Technical Memorandum

Arizona SPS-2 PCC Joint Seal Performance

Overview

The Arizona Special Pavement Studies (SPS) 2 jointed concrete pavement test site, located on eastbound I-10 between mileposts 106 and 109 was constructed in 1993 with 12 LTPP and 9 ADOT test sections. Each test section includes about 33 transverse joints, spaced at 15 ft, which were reportedly sealed using Crafco 34902 non-sag RoadSaver Silicone sealant. Various combinations of base type, concrete strength, slab width, and slab thickness, as shown below, were designed to allow statistical analysis of the contributions of each factor. A March 2013 evaluation of the condition of the joints and seals indicates correlations of base type and Portland cement concrete (PCC) strength with adhesion and sliver spall failures.

Section	Base*	PCC Strength, psi	Slab width, ft	Thickness, in
213	DGAB	550	14	8
214	DGAB	900	12	8
215	DGAB	900	12	11
216	DGAB	900	14	11
217	LCB	550	14	8
218	LCB	900	12	8
219	LCB	550	12	11
220	LCB	900	14	11
221	PB/DG	550	14	8
222	PB/DG	900	12	8
223	PB/DG	550	12	11
224	PB/DG	900	14	11
262	DGAB	550	14	8
263	PB/DG	550	14	11
264	PB/DG	550	12	11

* 6-in dense graded aggregate (DGAB); 4-in PBTB/4-in DGAB (PB/DG); 6-in Lean Concrete (LCB)

Transverse Seal Findings

Overall performance of the SPS-2 joint seal systems is extraordinarily good, considering the seals have been in place for 20 years and the truck lane has carried about 31 million Equivalent Single Axle Loads (ESALs). As figure 1 illustrates, no section exhibits more than 35 percent overall seal failure with six sections remaining below ten percent. Five randomly-selected transverse joints were evaluated in each section.

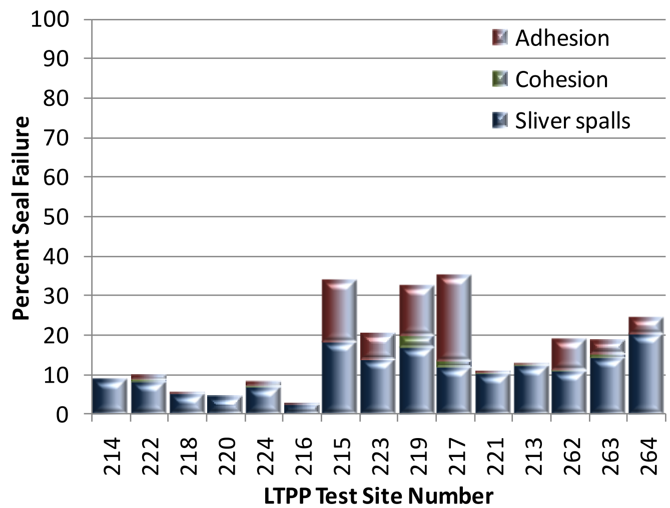

Figure 1. Overall failure rates on transverse joints

Primary modes of failure include sliver spalls and loss of adhesion with the joint walls. Additionally, slight cohesive failure was identified when the installed seal thickness (less than 0.125 in) fell below the design thickness (0.25 in). Full depth sliver spalls, shown in figure 2, typically progress around or through the aggregate adjacent to the joint wall.

These sliver spalls accounted for more than 65 percent of the seal system failures with 2.4 times more failure noted in 550 psi than the 900 psi compressive strength

Figure 2. Spall failure – transverse joint (section 264).

concrete. Figure 3 illustrates this trend, showing statistically similar failure rates under each Duncan grouping bar. Most likely the increased spall failure with decreased concrete strength results from the effect of the non-relaxing stresses induced on the concrete face by the silicone seals as the joint opens. The weaker mortar found in the lower strength concrete is less able to resist this stress, particularly when shear stresses are induced by passing truck tires, resulting in increased spall formation.

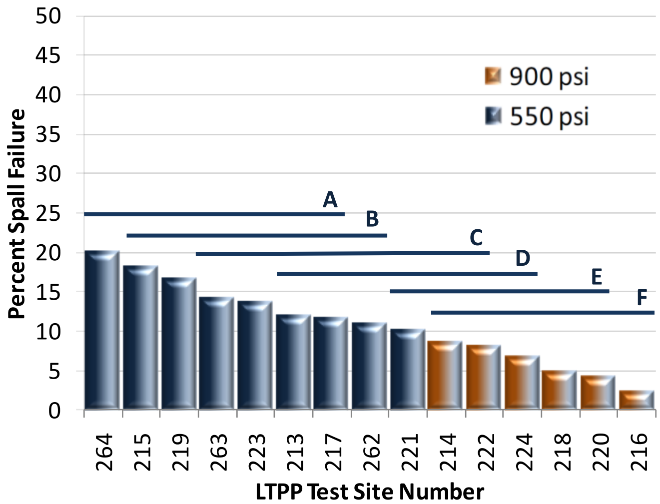

Figure 3. Sliver spall failure rates on transverse joints.

Concrete strength also affected the rate of adhesive failure (see figure 4). Twenty times more adhesive loss occurred in the 500 psi sections than for the 900 psi concrete. Field observations reveal frequent granules of sand and aggregate adhered to the seal edges following adhesive failure. This indicates that weaker mortar, combined with sustained stress at the seal-concrete bond, resulted in additional adhesive failure. Figure 5 demonstrates this type of adhesive failure. Notice the exposed large aggregate on the surface, indicative of weaker mortar with less resistance to stress.

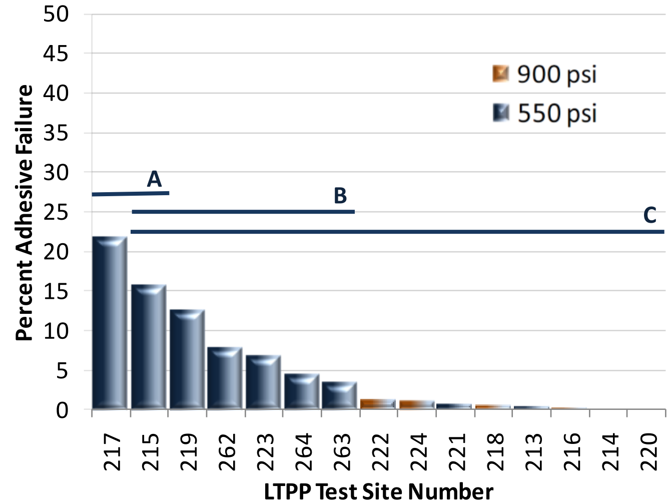

Figure 4. Adhesive failure on transverse joints

Figure 5. Adhesive failure – transverse joint (sect. 215)

Additionally, no correlation was found between base type and spall or adhesive failure. Similarly, faults averaging 0.21 in on the undoweled 8-inch PCC over dense graded aggregate base (DGAB) section 262 did not contribute to a statistically larger amount of spall or adhesive failure on dowelled companion section 213.

Furthermore, variations in concrete surface thicknesses (8- and 11-in) have not led to statistical differences in adhesive or spall failure, when other factors (except slab width) are held steady. This can be seen by comparing sections 214 and 216, 217 and 219, 221 and 223, and 222 and 224. Lane width variations produced statistically negligible effects on adhesive or spall levels, with only a 6 percent increase in spall failure for 12-ft (264) versus 14-ft (263) lanes.

Pull tests performed on seals from each section indicate that the material has lost elasticity, although its adhesive properties remain high. Average extension rates have reduced from installed levels (300 percent) to typically less than 100. However, nearly all tested seals failed in cohesion, indicating that a strong bond remains between the seal and adjacent concrete.

Longitudinal Seal Findings

Longitudinal shoulder joint seals typically do not experience the expansion, contraction, and load deflections experienced by transverse lane joints. However, as figure 6 indicates, the average overall failure of the SPS-2 longitudinal seals exceeded 40 percent, compared with 17 percent for transverse seals. Additionally, the overall ratio of adhesion to spall failure increased from 0.5 in transverse joints to 1.7 times in longitudinal joints.

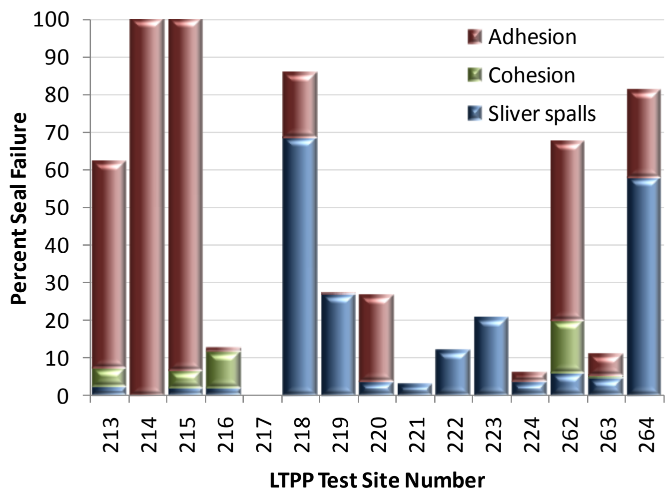

Figure 6. Overall failure rates on longitudinal joints.

These increases can be explained by the frequent widening of the original 0.375-in joint to more than 1.0-in width. Such extreme increased extensions exceed the typical 25 percent silicone seal design limits. It is therefore surprising that many seals (figure 7) have extended to more than 300 percent and remain partially bonded.

Figure 7. Adhesive failure on longitudinal joints.

As figure 8 illustrates, adhesive failure increases about 12 percent for every 0.1 in of increased longitudinal joint width. This figure also reveals an effect of base type on joint width, and hence on adhesion failure. On average, longitudinal joints over the 6-in DGAB widened 2.7 times. Joints in concrete overlying 4-in permeable bituminous treated base (PB) and 4-in DGAB were widened 1.8 times, and those over lean concrete base (LCB) increased 1.2 times on the day of testing. Adhesion failure rates increased accordingly.

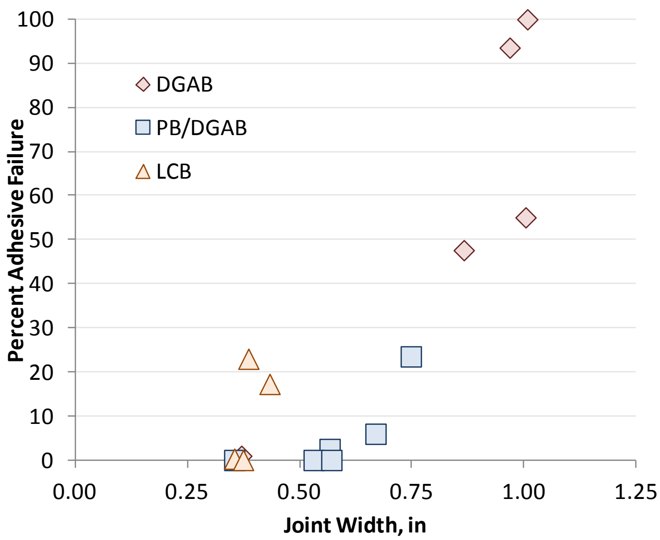

Figure 8. Overall failure on longitudinal joints.

This trend can be expected since typical horizontal friction levels between PCC and cement or asphalt stabilized bases triple those of DGAB. Current practices of tying concrete shoulders to traffic lanes will alleviate this extreme movement and resulting seal failure.

Increased thickness of the PCC surface led to better longitudinal joint seal adhesive performance in section 216 (11-in) versus section 214 (8-in), whereas the opposite was true for sections 213 (8-in) and 215 (11-in). Spall failure levels also increased with pavement strength for sections 217 vs. 219 and 221 vs. 223. However, no significant difference in spall failure could be attributed to pavement thickness. Overall seal failure increased with greater thickness, as illustrated by sections 213 vs. 215, 217 vs. 219, and 221 vs. 223.

Concrete strength levels did not correlate well with longitudinal joint seal adhesive or spall failure. This may result from an overpowering effect of extreme joint movement.

Conclusions

Silicone seals in the transverse joints of the Arizona SPS-2 site remain in excellent condition, affected primarily by the strength properties of the concrete pavement. Figure 9 provides an example of high performing seal from section 222. Average adhesion failure rates of 5 percent after 20 years indicate high quality materials and installation practices.

Figure 9. Transverse joint seal in section 222.

Seals installed in transverse joints with standard strength 500-psi concrete developed significantly greater spall and adhesion failure than those in 900-psi concrete. Average spall rates increased by 2.4 times in the standard strength sections, and adhesion failure increased by 20 percent. No statistical differences in seal performance were noted between 8- and 11-in thick pavements. Similarly, lane width variations resulted in no significant difference is seal effectiveness.

Silicone seal effectiveness on longitudinal joints ranged from 0 to 100 percent, averaging 41 percent. Figure 10 illustrates good seal performance in a 900 psi concrete over PB/DB base.

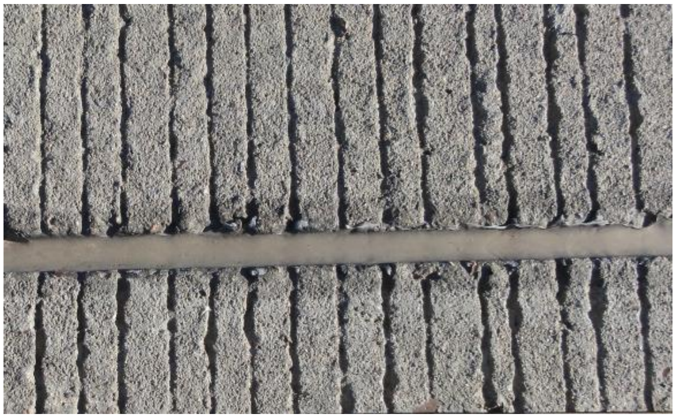

Figure 10. Longitudinal joint seal in section 222.

Widening of the longitudinal joint to more than 2 times its original width overshadowed any differentiating affects of pavement thickness and pavement strength on seal failure. Joint widening is clearly correlated with the type of underlying base material. DGAB results in the widest joints and LCB in the narrowest.

Evaluation of seal performance at other SPS-2 sites may lead to further verification of these conclusions and additional related findings. Particularly, if good seals are evaluated in conjunction with unsealed sections, a better understanding of the effects of pavement seals on pavement performance will be obtained.

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