

***EVALUATION OF VARIOUS
CONCRETE PAVEMENT
JOINT SEALANTS***

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**MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT**

Evaluation of Various Concrete Pavement Joint Sealants

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May 1, 2000

**Testing and Research Section
Construction and Technology Division
Work Plan No. 137
Research Project G-0300
Research Report No. R-1376**

**Michigan Transportation Commission
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1. Report No. Research Report R-1376	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle: Evaluation of Various Concrete Pavement Joint Sealants		5. Report Date April 1, 2000	
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9. Performing Organization Name and Address Michigan Department of Transportation Construction and Technology Division P.O. Box 30049 Lansing, MI 48909		8. Performing Org Report No. R-1376	
12. Sponsoring Agency Name and Address Michigan Department of Transportation Construction and Technology Division P.O. Box 30049 Lansing, MI 48909		10. Work Unit No. (TRAIS)	
		11. Contract/Grant No.	
15. Supplementary Notes		13. Type of Report & Period Covered Final, September 1994 - April 1999	
		14. Sponsoring Agency Code	
<p>16. Abstract</p> <p>A test section of pourable sealants was placed on reconstructed I-94 between Watervliet and Hartford, in the fall of 1994. Five sealants, Dow 888 and 890SL, Sikaflex 15LM and 1CSL, and Crafcro Roadsaver SL, were each used to seal 60 contraction joints. Preformed neoprene, Michigan's standard sealant, was used on the remainder of the job.</p> <p>The sealants were visually evaluated and rated twice a year for three and a half years. A rating system of 1 to 5 was used in three categories: sealing (adhesion to the concrete), weathering, and debris intrusion. The number given depended on the amount of failure as measured along the length of the joint. A rating of five was the best and meant the sealant was in the same condition as when it was placed. A rating of one meant that more than 50 percent of the sealant failed.</p> <p>Sikaflex 1CSL performed the best of the pourable sealants. It had the best sealing rating after 44 months and the failures it did have were small. It was followed by Dow 890SL, which also had small failures but more than Sikaflex 1CSL, and Sikaflex 15LM. Crafcro Roadsaver SL and Dow 888 both performed poorly. Crafcro Roadsaver SL had a mixture of small to moderate failures about half of which were cohesive (tear within the sealant). Dow 888 had many large failures including a handful of joints where the sealant is completely missing.</p> <p>The Preformed Neoprene performed better than any of the pourable sealants. It is in the same condition as when it was first placed. Weathering is not a problem with any of the sealants. Debris intrusion is a function of the sealing. With more sealant failures more debris can enter the joint reservoir.</p>			
17. Key Words Concrete, pavement, joint, sealant, silicone, polyurethane, neoprene.		18. Distribution Statement No restrictions. This document is available to the public through the Michigan Department of Transportation.	
19. Security Classification (report) Unclassified	20. Security Classification (Page) Unclassified	21. No of Pages	22. Price

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EXECUTIVE SUMMARY

A test section of pourable sealants was placed on reconstructed I-94 (Control Section 80023, Job Number 32517) between Watervliet and Hartford, in the Fall of 1994. Five sealants, Dow 888 and 890SL, Sikaflex 15LM and 1CSL, and Crafcro Roadsaver SL, were each used to seal 60 contraction joints. Preformed neoprene, Michigan's standard sealant, was used on the remainder of the job.

The sealants were visually evaluated and rated twice a year for three and a half years. A rating system of 1 to 5 was used in three categories: sealing (adhesion to the concrete), weathering, and debris intrusion. The number given depended on the amount of failure as measured along the length of the joint. A rating of five was the best and meant the sealant was in the same condition as when it was placed. A rating of one meant that more than 50 percent of the sealant failed.

Sikaflex 1CSL performed the best of the pourable sealants. It had the best sealing rating after 44 months and the failures it did have were small. It was followed by Dow 890SL, which also had small failures but more than Sikaflex 1CSL, and Sikaflex 15LM. Crafcro Roadsaver SL and Dow 888 both performed poorly. Crafcro Roadsaver SL had a mixture of small to moderate failures about half of which were cohesive (tear within the sealant). Dow 888 had many large failures including a handful of joints where the sealant is completely missing.

The Preformed Neoprene performed better than any of the pourable sealants. It is in the same condition as when it was first placed.

Weathering is not a problem with any of the sealants. Debris intrusion is a function of the sealing. With more sealant failures more debris can enter the joint reservoir.

ACTION PLAN

1. Report presented to Pavement Committee.
 - a. Accept or modify the report's conclusions and recommendations.
2. Report presented to Engineering Operations Committee.
 - a. Accept report.
 - b. Ban the use of silicones and polyurethanes as joint sealants in new concrete pavements.

INTRODUCTION

Since the late 1960's Preformed Neoprene rubber has been the standard sealant for contraction joints on Michigan concrete pavements. In 1985, the Michigan Department of Transportation (MDOT) used silicone as a concrete pavement contraction joint sealant on a section of I-69 north of Lansing. Between that first job and 1992, silicone was used on over a dozen new concrete pavements. However, several projects experienced extensive silicone adhesion failures - some as soon as six months after placement. In response to these failures, in August of 1992 the Engineering Operations Committee at MDOT put a moratorium on the use of silicone for sealing contraction joints in new concrete pavements. Silicone is still allowed for resealing projects since varying joint widths and spall repair make it difficult and cost prohibitive to reseal with neoprene.

The same year that silicone was prohibited from use another pourable joint sealant was being introduced in Michigan. This one was a polyurethane. Polyurethanes had been tried before, but this one had improved properties. In May 1992, a section of 60 contraction joints on I-96 near Howell were sealed with this new polyurethane. Later that year another 60 joints on I-496 west of Lansing were also sealed with polyurethane. The I-96 job had many adhesion failures while the I-496 job performed satisfactorily over a four year evaluation period.

In 1993, the Materials Research Group of MDOT's research laboratory undertook a study to determine the reasons for the adhesion problems with silicone. Four factors were investigated to see if they had an impact on the adhesive properties of three pourable sealants - two silicones and one polyurethane. The four factors were:

1. Concrete cure time before sealing, primed and unprimed.
2. Minimum sealing temperature and saturated surface dry conditions.
3. Type of coarse aggregate used.
4. Percent fly ash content in the concrete.

A short write-up of the results and an internal memo outlining the conclusions of this study can be found in the Appendix.

Based on the results of the study, it was decided that a field test section was needed. This test section would be installed under the watchful eye of the Materials Research Group and representatives from the manufacturers of the joint sealants involved. The purpose was to install the joint sealants under "ideal" conditions commonly accepted by the sealing industry at that time. These "ideal" conditions included the following:

- ! A minimum seven day cure of the concrete prior to sealing the joints.
- ! Ambient and pavement temperatures above 4 °C.

- ! No moisture present in the joint or on the joint sidewalls.
- ! No saw slurry, dirt, or dust on the joint sidewalls.
- ! Sealant placed with a width to depth ratio of two to one.
- ! Full-width of the pavement sealed at one time (no partial-width sealing).

A section of westbound I-94 between Watervliet and Hartford being rebuilt in 1994 was chosen as the site for the joint sealant test section. The site is approximately 30 miles west of Kalamazoo. The pavement is a 280 mm thick, jointed, reinforced concrete pavement with 8.23 meter joint spacing. The base is an open-graded drainage course (OGDC) with a sand sub-base. A geotextile fabric separates the OGDC base from the sand sub-base. The median lane is 3.6 m wide while the outside lane is 4.2 m wide. There are no super elevations or ramps in the entire test section. The shoulders are bituminous and therefore have no joints.

The average annual daily traffic is 25,000 with 30 percent of that being commercial. From 1994 to 1999 the average temperature was 9.5 °C, the average annual rainfall was 870 mm, and the average annual number of days below freezing was 125.

Five one-component, pourable joint sealants were chosen to be in the test section as a comparison to the standard neoprene compression seal. The five sealants are: Dow 888 and 890SL, Crafcro Roadsaver SL, and Sikaflex 15LM and 1CSL. The 888, 890SL, and Roadsaver SL are silicones, while the 15LM and 1CSL are polyurethanes. The 888 and 15LM are non-sag sealants, meaning they require tooling to force the material against the sides of the joint for proper adhesion. The 890SL, 1CSL, and Roadsaver SL are all self-leveling sealants that require no tooling.

All sealants except the 1CSL had been used at least once on other pavements prior to this test section. The 1CSL was a sealant that had been introduced to the department that winter. Laboratory testing was conducted on the 1CSL prior to its inclusion in the test section to see how it compared with the other sealants. It was found to have a lower percent elongation and much higher bond strength to concrete than the other four. It was decided to include 1CSL based on its bond strength test results.

CONSTRUCTION

The test sections were paved on August 31, 1994. Joint sealing occurred on September 20 and 21 so the concrete had 20 days of cure time before sealing which exceeded the seven day industry recommendation. Sikaflex 1CSL and Crafcro Roadsaver SL sections were completed on September 20. Sikaflex 15LM, Dow 890SL, and Dow 888 sections were completed on September 21. Weather during both days was sunny with temperatures ranging from 15 °C to 27 °C during sealing operations.

Joint reservoirs were sawed $14 \text{ mm} \pm 1.5 \text{ mm}$ wide and 63 mm deep. Each sealant was used in 60 consecutive joints. The remainder of the new pavement was sealed with 32 mm preformed neoprene. Longitudinal joints were sealed with hot-pour rubber asphalt. The transverse sealant was placed in the longitudinal joint for 300 mm in each direction from the transverse joint.

The joints were sandblasted and then cleaned with compressed air immediately prior to sealing. The three sealant manufacturers involved had a representative on site to make sure that recommended joint preparation and sealing procedures were followed for their products. All three stated that they approved of the work done with their respective products.

PROBLEMS

Very few problems occurred during construction. During the sealing of the Sikaflex 1CSL section, the pump pressure started out at around 750 kPa. This was too much pressure because the sealant was coming out too fast and the joints were overfilled. The pressure was dropped back to 520 kPa at first and then finally to 380 kPa which was a comfortable level for the sealer. During sealing of the Crafcro Roadsaver SL section, a wand with a ball on the end was used for the first three joints. This was not directing the sealant into the reservoir very well so the sealing crew went back to a wand with no end piece. Occasionally, small bubbles were noticed in this sealant. Air bubbles can be a starting point for cohesive failures so every bubble that appeared on the surface was immediately popped.

During the first day of sealing, the contractor had 22 mm backer rod which is too large for 14 mm joints. The specification calls for backer rod that is 25 percent larger in diameter than the joint width. The larger backer rod was harder to place in the reservoir. It had to be stretched slightly for ease of placement. This resulted in the backer rod breaking. An attempt was made to place the two broken ends as closely together in the joint as possible. However, there were a few gaps that created a “sinkhole” effect. These “sinkholes” had to be touched up with sealant by hand after the sealant had plugged the hole. It is believed that this didn’t have any detrimental effect on sealant performance.

EVALUATION

Evaluation was by a visual inspection of the sealant condition in the outside (or driving) lane. Inspections occurred approximately every six months. A rating scale developed by the Pennsylvania Department of Transportation (Figure 1) was used. The scale is a rating of 1 to 5 in three categories: sealing, weathering, and debris intrusion. Each joint was rated in the three categories and then an average was found for each material. The same person did the rating each time so that subjectivity between raters was avoided. A section of joints sealed with neoprene was also visually inspected, but not rated.

Joint Seal Rating Levels

Sealing

<u>Rating</u>	<u>Degree</u>	<u>Description</u>
5	None	Seal is intact and in the same condition as constructed.
4	Slight	Seal has experienced adhesion, cohesion, and/or raveling defects in less than 5 percent of the joint length.
3	Moderate	Seal has experienced adhesion, cohesion, and/or raveling defects in less than 25 percent, but more than 5 percent of the joint length.
2	Severe	Seal has experienced adhesion, cohesion, and/or raveling defects in less than 50 percent, but more than 25 percent of the joint length.
1	Deteriorated	Seal has experienced adhesion, cohesion, and/or raveling defects in more than 50 percent of the joint length.

Weathering

5	None	Seal is intact and in the same condition as constructed.
4	Slight	Seal surface aged or oxidized.
3	Moderate	Seal surface has weather checking.
2	Severe	Seal surface has alligator cracking.
1	Deteriorated	Seal surface has eroded.

Debris Intrusion

5	None	Seal is intact and in the same condition as constructed.
4	Slight	Seal is intact and in the same condition as constructed with debris accumulated, but no intrusion.
3	Moderate	Seal has accumulated debris with scattered intrusion.
2	Severe	Seal has accumulated debris with much intrusion.
1	Deteriorated	Seal is broken and eroded by excessive intrusion of debris.

Figure 1. Penn DOT joint seal rating levels.

Tables 1, 2, and 3 contain the average ratings after each evaluation for sealing, weathering, and debris intrusion, respectively. Weathering was not a problem for any of the materials. The lower ratings for weathering in the later evaluations were due to several joints that had very little to no sealant left. Any debris in the joint was due to failures in the sealant so the debris intrusion rating usually followed the sealing rating. Since weathering was not a problem and debris intrusion was a function of sealing, the remainder of this section will deal with the sealing category.

Sealing Ratings								
<i>Evaluation Date</i>	Feb. 95	Aug. 95	Feb. 96	Oct. 96	May 97	Oct. 97	May 98	Apr. 99
Dow 888	5.0	4.7	4.2	4.1	3.1	2.8	2.6	2.3
Dow 890SL	4.9	4.8	4.6	4.6	4.4	4.3	4.4	4.0
Sikaflex 15LM	4.9	4.8	4.5	4.4	4.2	4.1	4.2	3.6
Sikaflex 1CSL	4.9	4.8	4.6	4.6	4.5	4.5	4.6	4.2
Crafco Roadsaver SL	4.7	4.4	3.8	3.6	3.6	3.5	3.4	3.1

Table 1. Average ratings for the sealing category.

Weathering Ratings								
<i>Evaluation Date</i>	Feb. 95	Aug. 95	Feb. 96	Oct. 96	May 97	Oct. 97	May 98	Apr. 99
Dow 888	5.0	5.0	5.0	5.0	4.3	4.0	3.6	3.2
Dow 890SL	5.0	5.0	5.0	5.0	5.0	5.0	4.1	4.1
Sikaflex 15LM	5.0	5.0	5.0	5.0	5.0	5.0	4.6	4.9
Sikaflex 1CSL	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Crafco Roadsaver SL	5.0	4.9	5.0	5.0	4.7	4.6	4.5	4.9

Table 2. Average ratings for the weathering category.

Debris Ratings								
<i>Evaluation Date</i>	Feb. 95	Aug. 95	Feb. 96	Oct. 96	May 97	Oct. 97	May 98	Apr. 99
Dow 888	5.0	4.9	4.6	4.5	3.4	3.2	2.8	2.3
Dow 890SL	5.0	5.0	4.8	4.9	4.9	4.9	4.7	4.2
Sikaflex 15LM	5.0	4.9	4.9	4.9	4.9	4.9	4.5	4.7
Sikaflex 1CSL	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.7
Crafco Road saver SL	4.9	4.8	4.3	4.1	4.1	4.0	4.0	3.7

Table 3. Average ratings for the debris category.

The Michigan Department of Transportation does not have specifications concerning the performance of joint sealants based on the Penn DOT or any other rating system. Currently, a sealant is judged good or bad based on subjective opinion. The Penn DOT rating system will be used to compare performance of the different sealants rather than as an absolute scale.

From Figure 2 we can see that Sikaflex 1CSL had the highest rating after 44 months. One-third of the joints showed some signs of adhesive loss. All but one of these had less than 5 percent (18 cm) failure as measured along the length of the joint, which is a rating of four. This results in a fairly good final rating of 4.6.

Sealing Ratings

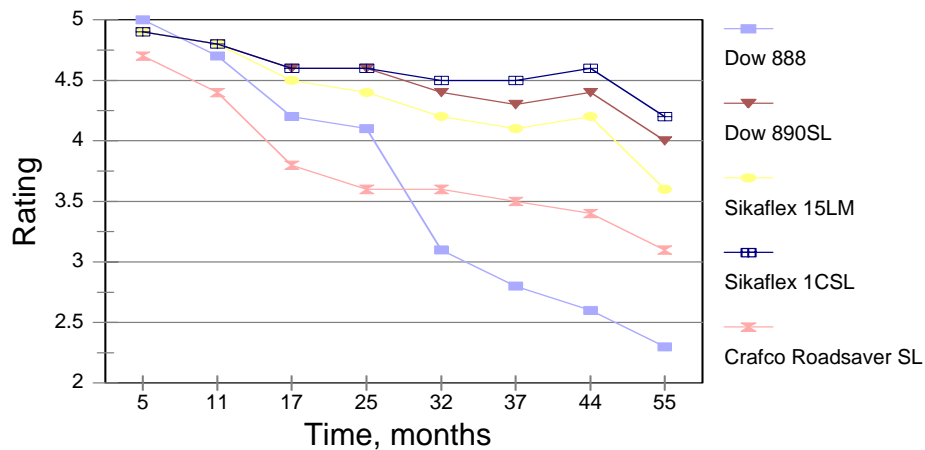


Figure 2. Graph of sealing category ratings

The next best performer was Dow 890SL with a final rating of 4.4. Seventy-five percent of the Dow 890SL joints have some adhesion loss. All of the failures were less than 5 percent of the joint length resulting in ratings of four. Following closely behind was Sikaflex 15LM. Just over half of the Sikaflex 15LM joints experienced adhesive failure. The majority of these were rated as a four, but five joints had more than 50 percent failure.

All three of the above sealant's ratings were slowly declining with time suggesting an increase in failures with successive winter cycles. The last rating, however, went up for all three. This is possibly due to the 44 month evaluation being done on a day with higher ambient temperatures. The joints would be closed more and therefore smaller adhesive failures, as was typical with these sealants, would be harder to see. This could result in slightly higher ratings.

Crafco Roadsaver SL declined rapidly within the first year. All but one of the sixty joints sealed with Crafco Roadsaver SL had failures. Roughly two-thirds of these failures were cohesive, making this the only sealant to see that type of failure. Cohesive failures are common when the sealant width to depth ratio is too large or too small. Typically the sealant should be placed so that the depth is about half the width. When the depth is less than this cohesive failures usually occur. Several joints were checked for the depth of sealant by pulling up the failed area. In all but one case, the sealant depth was proper. This suggests that the material is weak when extended. Another possible explanation is that it takes longer to fully cure. This increases the chances of it being extended during this weaker state when the joint opens due to temperature decreases.

There was another problem with the Crafco Roadsaver SL. About sixteen consecutive joints had an abnormal blackened section approximately 300 mm long and 600 mm in from the outside shoulder. The length of blackened sealant at each joint seemed to get larger over the last several evaluations. A Crafco representative took a sample back to their laboratories for analysis and found it contaminated by a heavy hydrocarbon that made it swell. The swelling could have then been hit by tire traffic leading to the blackening. It is possible that something was spilled by the construction crew, or from a vehicle, which caused the swelling. This is not believed to be reflective of the sealant itself and was not taken into account when these joints were rated.

Dow 888 ended up being the worst performer. It also started out on a fast deterioration rate and continued throughout the evaluations. Only four of the sixty joints had no signs of failures. Twenty-seven had more than 25 percent failure along the length of the joint with 16 having more than 50 percent failure. This was typical of the type of failures we had been seeing in Michigan - when silicones fail, they fail quickly.

During each evaluation we also looked at sixty neoprene sealed joints immediately following the test section. After 44 months the neoprene is in the same condition as was when it was placed.

The amount of joint movement these sealants experienced was also monitored. Ten consecutive joints in each section were pinned and measured for the first year to see if they were moving and the relative amount. Measurements were taken at the same time as the visual evaluation of the sealants.

The coldest temperature during measurements was -4 °C (February) and the warmest was 24 °C (August). Going from the cold temperature to warm, the pavement is expected to expand and therefore the joints would close. Going from cold to warmer temperatures, 87 percent of the pinned joints did close. Average and maximum movement for the February to August time period can be found in Table 4.

Joint Movement		
Sealant	Average Movement, mm	Maximum Movement, mm
Dow 888	0.91	4.11
Dow 890SL	0.91	1.70
Sikaflex 15LM	1.01	2.26
Sikaflex 1CSL	1.22	2.06
Crafco Roadsaver SL	1.24	2.16
Preformed Neoprene	1.32	1.91

Table 4. Average and maximum joint movements for each sealant section.

The movement at a contraction joint in a concrete pavement can be estimated by the following equation¹:

$$\Delta L = CL(\alpha\Delta T + \epsilon)$$

where:

ΔL = joint movement in mm

C = base/slab frictional restraint factor (0.65 for stabilized bases, 0.80 for granular bases)

L = slab length in mm

α = coefficient of thermal expansion of concrete

ΔT = temperature range over which the movement occurs

ϵ = coefficient of drying shrinkage of concrete

Using -4 °C to 24 °C as a temperature range, 8230 mm for slab length, 0.80 for MDOT's open-graded drainage course, $9 \times 10^{-6}/^{\circ}\text{C}$ for the thermal expansion coefficient, and 28 °C for temperature range, results in 1.66 mm of expected joint movement. Since drying shrinkage occurs in a brand new pavement and we are looking at the movement after six months of pavement life, the drying shrinkage coefficient was ignored. The average measured joint movements were less than the expected movement so it appears that the sealants were not under large movement conditions that could possibly cause failures.

CONCLUSIONS

Sikaflex 1CSL was performing the best. It had the best sealing rating after 55 months with mostly small failures. It was followed by Dow 890SL, which also had small failures but more than Sikaflex 1CSL, and Sikaflex 15LM. Crafcro Roadsaver SL and Dow 888 both performed poorly. Crafcro Roadsaver SL had a mixture of small to medium failures about half of which were cohesive. Dow 888 had many large failures including some joints where the sealant is completely missing.

Sikaflex 1CSL was the only sealant that performed close to satisfactorily. It did, however, have many small (less than 150 mm) adhesive failures. The concern now is - will those small adhesive losses increase with repeated joint openings and closings over the next several winters? Typically, adhesive failures will tend to progress like a zipper after a winter of joint movement. Sealing ratings continued to drop suggesting that the failures that were already present were increasing.

Performance of the preformed neoprene, which had no failures, exceeds that of the pourable sealants. It is known from past projects that silicones and urethanes cost about the same installed as the neoprene. Because neoprene provides better performance for the same cost, it is recommend that neoprene remain MDOT's only standard contraction joint sealant for new concrete pavements.

RECOMMENDATIONS

The following recommendations are made:

- ! Preformed neoprene should remain the standard sealant when sealing contraction joints in new concrete pavements.
- ! Silicones and polyurethanes should not be used as a joint sealant for new pavements.

REFERENCES

1. Huang, Yang H, 1993. *Pavement Analysis and Design*, Prentice Hall.

Appendix

1993 Joint Sealant Study

In 1993, the Materials Research Group conducted testing on silicone and polyurethane concrete joint sealants. The purpose was to see if there were any factors affecting the adherence of silicone and polyurethane to concrete other than those already known - proper joint design, joint cleanliness, correct size backer rod and installation techniques.

Testing involved four different phases:

- Phase I: Concrete cure time. The concrete specimens were allowed to cure a specified number of days before sealing.
- Phase II: Minimum sealing temperature and saturated surface dry conditions.
- Phase III: Different aggregate types. Gravel, limestone, and slag were used.
- Phase IV: Fly ash content of the concrete as a percentage replacement of cement.

The three sealants used in the study were Dow Corning 888 and 890SL (self leveling) silicones, and Sikaflex-15LM (low modulus) polyurethane. Half of the Phase I samples were coated with a primer prior to sealing to see if this helped adhesive properties of the sealants. Primer was not used in any of the other phases and a seven day cure of the concrete was used in Phases II, III, and IV. Limestone was the standard aggregate in all phases except Phase III, where gravel and slag were used. The fly ash used in Phase IV was a Type F from West Olive, Michigan and sold by U.S. Sales.

The test samples used were two 1" x 2" x 3" concrete blocks sandwiched around a ½" x ½" x 2" seal. The sealing occurred at normal laboratory temperatures (75F, 50 percent relative humidity) for all phases except Phase III. The samples were tested according to modified ASTM D3583 to get a bond strength and percent elongation for each sealant. The results of this test are referred to as SATEC, the brand name of the machine used, in the results tables that follow. They were also run through three bond test cycles at -20F according to ASTM C719. The results of bond testing were reported as pass/fail.