

Prevention of Transverse Bumps Over Crack Sealant During Asphalt Overlay Construction

Crack sealants are often utilized as a pavement preservation tool in asphalt pavements. These sealants are placed in transverse and longitudinal cracks to prevent water intrusion into the subgrade. By reducing water intrusion into the subgrade, the strength of these layers is maintained and acceptable pavement performance is extended. However, when a hot mix asphalt overlay is placed on top a pavement with transverse cracks containing crack sealants, a bump often occurs in the new overlay consistent with the location of the crack sealant. This paper presents results from a study designed to determine the cause of these bumps and to determine the means for preventing their occurrence. Five independent variables were evaluated. These were 1) breakdown roller type, 2) roller speed, 3) crack seal installation method, 4) asphalt mixture type, and 5) pavement gradient. The resulting factorial experiment was designed with 48 treatments and three replicates for a total of 144 cracks. Results of the experiment indicate that pavement gradient and vibratory breakdown rolling at 300 feet per minute contributes most to the creation of the bumps and transverse cracks during overlay construction. The crack sealant installation method had little effect on bumps but the warm mix asphalt slightly reduced the occurrence of bumps.

Key Words: Asphalt pavement maintenance, pavement performance, pavement preservation, transverse pavement bumps

Background

Crack sealing is a common method of pavement preservation. This sealing is done to reduce moisture and debris infiltration into the pavement structure, thereby, theoretically improving pavement performance. During the life of most asphalt concrete pavements overlays are placed to rehabilitate and further extend pavement life. During breakdown rolling of the overlay transverse bumps and cracks have been known to form above and in front of the location where crack sealant was placed in the underlying pavement. It is believed that multiple reasons may cause this phenomenon, including mixture design, climatic conditions, paving and compaction equipment, timing of the overlay with respect to sealant placement, sealant type and pavement grade. The mechanism of bump formation is hypothesized to be the result of the breakdown roller creating a 'bow wave' or shoving of the overlay asphalt during the first pass. Heat from the overlay may be transferred down into the substrate pavement and crack sealant. The heated substrate pavement expands and transverse cracks shrink, exuding the crack sealant toward the overlay. The adhesive nature of the crack sealant produces a resistant force to the forward movement of the 'bow wave' in front of the breakdown roller. When the 'bow wave' cannot move forward due to this resistant force, the roller passes over the 'bow wave' creating a bump. The location of this bump is then located slightly in front of the transverse crack containing the sealant. With more focus on ride quality and pavement smoothness; paving contractors, asphalt concrete providers, paver manufacturers, and roller manufacturers, engineering firms and agencies have all investigated ways to prevent bumps.

This paper summarizes a recent study done to evaluate several independent variables thought to contribute to transverse bump formation.

Literature Review

Although bumps and transverse cracks have appeared in new asphalt overlays on top of crack sealant for some time, little objective research has been done to determine the cause and prevention. Suggestions at solutions by interested parties in the asphalt industry based on observations and anecdotal evidence include overlay mixtures with high frictional properties such as open graded mixtures, stone mastic asphalt, or dense graded mixtures with highly angular and fractured aggregate tend to experience less shoving than mixes containing low angularity aggregate (Flexible Pavements of Ohio.) The use of compaction equipment with non-driven front rollers tends to push the mixture creating a larger 'bow wave' resulting in transverse bumps. Use of stiffer tack coats has resulted in less overlay shoving and less bump formation. Hard, stiff sealants may not adhere to the overlay while soft, low melt temperature sealants may soften enough when heated by the overlay to not restrain the mix if it displaces during compaction. However, medium stiffness sealants with elastic properties may have a tendency to soften, adhere and restrain the overlay 'bow wave' (Crafco, 2003).

A recent study indicated that the speed of the vibrating steel roller during breakdown influenced bump formation as well as the number of roller passes (Shuler 2009). A study conducted for Colorado DOT (Shuler 2011) found that bumps accompanied by transverse cracking occurred after the crack sealants had been in service for two years in one test pavement. The number of passes of the vibrating steel rollers further exacerbated the presence of the bumps and cracks. The same rollers used in static mode reduced the effect, and pneumatic rollers used for breakdown eliminated the effect. The ambient temperature and temperature of the substrate pavement during construction was reported to have little effect (Shuler, 2011). Transverse bumps over crack sealant on a flat gradient pavement (Shuler 2011) have been reported. However, a relatively large 'bow wave' was also reported during breakdown rolling during this research. A diagram of what is meant by 'bow wave' is shown in Figure 1. This 'bow wave' could be related to the occurrence of transverse bumps. Therefore, two pavement gradients were introduced in the study reported here in an attempt to create different sized 'bow waves'.

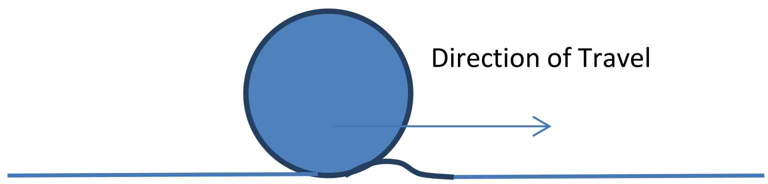

Figure 1: 'Bow Wave' Created by Breakdown Roller

Experimental Method

This experiment was designed as a blocked, partial factorial with replication and four independent variables as shown below:

Sealant Application
- Recessed
- Flush
- Overbanded
- Overbanded with Release

Breakdown Roller
- Vibrating Steel
- Static Steel
- Pneumatic

Overlay Type:
- Hot Mix
- Warm Mix

Pavement Grade:
- 0-1%
- 3-4%

These variables were originally intended to analyze the effect on bump generation using a full factorial design. However, certain factors influencing the construction of the test pavement prevented this. These included the elimination of the overlay over cracks 73 to 120 on the 3-4% grade pavement and significant sticking of the hot and warm mix asphalt to the tires of the pneumatic roller during breakdown attempts. However, cracks 73 to 120 were added to the 0-1% grade pavement resulting in the same number of total cracks sealed and overlaid. After these modifications to the original, planned design the matrix shown in Table 1 was utilized with three replicate cracks sealed for each treatment combination resulting in a total of 144 sealed cracks. The blocked variable was pavement grade since these two pavements were in different locations and required paving on different days.

Crack sealant properties are shown in Table 2.

Table 1
Experimental Plan with 144 Cracks to Evaluate

		Pavement Gradient			
		0 - 1%		3 - 4%	
		Mixture			
Roller	**Installation**	HMA	WMA	HMA	WMA
Static 300	Recess	1	37	85	121
		2	38	86	122
		3	39	87	123
	Flush	4	40	88	124
		5	41	89	125
		6	42	90	126
	Overband	7	43	91	127
		8	44	92	128
		9	45	93	129
	Overband+	10	46	94	130
		11	47	95	131
		12	48	96	132
Vibrating 200	Recess	13	49		
		14	50		
		15	51		
	Flush	16	52		
		17	53		
		18	54		
	Overband	19	55		
		20	56		
		21	57		
	Overband+	22	58		
		23	59		
		24	60		
Vibrating 300	Recess	25	61	97	133
		26	62	98	134
		27	63	99	135
	Flush	28	64	100	136
		29	65	101	137
		30	66	102	138
	Overband	31	67	103	139
		32	68	104	140
		33	69	105	141
	Overband+	34	70	106	142
		35	71	107	143
		36	72	108	144
Static 200	Recess	73	109		
		74	110		
		75	111		
	Flush	76	112		
		77	113		

		78	114
	Overband	79	115
		80	116
		81	117
	Overband+	82	118
		83	119
		84	120

Table 2
Physical Properties of Crack Sealants

Property	D6690 Specification-Type II	Test Result
Cone Penetration, 25C	90, max	75
Softening Point, C	80C, min	90
Resilience, %	60, min	85
Asphalt Compatibility, 60C, 72 hrs	Pass	Pass

Asphalt concrete used in the overlay was both hot mix asphalt (HMA) and warm mix asphalt (WMA). The same mixture was used for both processes, that is, a foaming process was utilized with the hot mix asphalt mixture to allow lower mixing and compaction temperatures with the same mixture. Properties of this mixture are shown in Table 3.

Table 3
Aggregate and Asphalt Mixture Properties

Aggregate Property	Result	Specification
Micro Deval, Loss %	7.6	18, max
L.A. Abrasion, Loss %	13	45, max
Fractured Faces, 2+ %	100	80, min
Fine Aggregate Angularity, %	46.4	45, min
Sand Equivalent, %	77	45, min
Flat and Elongated, 1:5, %	3	10, max
Adherent Fines, %	0.4	0.5, max
Asphalt Mixture Property	**Result**	**Specification**
Asphalt Content, %	4.9	n/a
Voids in Total Mix, %	3.8	3 – 5
VMA, %	14.7	14.7, min
VFA, %	74.1	65 – 75
Hveem Stability	46	30, min
Dust to Asphalt Ratio	1.2	0.6 – 1.2
Dry Indirect Tensile Strength, psi	103	30, min
Tensile Strength Ratio	96	80, min

The dependent variable in this experiment is the appearance of transverse bumps and cracks on top of the sealants in the substrate pavement. Bumps and cracks were evaluated quantitatively depending on when the bump or cracks appeared after breakdown rolling as shown in Table 4. These bumps were visually identified by the author and verified by the paving crew.

Table 4
Rating Scale for Bump and Crack Appearance After Breakdown

Rating	Appearance of Bump and/or Cracks
4	First Pass of Breakdown Roller
3	Second Pass
2	Third Pass
1	Fourth Pass
0	No Bump/Cracks

Construction

Two pavements in Golden, Colorado were selected for evaluation in this experiment. Location 1 on Yank Street was selected because of the 0 to 1 percent grade. Location 2 on 55th Place was selected for the 3 to 4 percent grade. Both pavements had transverse cracks of approximately the same severity of ¼-inch wide traversing the entire pavement width.

Each crack to be sealed was identified prior to installation and numbered on the edge of the pavement. Installation was done by the Jefferson County Colorado Road and Bridge Division at both pavement locations on March 17, 2011. The sealant was installed in accordance with recommendations supplied by Deery American Corporation for the crack sealant.

Crack preparation method included blowing out the cracks using 100-psi compressed air. Sealant was applied to the cracks by hot pouring using a pressure wand and either sealing to level with the surrounding pavement or sealing to slightly over full and then spreading the excess off the surface with a V-shaped squeegee creating the 'over-band' application. Two-ply Charmin toilet paper was used as a release agent on top of specific overbanded cracks prior to overlay construction on August 31, 2011.

Table 5 is a summary of the site characteristics.

Table 5
Test Site Characteristics

Site	**Section**	**Subgrade Soil**	**Elevation**	**Mean Annual Temp, F**	**Traffic, AADT**	**Mix Type**
Yank St	2 inches 1/2" HMA or WMA* 8 inches Class 6**	A3-Silt	5495	41-45	500	HMA Southbound WMA Northbound
55th Place	3 inches ½" HMA or WMA 6 inches Class 6	A1-cohesionless	5620	43-47	200	HMA Westbound WMA Eastbound

* HMA refers to hot mix asphalt pavement, WMA refers to warm mix asphalt, ½" or ¾" refers to approximate maximum aggregate size

** Class 6 is a water-bound crushed aggregate base

The weather conditions and pavement temperature during installation were clear and dry with no moisture present in the cracks. Pavement temperatures ranged from 94 to 102F during construction at both sites. A 94% relative to maximum theoretical density was achieved on all sections. It was achieved with fewer passes of the vibratory breakdown roller, but still achieved with static breakdown.

The hot mix and warm mix asphalt was produced by Asphalt Paving Company of Golden, Colorado. The materials were delivered to the jobsites in covered tandem 12 ton dump trucks operated by Jefferson County. All paving was accomplished by Jefferson County using a Caterpillar AP1055D paving machine, a Caterpillar CB534D vibratory steel wheel roller with drum amplitude set at the Number 1 position and a Caterpillar PS150C pneumatic tire roller adjusted to 75 psi tire pressure. Temperatures of the hot mix and warm mix asphalt ranged from 255F to 280F and from 235F to 255F, respectively for the Yank Street and 55th Place pavements . Paving operations occurred in the downhill direction for 55th Place.

Results

Transverse bumps appeared after breakdown rolling. Sometimes these bumps appeared after the first pass, sometimes multiple passes were required to manifest the bumps. Bumps tended to be more severe, i. e., larger, when they were manifested after a single pass of the breakdown roller. Therefore, the number of passes of the breakdown roller required to cause the bumps was observed and noted during construction. The results of these individual observations for each crack are shown in Table 6. If no bump occurred regardless of breakdown roller activity, the numeral 0 is shown in the figure, if four passes were required to manifest a bump (the least severe), the numeral 1 appears, if three passes, the numeral 2 appears, and so on. Figure 2 is a graphical representation of the average values of bump generation for the breakdown roller operating at 300 feet per minute on the 3-4 percent grade pavement.

Table 6

Appearance of Bumps After Breakdown Rolling

		Pavement Gradient			
		0 - 1%		3 - 4%	
		Mixture			
Roller	**Installation**	HMA	WMA	HMA	WMA
Static 300	Recess	0	0	0	0
		0	0	0	0
		0	0	0	0
	Flush	0	0	0	0
		0	0	0	0
		0	0	0	0
	Overband	0	0	1	0
		0	0	0	0
		0	0	0	0
	Overband+	0	0	0	0
		0	0	0	0
		0	0	1	0
Vibrating 200	Recess	0	0		
		0	0		
		0	0		
	Flush	0	0		
		0	0		
		0	0		
	Overband	0	0		
		0	0		
		0	0		
	Overband+	0	0		

		0	0		
		0	0		
Vibrating 300	Recess	0	0	3	3
		0	0	3	2
		0	0	2	2
	Flush	0	0	3	3
		0	0	4	3
		0	0	3	2
	Overband	0	0	4	3
		0	0	4	4
		0	0	4	3
	Overband+	0	0	3	4
		0	0	4	4
		0	0	4	3
Static 200	Recess	0	0		
		0	0		
		0	0		
	Flush	0	0		
		0	0		
		0	0		
	Overband	0	0		
		0	0		
		0	0		
	Overband+	0	0		
		0	0		
		0	0		

Note: 0 = No bump appearing , 1=bump after 4 passes, 2=bump after 3 passes, 3=bump after 2 passes, 4=bump after 1 pass.

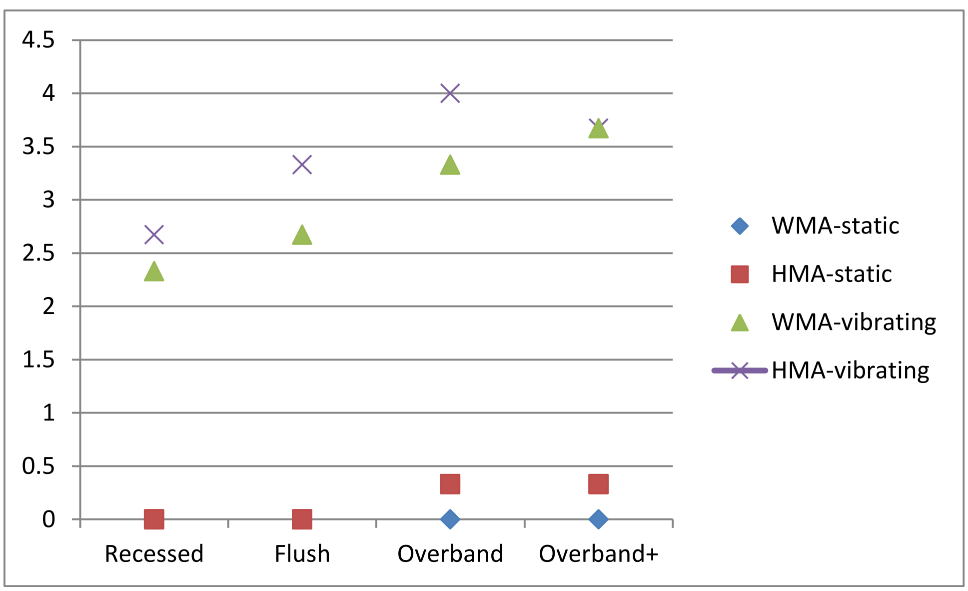

Figure 2: Average Bump Appearance at 300 fpm on 3-4% Grade

Analysis

There was a significant difference whether bumps were created during breakdown rolling between the two sites. No bumps were generated at the 0-1% grade site on Yank Street. This was true regardless of crack seal preparation method, asphalt mixture type or the type or speed of breakdown roller used. However, at the 3-4% site on 55th Place bumps and transverse cracks were created. These bumps and transverse cracks were dependent on roller type, mixture type and crack seal preparation method. The most significant reduction in bump appearance occurred when the static steel wheel roller was used for breakdown rolling over the recessed and flush sealed crack sealants. However, only very minor bumps and transverse cracking occurred with static rolling over the overbanded crack sealants. Vibratory breakdown rolling produced the most significant bumps and cracks over the overbanded and overbanded with release agent crack sealant for the hot mix overlay. However, bumps and cracks also appeared over the recessed and flush sealed cracks after two or three passes of the roller. Bumps and cracks also occurred in the warm mix overlay over all four types of crack preparation, but generally required one additional pass of the breakdown roller to occur.

Observations on Yank Street (0 to 1% grade) indicate the size of the ‘bow wave’ in front of the breakdown roller was very small or non-existent but on 55th Place (3 to 4% grade) the ‘bow wave’ was larger. This could mean the ‘bow wave’ or pushing of the asphalt mixture is directly related to the propensity of the mixture to form a bump over crack sealant. The relatively stiff asphalt mixture used in this research, as indicated by the properties shown in Table 2, may provide evidence for the lack of bumps on Yank Street where a small ‘bow wave’ was observed and the occurrence of bumps on 55th Place where a larger ‘bow wave’ was generated due to the downhill paving operation.

Conclusions

Pavement grade had a significant effect on the appearance of transverse bumps and cracks appearing in both hot and warm mix asphalt overlays placed over crack sealants. Regardless of the crack sealant preparation method, breakdown roller type or speed and overlay mixture type, no bumps were created on the test pavement with 0 to 1 percent grade. However, when the same asphalt mixtures were placed on a pavement with 3 to 4 percent grade bumps could be generated at will when the steel breakdown roller was used in vibrating mode at 300 feet per minute. Warm mix asphalt was slightly less susceptible to bump generation than hot mix asphalt with both static and vibrating rollers. Recessed and flush sealed crack preparation was slightly effective in reducing bumps when vibratory breakdown was used.

Recommendations

The ‘bow wave’ generated in front of the breakdown roller appears to contribute to bump formation in overlays placed over transverse crack sealant. This ‘bow wave’ was related to the pavement grade in this study but could be caused by asphalt mixture properties. Therefore, further study of bump creation based on ‘bow wave’ size is recommended.

References

1. Bump Formation & Prevention In Asphalt Concrete Overlays Which Have Been Crack Sealed, *Crafco, Chandler, Arizona, 2003*

2. Shuler, Scott, (2009), “Short-Term Crack Sealant Performance and Reducing Bumps and Transverse Cracking in New Hot Mix Asphalt Overlays Over Crack Sealants”, Colorado Department of Transportation Report No. CDOT-2009-9, Interim Report.

3. Shuler, Scott, (2011), “Investigating Crack Sealant Performance and Causes of Bumps in New Hot Mix Asphalt Overlays Over Crack Sealants”, Colorado Department of Transportation Report No. CDOT-2011-10, Final Report.

4. Smith, Kelly L., and Romine, Russell, (1987) "Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements", SHRP-H-348, Manuals of Practice, Strategic Highway Research Program, National Research Council, TRB, Box 289, Wash. DC 20055.

5. Use Of Crack Sealing Prior To Placement Of Hot Mix Asphalt, *Flexible Pavements of Ohio Technical Bulletin. No date available.*