	2.351	4-5	102	101
		2.399	3-4	96	
		2.450	1-2	104	

* Vibratory Steel Roller and Pneumatic Roller

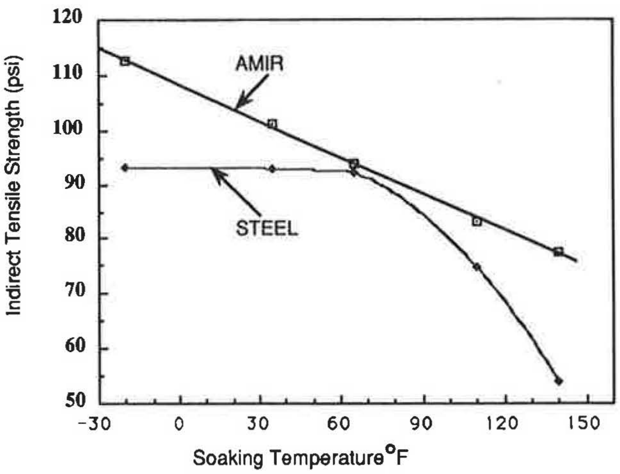

FIGURE 1 Relationship between soaking temperature and indirect tensile strength.

Soaking After Sealing

This experiment was designed to confirm that construction cracks provide a path for surface water to penetrate the pavement freely. In the previous experiment, when vacuum saturation was used the amount of water entering cores was relatively the same for both compaction methods. The sides of cores are not coated and, therefore, during vacuum saturation a large amount of water penetrated through the sides without regard to the surface condition. Measurements made immediately after removal of the plastic sheets and before loading the cores indicated that the AMIR-compacted core allowed 0.9 percent of its weight in water to enter the cores; the steel roller–compacted core allowed 1.3 percent to enter the cores. Test results are shown in Table 2. Figure 2 shows

TABLE 2 Indirect Tensile Strength Results (Soaking After Sealing)

Conditioning Temperature (°F)	Type of Compaction	Bulk Specific Gravity	%Water After Soaking	Indirect Tensile Strength (psi)	Average Strength (psi)
110	VSR/PR*	2.404	-	-	86
		2.380	1.3	86	
		2.378	1.4	86	
	AMIR	2.443	0.8	112	113
		2.439	0.9	120	
		2.436	1.0	107	
65	VSR/PR*	2.382	-	124	117
		2.364	-	108	
		2.410	-	120	
	AMIR	2.447	-	102	121
		2.438	-	129	
		2.436	-	134	
35	VSR/PR*	2.406	-	141	120
		2.383	-	120	
		2.371	-	100	
	AMIR	2.449	-	126	131
		2.436	-	141	
		2.432	-	126	
		Control Group – Tested Dry			
	VSR/PR*	2.406	-	121	120
		2.383	-	120	
	AMIR	2.460	-	128	122
		2.422	-	116	

- *data unavailable*

*Vibratory Steel Roller and Pneumatic Roller

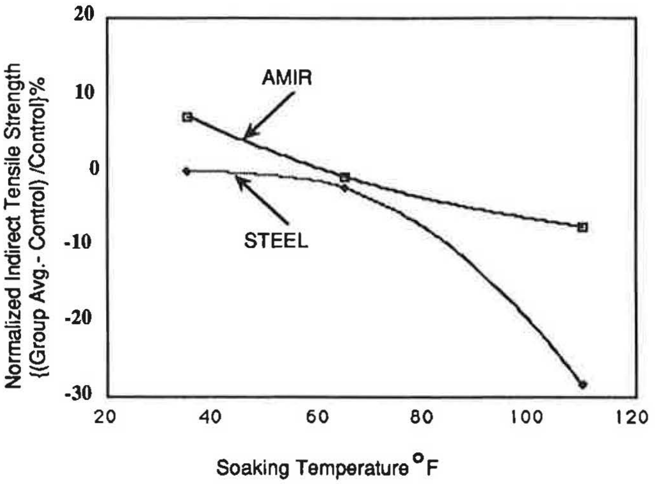

FIGURE 2 Relationship between soaking temperature and normalized indirect tensile strength.

the relationship between soaking temperature and normalized indirect tensile strength for protected (sealed) cores.

After soaking at 35°F for 7 days, the strength of protected crack-free cores (AMIR) increased by 7.2 percent. The increase in strength was more than that observed for similar unprotected cores following vacuum saturation and soaking for 2 days. This increase was the result of preventing water from entering the cores. No substantial change was observed to be due to the 65°F exposure. The 1 percent decrease in strength was much less than that observed following soaking after vacuum saturation (9.8 percent). This difference may be attributed to the fact that soaking after sealing allowed less water to enter the aggregate-asphalt matrix interface than vacuum saturation. After 7 days of exposure at 110°F, protected crack-free cores lost 7.4 percent of their strength. Unprotected crack-free cores soaked for only 2 days after vacuum saturation resulted in 17.3 percent decrease in strength.

Soaking protected steel roller–compacted cores at 35 and 65°F had no effect on indirect tensile strength as compared with the unsealed cores after vacuum saturation and soaking. Tests on protected steel-compacted cores soaked at 110°F indicated a decrease in strength of 28 percent. This decrease is substantially more than the 7.4 percent decrease observed for the crack-free cores under the same conditions. All cores were obtained from the same mix compacted to relatively the same density. The only major difference was the presence or lack of cracks after compaction. These cracks provided access for surface water to the interior of the cores, thereby enabling stripping to proceed.

An additional consideration is the influence of vacuum saturation on the test results. The vacuum-saturated crack-free cores after only 2 days of soaking indicated a decrease in strength of 17.3 percent. In contrast, the cores that were simply allowed to soak in the bath (i.e., not vacuum-saturated) showed a decrease of only 7 percent after 7 days of soaking. These data verify a common concept, that vacuum saturation forces water into the core. However, there was no substantial difference for the steel roller–compacted cores, that is, vacuum saturation had no effect. This observation is important because vacuum saturation has in the past obscured the potential benefits of relatively crack-free construction and has led to difficulties in accurately evaluating stripping susceptibility.

CONCLUSIONS

The results presented in this paper support the following:

1. Construction-induced cracks formed during compaction by conventional steel rollers allow excessive surface water penetration of the compacted mixture.
2. Cracks through the dense surface formed by migration of fines to the surface after steel vibratory rolling negate any possible benefit of the dense surface.
3. The crack-free cores offered better resistance to stripping damage when soaked in water without vacuum saturation. This indicates that a crack-free asphalt concrete surface can resist the free flow of surface water into the pavement. Vacuum pressure, used in the past for moisture conditioning, obscured the influence of surface cracks on the stripping problem.

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