

Factors Affecting the Appearance of Transverse Bumps in New Asphalt Overlays

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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 near the location of the crack sealant. Recent research indicates that tack coat asphalt reduces the potential for these transverse bumps. Asphalt tack coats are used to provide adhesion between new asphalt overlays and existing pavements. The amount of tack coat asphalt is related to the adhesion provided between the new and old surfaces. Increasing this adhesion seems to be related to a reduction in bump creation. This study evaluated eight independent variables including tack coat asphalt to determine which affected the appearance of transverse bumps in new asphalt overlays. These were overlay thickness, breakdown roller type, roller speed, crack seal installation method, crack seal type, asphalt mixture type, pavement gradient, and tack coat application rate. Results of the research indicate that pavement gradient and rapid vibratory breakdown rolling contributes most to the creation of bumps over crack sealant. The volume of tack coat asphalt, breakdown roller type and speed of the breakdown roller had the most significant effect on the elimination of bumps.

Keywords: Asphalt pavement maintenance, asphalt tack coat, 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 roller 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 as shown in Figure 1.

Tack coat asphalt is used as an adhesive between the new overlay and the old pavement and may provide a means of reducing the size of the 'bow wave' in front of the breakdown roller. If so, the tack coat might be a means of reducing or even eliminating the transverse bumps over crack sealants. Some anecdotal evidence was collected by the authors that indicated the quantity of tack coat asphalt applied to the substrate pavement prior to overlay placement has an effect on bump creation. Therefore, a designed experiment was developed to test this hypothesis.

With more focus on ride quality and pavement smoothness; paving contractors, asphalt concrete providers, paver manufacturers, and roller manufacturers, engineering firms and owner agencies have all investigated ways to prevent bumps.

This paper summarizes three studies done from 2007 until 2013 to evaluate several independent variables thought to contribute or reduce the appearance of transverse bump formation.

Figure 1: Transverse Bump in New Asphalt Overlay Placed Over Crack Sealant

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 2.

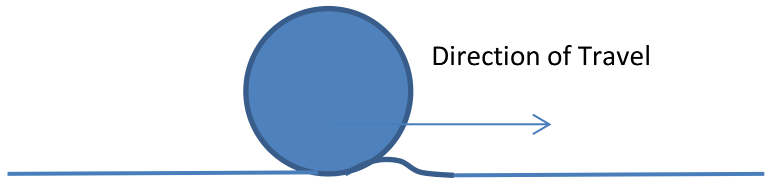

Figure 2: 'Bow Wave' Created by Breakdown Roller

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'. In addition, there is anecdotal evidence that tack coat application rate may have an effect on bump creation, and an experiment was designed to test this notion, as well.

Experimental Method

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

- Sealant Application
  - Recessed
  - Flush
  - Overbanded
  - Overbanded with Release
- Breakdown Roller
  - Vibrating Steel
  - Static Steel
  - Pneumatic
- Roller Speed
  - 200 fpm
  - 300 fpm
- Overlay Type:
  - Hot Mix
  - Warm Mix
- Pavement Grade:
  - 0-1%
  - 3-4%
- Tack Coat Rate
  - 0.000
  - 0.025
  - 0.050

The observations reported in this paper are from three sites constructed from 2007 to 2013. This experiment was done in steps. That is, observations made experimental site 1 were used to refine the experiment at Site 2, and observations made at Site 2 were further refined to make observations at Site 3. All observations have been documented herein and are presented below.

Site 1

Independent Variables

Independent variables for this site were suppliers A, B and C and ASTM D6690 sealant types II and IV; preparation methods: routing, hot air lance (HAL) and air blow; sealant treatments: overband, flush and recessed; breakdown roller type: vibrating steel, static steel and pneumatic and overlay thickness: 2 inches and 3 inches.

Table 1 is a summary of the 126 combinations* of variables evaluated at Site 1.

Table 1
Experimental Matrix Site 1*

		Sealant Application		
Supplier-ASTM D6690 Type	Preparation	Flush	Overband	Recessed
A-IV	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
B-IV	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
C-II	Rout	x	x	x
	HAL	x	x	
	Air	x	x	

- This matrix is repeated three times for each of the breakdown roller types and doubled for the 2 and 3 inch overlays, respectively.

Site 2
Independent Variables
Independent variables for this site were sealant treatments: recessed, flush, overband and overband+; roller speed: 200 and 300 fpm; roller type: static and vibrating; pavement grade: 1% and 2%; and mixture type: WMA and HMA.

Table 2 is a summary of the 48 combinations of variables evaluated at Site 2.

Site 3
Independent Variable
The independent variable evaluated at Site 3 was the tack coat rate. The tack coat was applied at 0, 0.025 and 0.05 gallons per square yard of undiluted CSS-1h asphalt emulsion.

Table 2
Experimental Matrix Site 2

		Pavement Grade			
		0-1%		3-4%	
		Mixture			
Roller	Install	HMA	WMA	HMA	WMA
Static 300	Recess	x	x	x	x
	Flush	x	x	x	x
	Overband	x	x	x	x
	Overband+	x	x	x	x
Vibrate 200	Recess	x	x		
	Flush	x	x		
	Overband	x	x		
	Overband+	x	x		
Vibrate 300	Recess	x	x	x	x
	Flush	x	x	x	x
	Overband	x	x	x	x
	Overband+	x	x	x	x
Static 200	Recess	x	x		
	Flush	x	x		
	Overband	x	x		
	Overband+	x	x		

* HMA = Hot Mix Asphalt WMA=Warm Mix Asphalt

The dependent variable in this experiment was 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 3. These bumps were visually identified by the author and verified by the paving crew.

Construction

Site 1

Site 1 is a major US highway in the southern part of the state. Three transverse cracks were identified for crack sealing for each of the treatment combinations shown in Table 1. These crack sealants and application methods were installed by company representatives for each sealant type to be certain installation methods were in accordance with recommended practices. Crack sealing occurred in October, 2007. The overlay asphalt was not constructed until September, 2009. This two year interval was planned because of reports that bumps may be more prevalent in overlays placed over recently installed crack sealants (Crafco 2003). Vibratory steel rollers were a Bomag BW190AD and a Caterpillar CB534C. Pneumatic rollers were a Hypac C530AH and a Caterpillar PS150B. The static condition was tested by operating the vibratory steel rollers in static mode.

Site 2

Crack sealing at Site 2 was on two city streets on March 17, 2011. Crack sealant was installed in accordance with recommendations supplied by Deery American Corporation.

The 'overband +' application process consisted of filling the cracks as usual, then applying the squeegee to provide an overband of approximately three inches wide, then applying two-ply Charmin toilet tissue as a release agent on top. The Charmin was not applied until overlay construction began in August, 2011.

Hot mix and warm mix asphalt was produced by a local materials supplier and placed by county personnel. All paving was accomplished 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.

Site 3

This experiment was placed on a two lane state highway by state maintenance personnel in August, 2013. The substrate pavement contained many transverse cracks which had been crack sealed with overbanded ASTM D6690 Type II placed in the summer of 2012. Five pavement sections were identified for testing. These sections consisted of Control Sections 1 and 2 at 0.05 gallons per square yard of undiluted CSS-1h, Section 3 at 0.025 gallons per square yard of undiluted CSS-1h and Sections 4 and 5 with 0 gallons per square yard of undiluted CSS-1h.

Construction occurred in August, 2013. The paver was a Caterpillar AP1055D paving machine and the only roller was a Hypac.

Transverse cracks were marked with pavement marking paint prior to the overlay placement so that after the overlay was placed the locations could be observed to determine if bump formation was occurring after rolling.

Results

Site 1

Bumps in the overlay at Site 1 occurred for all three brands of crack sealants which represented ASTM D6690 Types II and IV for overlay thicknesses. These bumps only occurred when the breakdown roller was operated in the vibrating mode and only when the crack sealant was overbanded.

Site 2

Bumps appeared only for the 3-4% grade pavement when vibrating on breakdown but for all crack sealant installation methods and both warm mix and hot mix asphalt overlays.

Site 3
Bumps occurred only in the pavement sections where no tack coat was applied and only after five or more passes of the relatively lightweight breakdown roller. Roller vibration and speed had no effect.

Analysis

Site 1
A summary of the results from Site 1 are shown in Table 3. These results indicate under what circumstances bumps occurred. Pneumatic breakdown rolling was done by the contractor to eliminate bumps. The empty cells in Table 3 are an indication of the success of this practice.

Table 3
Bump Creation at Site 1

		Vibrating Breakdown Roller					
		2-inch Overlay			3-inch Overlay		
		Sealant Application			Sealant Application		
Supplier-ASTM D6690 Type	Preparation	Flush	Overband	Recessed	Flush	Overband	Recessed
A-IV	Rout						
	HAL					Bumps	
	Air						
B-IV	Rout						
	HAL		Bumps			Bumps	
	Air						
C-II	Rout						
	HAL					Bumps	
	Air						

Initial analysis of these results indicates that manufacturer, sealant type and overlay thickness appear to have no effect on bump creation.

Site 2
All efforts to create bumps during breakdown rolling at the 0-1% grade site failed to produce any. However, as seen in Table 4, bumps were created in the pavement at the 3-4% grade site. In the table ‘bump-‘ means that two passes of the breakdown roller were required to create the bump. When ‘bump+’ appears it means that a bump occurred after only one pass.

In this case, type of mixture and installation method had no effect on bump creation.

Observations on the 0 to 1% grade street indicate the size of the ‘bow wave’ in front of the breakdown roller was very small or non-existent but on the 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.

Site 3
Bumps only occurred at Site 3 when no tack coat was applied to the substrate pavement. Vibratory breakdown rolling was used for the sections with tack coat but produced no bumps.

Table 4

Bump Creation at Site 2

		Pavement Grade			
		0-1%		3-4%	
		Mixture			
Roller	Install	HMA	WMA	HMA	WMA
Static 300	Recess				
	Flush				
	Overband				
	Overband+				
Vibrate 200	Recess				
	Flush				
	Overband				
	Overband+				
Vibrate 300	Recess			Bump-	Bump-
	Flush			Bump-	Bump-
	Overband			Bump+	Bump+
	Overband+			Bump+	Bump+
Static 200	Recess				
	Flush				
	Overband				
	Overband+				

Conclusions

Certain factors which appear to have little or no effect regarding the appearance of transverse bumps in asphalt overlays placed over crack sealant observed at Site 1 are as follows:

1. age of crack sealant
2. type of crack sealant
3. crack sealant manufacturer
4. sealant installation method
5. overlay thickness
6. compaction temperature

Factors which appear to have a significant effect on the appearance of transverse bumps in asphalt overlays placed over crack sealant are these:

1. vibratory breakdown rolling at Site 1caused bumps, but
2. vibratory breakdown rolling at Site 2 did not when sufficient tack coat was used
3. increasing pavement grade caused bumps at the Site 2 experiment
4. slowing the breakdown roller reduced bump appearance
5. pneumatic breakdown rolling eliminated bump appearance
6. increasing tack coat application rate eliminated bumps at Site 3

References

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