ARIZONA DEPARTMENT OF TRANSPORTATION

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PERFORMANCE EVALUATION OF PORTLAND CEMENT CONCRETE PAVEMENT JOINT SEALANTS

Final Report

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16. Abstract

In July 1986, the Arizona Transportation Research Center (ATRC) coordinated the installation of a joint sealant test site near Flagstaff, between mile posts 331.5 and 332.2, on the southbound lanes of Interstate 17. The original project was constructed in 1974, with 8 inches of portland cement concrete pavement (PCCP) over 6 inches of cement treated base (CTB). The test site consisted of 200 transverse joints sawed 2 inches deep, skewed 1:6, and spaced at a repeating sequence of 17, 15, 13, and 15 ft. The objective of the project was to evaluate the performance of five joint sealants: Dow Corning 888, Superseal 888, Allied Koch 9005, Crafco Roadsaver 231, and W.R. Meadows Sof-Seal. The highway sections abutting this test site were also rehabilitated and their pavement joints were sealed with Superseal 444 which, at that time, was a specified sealant in the Arizona Department of Transportation (ADOT) standards.

Field evaluations of the joint sealants were performed at nine months, one year, 1.5 years, 3 years, and 8 years after construction. The evaluations were based on: (i) sealant flexibility, (ii) length of joint with missing sealant, (iii) adhesive and cohesive failure of sealant, (iv) joint width and sealant depth, (v) joint spalling, (vi) sealant recess, (vii) FWD testing, and (viii) slab faulting. Generally, it appeared that after about eight years of service all five sealants had exhibited comparable performance level. Clearly, all test sealants performed better than Superseal 444 which was an ADOT specified joint sealant when the test site was installed in 1986.

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Concrete pavements, joints, sealants, performance, faulting.

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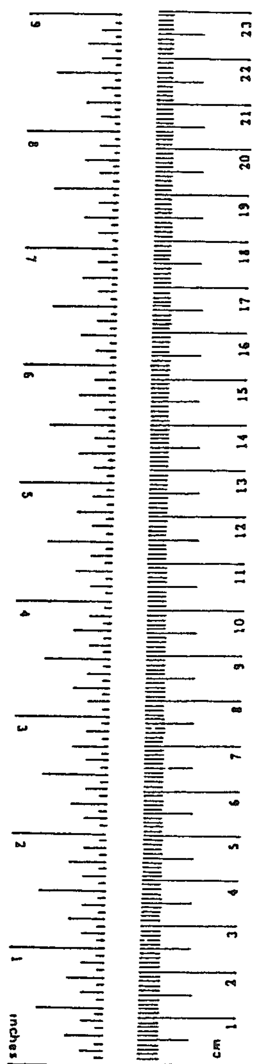
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

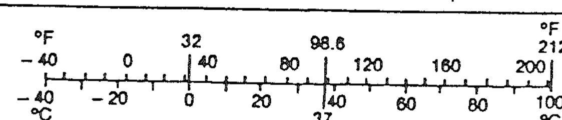
NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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1. INTRODUCTION

1.1 Background

The Arizona Department of Transportation (ADOT) installed a test site in July 1986 in Northern Arizona as part of a 26-mile joint resealing project IR-17-2(104). The original project was constructed in 1974, with 8 inches of portland cement concrete pavement (PCCP) over 6 inches of cement treated base (CTB). The test site for this project was 0.7 mile long and consisted of 200 transverse non-doweled joints sawed 2 inches deep, skewed 1:6, and spaced in a repeating sequence of 17, 15, 13, and 15 ft. The purpose of the project was to evaluate the performance of five joint sealants. The project was located near Flagstaff in the south bound lanes of Interstate 17.

Concrete pavements go through many cycles of contraction, expansion, and warping due to changes in climatic condition and its inherent material characteristics. To allow for these movements in concrete pavement slabs, and to reduce occurrence of cracking at random locations, the typical practice is to design transverse joints at certain spacing along the roadway. The spacing of transverse joints is usually variable between 13 to 17 ft. The joint spacing is varied to reduce joint-induced noise impact on the driver. Constantly spaced joints are unsafe and cause discomfort to the driver due to the convolution effect of a periodic cycle of noise and vibration. In addition, the transverse joints are not placed perpendicular to the line of travel. It is ADOT's practice to place joints at a 1:6 skew across the pavement to reduce joint damage due to wheel impact.

The main disadvantage of having transverse joints in pavement is that damage can occur to the base or subgrade support of the pavement due to water infiltration through the joint opening, which eventually may lead to faulting, cracking, or settlement. Also, if joints are doweled, the dowel bars used for load transfer between adjacent slabs can corrode as they come in contact with moisture. Incompressibles may enter into the joint opening and block the slab expansion movement. Blocking of slab expansion movement may result in spalling and blow-ups. The cumulative effect of all these pavement distresses result in reduced rideability and premature pavement failures.

Thus, although joints are important for proper performance of pavement, it can be attested that most of the concrete pavement distress are joint-related. This dilemma prompted efforts to seek better design and construction procedures for joints. The new procedures emphasized the need for quality construction and proper shape factors of the joint sealant

(*1*). Notwithstanding these recommendations, some highway agencies have continued to not seal their joints. Instead of joint sealing, they have used shorter slab spacing, non-pumping subbases, and narrower joint openings (*2*)

1.2 Purpose of the Project

The controversy over the issue of whether or not to use sealants precipitated many research projects. It was reported in NCHRP Synthesis #98 (*3*) that the consensus of most state highway agencies was that crack and joint sealing was beneficial and should be applied. Considering the benefits derived from joint sealing and the availability of several types of joint sealants, ADOT was interested in determining which of the sealant products would be suitable for application in Arizona. In order to answer that question, the Arizona Transportation Research Center (ATRC) initiated a joint sealant study. The main objective of the study was to investigate the performance of different sealants under Arizona's climate and traffic conditions.

1.3 Project Location

The project was located in Flagstaff, Arizona, in the south bound lanes of Interstate 17 between mileposts 331.5 and 332.2. The project roadway section carried an ADT of 12,000 of which 14 percent was commercial vehicles. A map showing the project location is given in Figure 1. The elevation of the test section is approximately 6700 feet above sea level. The average low temperature in the Flagstaff area is 15 degrees Fahrenheit during January, while the average high temperature is 80 degrees Fahrenheit in July. The average precipitation in Flagstaff is 19 inches.

2. EXPERIMENTAL PLAN

This section of the report describes how a multiple comparison experiment between five sealant products was designed to evaluate their field performance characteristics. While describing the experimental plan, some statistical properties were discussed which were considered in order to obtain meaningful results from the field experiment.

An important consideration in the statistical design of an experiment is to determine the required sample size, or number of replicates for each treatment, which will enable experimenters to draw statistically valid inferences. In this study, a sample size of 40 joints for each sealant material was selected. The sealant materials were supplied free of charge

ARIZONA STATE HIGHWAY SYSTEM

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Transportation Planning Division

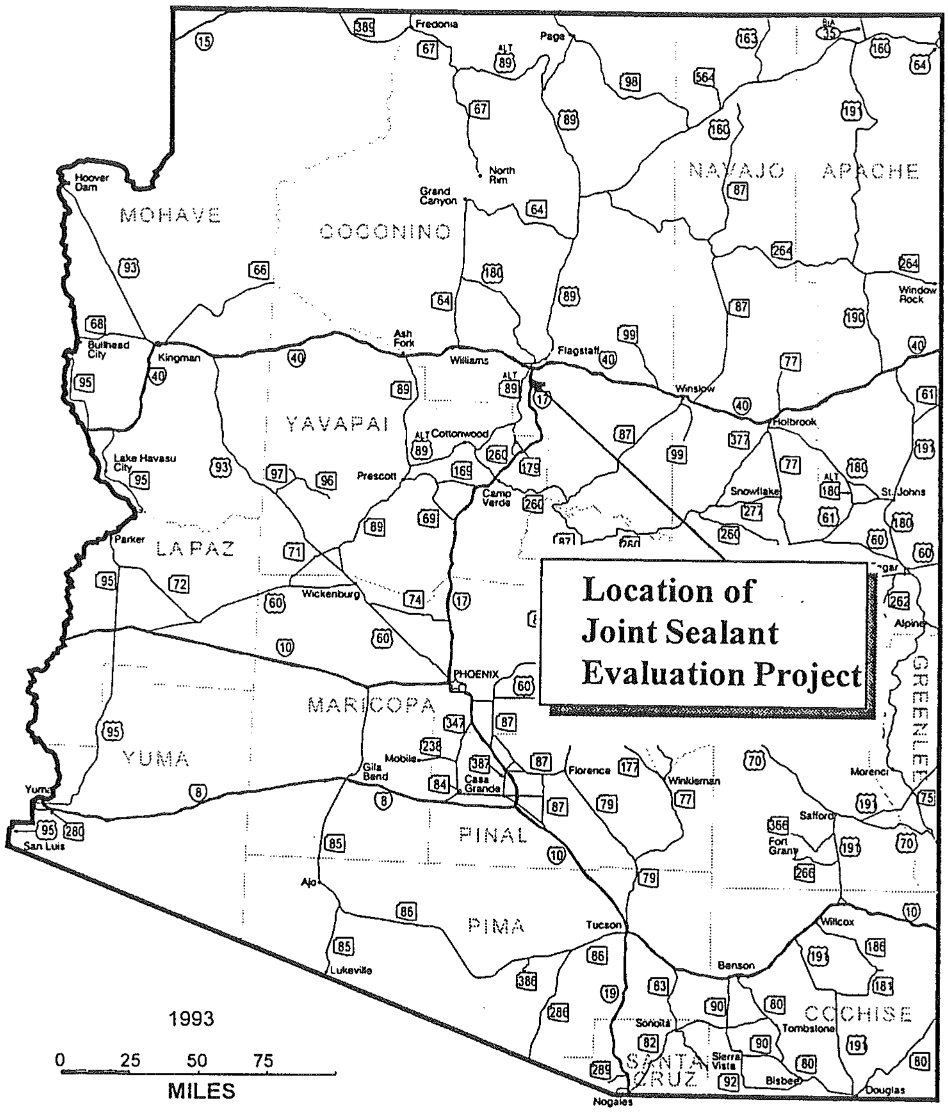

Figure 1 Location of Test Site for Joint Sealant Evaluation Project

to ADOT by the manufacturers. Therefore, the task of designing the experiment was to assign 40 pavement joints to each sealant.

Another important consideration in experimental design relates to the need to reduce variability due to external sources. In this study, the main source of variability which could affect the performance of sealant was non-uniformity of joints. It was difficult to achieve a high level of uniformity in the joints due to inherent construction and material variability along the roadway sections. To minimize the locational bias on sealant performance due to non-uniform joints, a repeating sequence of placement pattern for the five joint sealants was selected for this study. The repeating sequence of sealant placement was coded as A, B, C, D, and E for Dow Corning, Superseal, Allied Koch, Crafco, and Sof-Seal, respectively. The sealant installation sequence is depicted in Figure 2.

A more statistically efficient experimental layout could have been achieved by randomly assigning the joints to the sealants. However, it was felt that such completely randomized design would complicate construction operations.

Another design alternative was to divide the test site into five 40-joint sections, and randomly assign one sealant to each section. This design would be good if locational variability was not suspected or if the selected test site was so small that external sources of variability could reasonably be ignored. This design was easy to construct and would provide an opportunity to simultaneously monitor the sealant and joint distress and the overall performance of the pavement in terms of rideability of different test sections. The performance data from different test sections could indicate how different joint sealants affect long-term pavement performance. Nevertheless, for the purpose of this study, the sequential design of the experiment was a good compromise between eliminating locational bias and consideration of design constructibility.

3. PRODUCT DESCRIPTION

Five commercially available joint sealant products belonging to two classes of sealants were chosen for this study. These were:

1. Silicones:
    - Dow Corning 888
    - Superseal 888

Outside shoulder	Travel lane	Passing lane	Median shoulder
Joint # 1	A: Dow Corning		
2	B: Superseal 888		mile post 332.2
3	C: Allied Koch 9005	Direction of travel	
4	D: Crafco Roadsaver 231		
5	E: W. R. Meadows Sof-Seal		
6	A: Dow Corning		
7	B: Superseal 888		
8	C: Allied Koch 9005		
9	D: Crafco Roadsaver 231		
10	E: W. R. Meadows Sof-Seal		
196	A: Dow Corning		
197	B: Superseal 888		
198	C: Allied Koch 9005		
199	D: Crafco Roadsaver 231		mile post 331.5
200	E: W. R. Meadows Sof-Seal		

Figure 2: Placement sequence of sealants on Southbound lanes of I-17

2. Asphalt-based hot pours:
   - Allied Koch 9005
   - Crafco Roadsaver 231
   - Meadows Sof-Seal

The five sealants were selected based on their potential for future use in Arizona's climate and vendors' interest to participate in the experimental program. The silicones met Federal specifications SS-5-00230C and SS-5-001543A and the hot pours met ASTM D3405 and ASTM D3407 specifications. More information about the sealants can be found in the product promotional literature appended to the construction report of this project (*4*). The promotional literature was supplied by the manufacturer.

4. CONSTRUCTION PROCEDURES

The placement of Dow Corning, Superseal, Allied-Koch, and Sof-Seal was performed by the contractor CON-SEAL according to manufacturers' specifications. Crafco Road Saver 231 was placed by a Crafco representative. Dow Corning, Allied Koch, Crafco, and Sof-Seal joints were placed on July 8 and 9, 1986 and Superseal joints were installed on July 14 and 25, 1986.

The installation steps included sawing the pavement to desired depth, sand blasting the joint walls, air-blowing the debris, placing the backer rod to desired depth, pouring the sealant, and tooling the sealant to obtain the desired recess from the pavement surface. Figure 3 shows a cross section of a sealed joint. Silicone sealants were placed at ambient temperature, while the asphalt based products were placed at 360 to 380 degrees Fahrenheit. The construction procedures are described in detail in the project construction report (*4*). Generally, there were no major construction problems during the placement of Dow Corning 888, and Superseal 888. However, air bubbles were observed immediately after placement of Allied Koch 9005, Crafco Roadsaver 231, and W. R. Meadows Sof-Seal. Also, these three hot-pour sealants exhibited some flow characteristics in sections located on a roadway curve where the cross slope was about five percent.

5. FIELD EVALUATION

In order to conduct a meaningful field evaluation, it is first necessary to understand the purpose of using joint sealants. Joint sealants are generally required to serve three basic

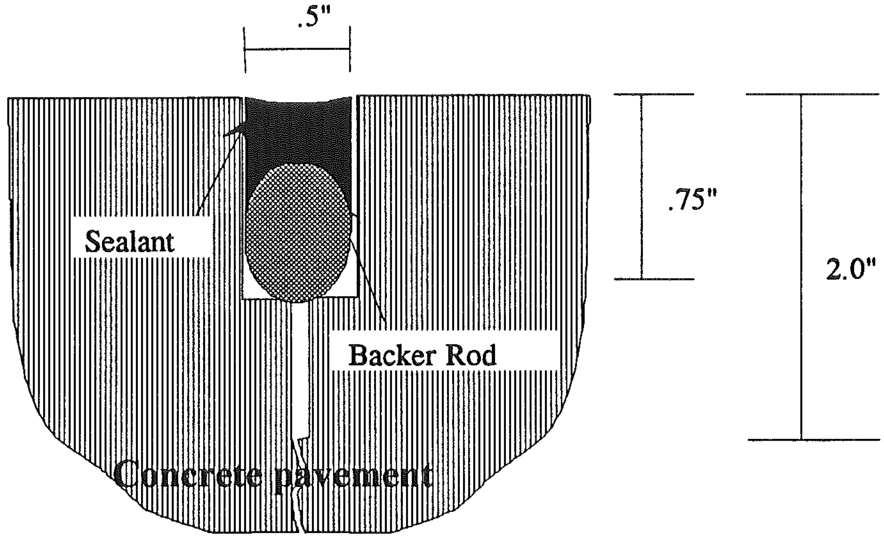

Figure 3: Placement Configuration of Sealants

purposes: (i) to provide a water-tight joint, (ii) to reject incompressibles, and (iii) to resist the effect of chemicals and environmental factors.

In order to provide a water-tight joint, the sealant must remain in contact with the joint walls, and must be resilient enough at high or low temperatures to accommodate joint movements. If the actual joint movement exceeds the strain limits of the sealant, then premature sealant failure will occur. To prevent this premature failure, joint design considerations need to include the following: (i) the shape factor of the sealant, (ii) the use of backer material, (iii) the working range of strain of the sealant, and (iv) the working range of movements of the joint.

The shape factor of sealant is the ratio of sealant depth to width. Investigations have shown that the most desirable range of shape factor is 1.0 to 1.5 to satisfy both bonding and strain requirements. The use of backer rod is necessary for field poured sealants to support sealant during curing, and to provide the desired shape factor. To ensure good performance of sealants, it is recommended that the backer rod: (i) should not bond with the sealant, (ii) should not react with sealant, and (iii) should not absorb water. Usually, the computation of joint movements is necessary in determining the required joint width and type of sealant to be used.

Field evaluations of the joint sealants were performed at nine months, one year, 1.5 years, 3.25 years, and 7.75 years after construction. The actual dates of the five field evaluations are listed in Table 1. Based on literature reviewed at the beginning of this study, there was no standard methodology which could have been adopted for the purpose of joint sealant evaluation. Although many state highway agencies had performed joint evaluations visually, the evaluations had been more qualitative than quantitative. Therefore, for the purpose of this study, it was decided that sealant performance would be evaluated on the basis of the following attributes:

5.1 Flexibility

This attribute is used to measure the resilience property of the sealant. The sealant needs to have good resilience to accommodate joint opening and closing. This property was surveyed subjectively by poking the sealant with a finger and observing how quickly the sealant regains its original shape. The result was noted as "bad" if it was very hard to poke

TABLE 1: HISTORICAL RECORD OF MAJOR PROJECT ACTIVITIES

Date	Period after construction	Project evaluation activity
July 1986	-	Installation of test sealants
April 14, 87	9 months	First 100 joints surveyed
August 20, 87	1 year	Walking survey from pavement shoulder. No data collected.
March 9, 88	1.5 years	Walking survey from pavement shoulder. No data collected.
October 10, 89	3.25 years	Field survey on a 30% random sample of test joints. Traffic control provided, sealant distress data collected from travel lane, and 15 cores extracted
April 11, 94	7.75 years	Field survey on a 50% random sample of test joints. Traffic control provided, sealant distress data collected from travel lane, and 15 cores extracted

or if the sealant did not regain the original shape at all. But if a sealant was soft and easy to poke, and if it regained its original shape or closely so, the sealant was noted to have "good" flexibility. Anything in between was marked to have "medium" flexibility.

5.2 Missing Sealant

This data item provides a measure of the amount of sealant missing from the joint. From a maintenance point of view, this item provides important information which can be used to determine the best time to reseal the joints.

5.3 Adhesive failure

Adhesive failure is the debonding of the sealant from the joint wall. The main reason for adhesive failure is often bad construction such as bad sand blasting of the joint wall. Other factors include improper shape factor, inadequate tooling, and dirty joint walls. Adhesive failure was measured in lineal feet along the joint and was characterized by two severity levels: partial depth failure, and full depth failure. A thin spatula and a steel ruler were used for measuring the failure depth.

5.4 Cohesive Failure

Cohesive failure is the internal material failure of the sealant. Cohesive stresses are developed within the sealant when the joint opens. If the sealant is insufficiently elastic or has weak inter particle bonds, it will fail in a cohesive mode. Also, if the shape factor is too high the material may have cohesive failures.

5.5 Intrusion of Incompressibles

The intend of this item was to quantify the sealant contamination due to intrusion by incompressible particles. Excessive presence of incompressibles cause spalling of joints. Presence of incompressibles in the sealant was measured in lineal feet along the entire joint length over which the sealant is intruded with solid contaminants.

5.6 Joint Width

To calculate the joint shape factor for the existing condition, joint width data were necessary. Only one measurement per joint was taken at random location along the 12-ft transverse joints.

5.7 Sealant Depth

In order to calculate the joint shape factor the second data item necessary is sealant depth. Again, only one measurement per joint was taken at random location. For silicones (products A and B) measurements were taken while doing the destructive test. For the asphalt based hot pours, measurements were taken in areas where sealants were missing from the joint.

5.8 Spalling

Spalling was a supplementary data item collected for the purpose of investigating factors that might influence pavement performance.

5.9 Faulting

Faulting data quantify the relative vertical movements between the adjacent slabs of a jointed concrete pavement. Two readings were taken on every transverse joint of the travel lane. Of the two readings, one was taken near the shoulder of the travel lane and the other near the centerline. A gauge developed by the Materials section of ADOT was used. The gauge (see Figure 4) has a 0.1 inch scale and can be read to the nearest 0.05 of one inch. Like spalling, faulting was a supplementary data item.

5.10 Recess

This item measures existing recess of the sealant from the pavement surface. If the sealant was filled up to the top of the pavement surface it was noted as zero recess or "surface." If the recess was approximately 1/8 inch below the pavement surface it was noted as "1/8 inch". If it was below 1/4 inch it was noted as "1/4 inch".

5.11 Failure Mode Under Destructive Testing

A destructive test was used to identify any trend in the type of failures among the silicone sealants. This test was only performed on silicones since it was easy to cut a tab from silicones. On the other hand, the test was not suitable for hot pour sealants since they were sticky under field conditions. In order to perform the test, three cuts were made in the sealant: (i) two 2-inch cuts along each wall of the joint, and (ii) a cut across the sealant at

Figure 4: Faulting gauge used for collecting slab faulting at sealant study site

one end of the two 2-inch cuts. The 2-inch tab thus formed was lifted up and pulled out of the joint at a steady rate. If the sealant first failed from the joint walls, it was noted as adhesive failure but if the tab broke it was considered as cohesive failure.

5.12 Joint Conditions on Pavement Cores

One purpose of taking cores was to investigate the effectiveness of joints in controlling cracks at the weakened plane. That is, to see whether cracks had formed at the joint as was expect. Also, cores provided additional information on sealant depth which was used to compute the sealant factor.

5.13 FWD Testing

FWD deflections were measured at 35 joints (seven for each sealant type) to evaluate the load transfer efficiency at the joint and to determine the presence of voids beneath the pavement. Two tests were conducted at each joint, one applying the load on the leave or downstream slab and the other on the approach or upstream slab. Deflections of both the approach slab and the leave slab were recorded for each test. Each test was conducted at three load levels and four sets of readings were taken for each load level.

6. RESULTS OF SEALANT EVALUATION

6.1 Evaluation at Nine, Twelve and Nineteen Months After Construction

In preliminary field evaluations, conducted within a period of eighteen months after project construction, all five sealants were found to have similar performance characteristics. In the 9-months evaluation survey, the first 100 joints of the test section were evaluated. For these 100 joints, almost all sealants appeared neat, possessed good resiliency, bonded nicely with joint walls, and rejected the incompressibles. However, the three hot-pour sealants were found to have more embedded stones and accumulated debris when compared with the two silicones. In general, the joints sealed with Allied Koch had more embedded incompressibles than others.

6.2 Evaluation at Three Years After Construction

The last field evaluation was conducted on October 10, 1989, on a 30 percent random sample of the test joints (i.e. 12 out of 40 joints for each sealant category). The emphasis during this evaluation was on collecting quantitative measures of sealant and joint distress. The condition survey was conducted on the travel lane only and involved both subjective and quantitative evaluation of different sealant and joint performance characteristics.

Appendix A shows the forms used in the collection of sealant performance data. A summary of this field evaluation survey is presented in Table 2. A total of 15 cores, 3 from each sealant type, were taken randomly out of the travel lane joints. The location of each core along the joint width was also randomly selected. The data set obtained from the cores is depicted in Appendix B.

The two silicone sealants Dow and Superseal, had similar performance characteristics in terms of resilience and rejection of incompressibles. After 3.25 years of service, both silicones possessed good resilience and rejected any intrusion of incompressibles. On the other hand, joints sealed with three hot-pour sealants, namely Crafco, Allied and Sof-Seal, had fine dust material along the joint wall and incompressibles embedded into them. These hot-pours also lost some of the resilience property. The differences among the three hot-pours, based on resilience and intrusion of incompressibles, were not statistically significant.

The results of the tab pull-out test indicated that Superseal out-performs Dow in residual adhesive bond strength because none of the tested Superseal joints failed in adhesion. The joints which failed in adhesion under the pull-out test had similar shape factor as those which failed in cohesion.

The average shape factors for silicone sealants were not significantly different than hot pour sealants. However, between the two silicones, average shape factor of Superseal was found to be significantly larger than that of Dow. This means that, assuming all joints have uniform width, larger quantity of Superseal material was used to obtain the same joint sealing as Dow. The differences in average shape factors among Allied Koch, Crafco, and Sof-Seal were not significant.

Analysis of joint faulting data revealed that average faulting of Superseal joints was larger than Dow joints. For the joints sealed with the three hot-pour sealants, average faulting values were similar. This implies that the level of faulting that had occurred at the test joints during the service period could not be one of the external source of any variability of sealant performance.The following general statements can be made based on the 1990 condition survey of joints sealants and the core evaluation.

TABLE 2: SUMMARY OF SEALANT CONDITION AFTER 3 YEARS

Description of Measure of performance	Details	Name of Sealant					Sealant category	
		Dow Corning	Superseal 888	Allied Koch 9005	Crafco Road Saver	Sof-Seal	Silicones	Hot pours
Average percent of joint length with good, bad or medium resilience	Good	75	75	0	25	8	75	11
	Medium	25	25	92	75	83	25	83.3
	Bad	0	0	8	0	9	0	5.7
Average sealant shape factor (depth/width)		0.75	1.00	0.91	0.98	0.94	0.88	0.94
Average % of joint length with sealant failure	Adhesive	6.94	0	29.16	65.97	54.86	3.47	50
	Cohesive	1.74	3.47	5.49	4.51	2.99	2.60	4.33
Average % of joint length with missing sealant		0.14	0	0.690	0	0	0.07	0.23

Note: This summary was based on a 30 percent random sample of travel lane joints

1. The overall performance of silicone sealants appeared better than the asphalt based hot-pour sealants.
2. The performance of Superseal 888 and Dow Corning 888 sealants were similar. However, based on the field evaluation experience, the Dow Corning appeared to have a little more resiliency than the Superseal.
3. Allied Koch had slightly less incompressibles, air bubbles and moisture; Crafco possessed slightly better resiliency; and Sof-Seal was less sticky.
4. Analyses of the performance characteristics of the three asphalt based sealants suggested that Allied Koch 9005, Crafco Roadsaver 231, and W. R. Meadows Soft-Seal performed comparably. Statistical tests conducted at the five percent significance level indicated that there was no evidence that any of the asphalt based sealants performed significantly better.

6.3 Evaluation at Eight Years After Construction

The following data items were collected from the travel lane on April 11, 1994, from a random sample of 100 of the original 200 test joints: (i) sealant flexibility, (ii) length of joint with missing sealant, (iii) adhesive and cohesive failure of sealant, (iv) joint width, (v) joint spalling, (vi) sealant recess, and (vii) slab faulting. In addition, ten cores (two for each sealant material) were extracted. The data set collected during this survey is given in Appendix C. Additionally, a half-mile section beyond the test site was surveyed. This survey was conducted in order to get a rough idea on how Superseal 444 had performed during the eight years of service. Superseal 444 was an ADOT standard sealant material when this project was constructed in 1986.

Figures 5 and 6 show a typical surface appearance of the silicone and asphalt-based sealants in April 1994. The results of data analysis for the 1994 field survey are summarized in Table 3 and depicted in Figures 7 through 10. The analysis indicated that eight years after the installation of the test section:

1. All sealants had good flexibility.
2. The average slab faulting was about 0.2 in. There was no significant difference in average faulting measurements among joint sets for the different sealants.
3. Dow Corning 888, Superseal 888, Crafco Roadsaver and Meadow Sof-seal sealants had experienced an average adhesive failure (partial and full

Figure 5: Typical appearance of silicone sealant joints after eight years

Figure 6: Typical appearance of hot pour sealant joints after eight years

TABLE 3: AVERAGE CONDITIONS OF JOINT SEALANT AT 8 YEARS AFTER CONSTRUCTION

Name of Sealant	Percent missing	Recess (inches)	Average Faulting (in)	Percent of Sealant Failure		
				Adhesive	Cohesive	Total
Dow Corning 888	3.00	0.220	0.199	68.50	1.5	70.0
Superseal 888	2.50	0.210	0.202	71.25	3.4	74.65
Allied Koch 9005	0.42	0.010	0.182	40.21	8.5	48.71
Crafco RoadSaver 231	0.21	0.003	0.190	67.71	3.5	71.21
M.R. Meadows Sof-seal	0.00	0.013	0.199	78.13	4.8	82.93

*This summary is based on a 50 percent sample of the travel lane joints.

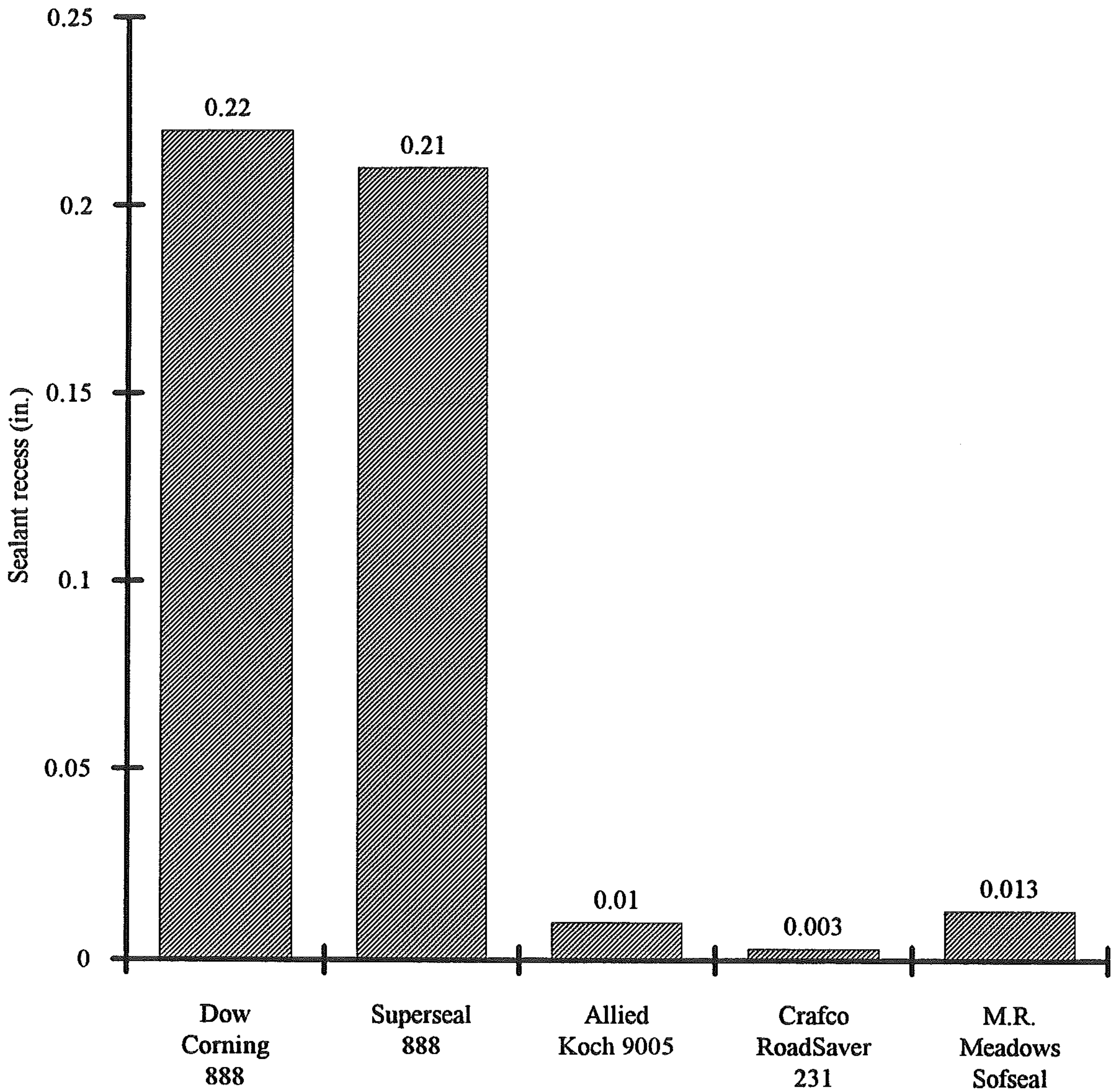

Figure 7: Average sealant recess (in inches) after eight years

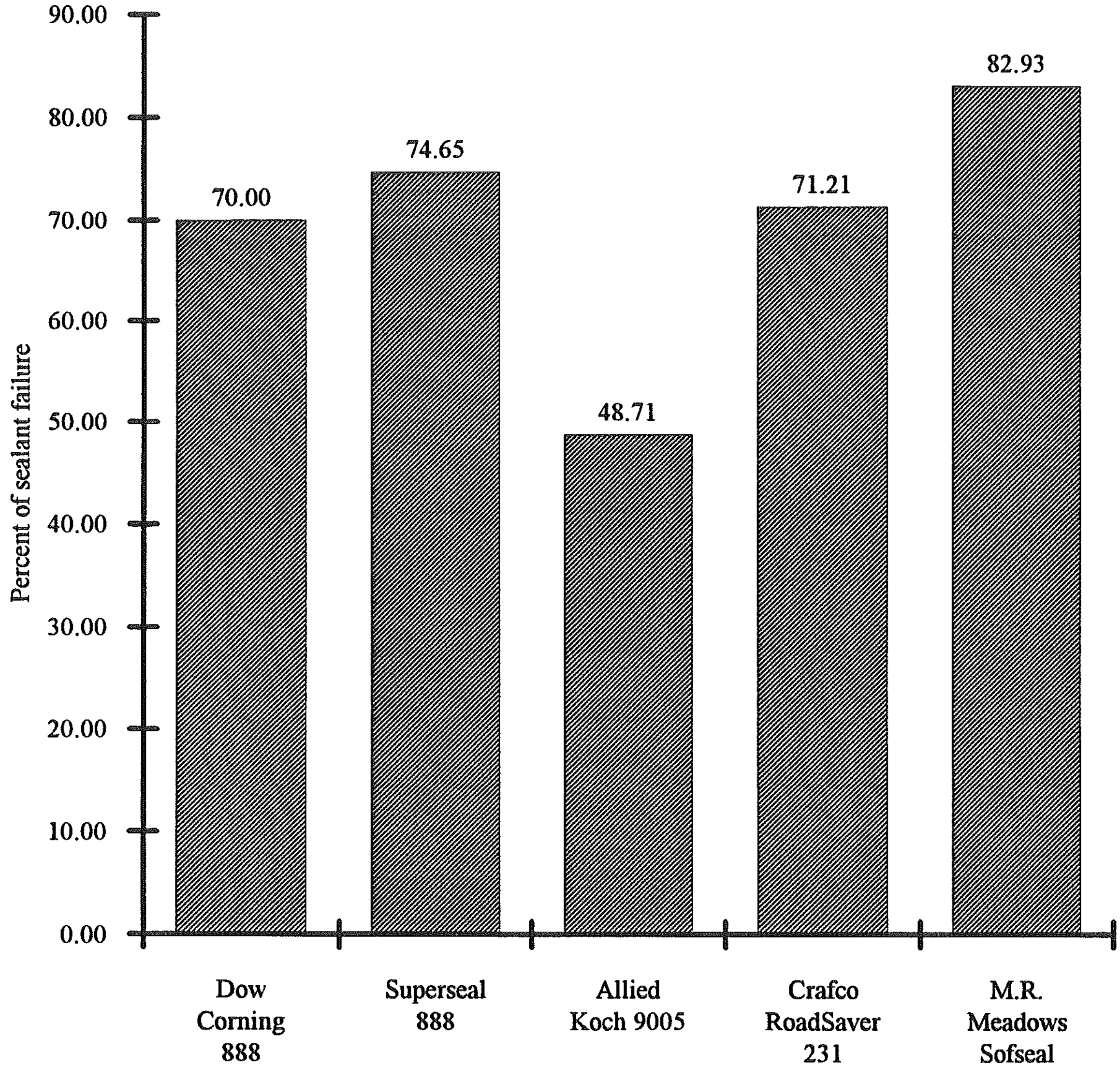

Figure 8: Percent of total sealant failure along joints

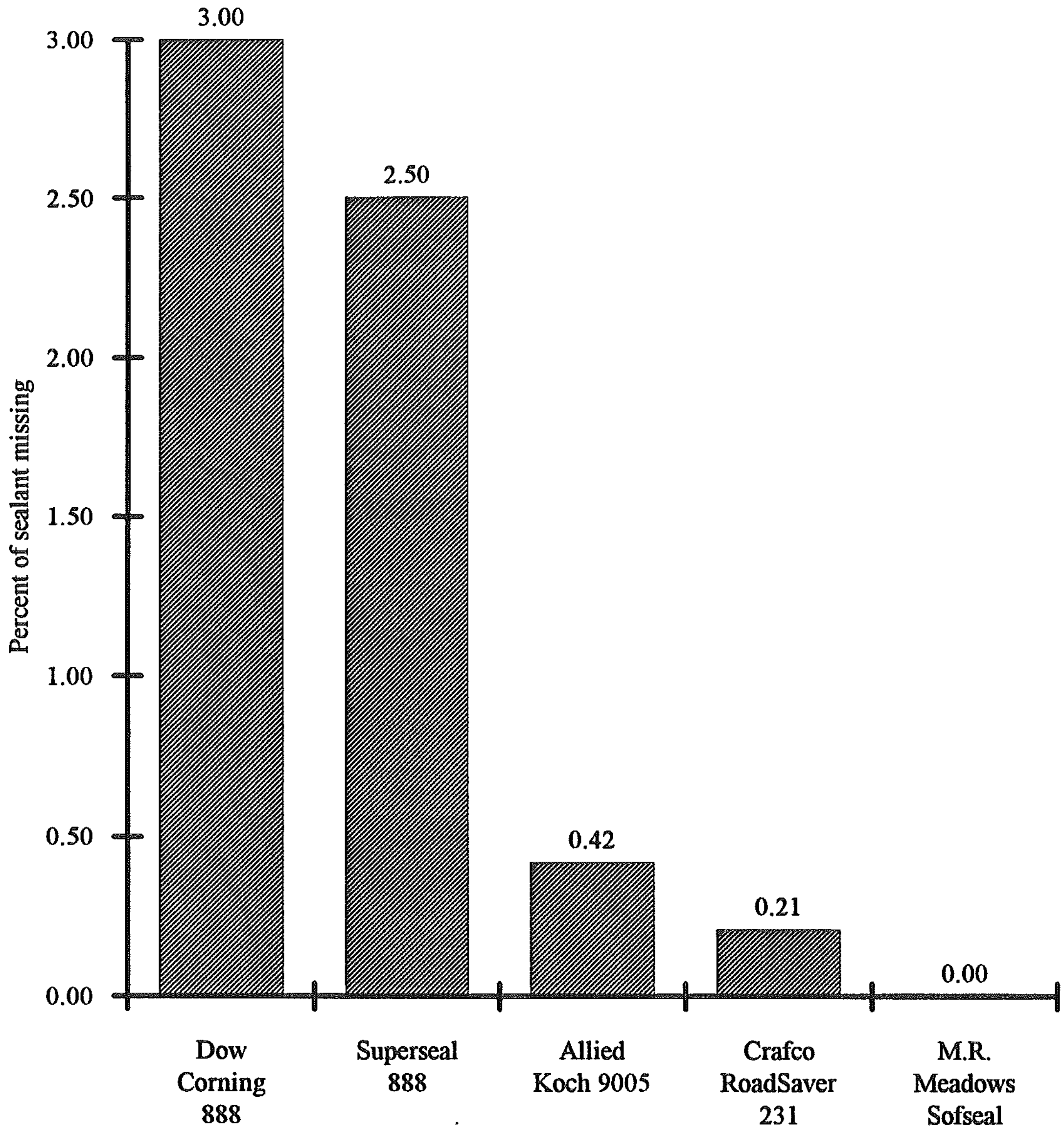

Figure 9: Percent of sealant missing from joints

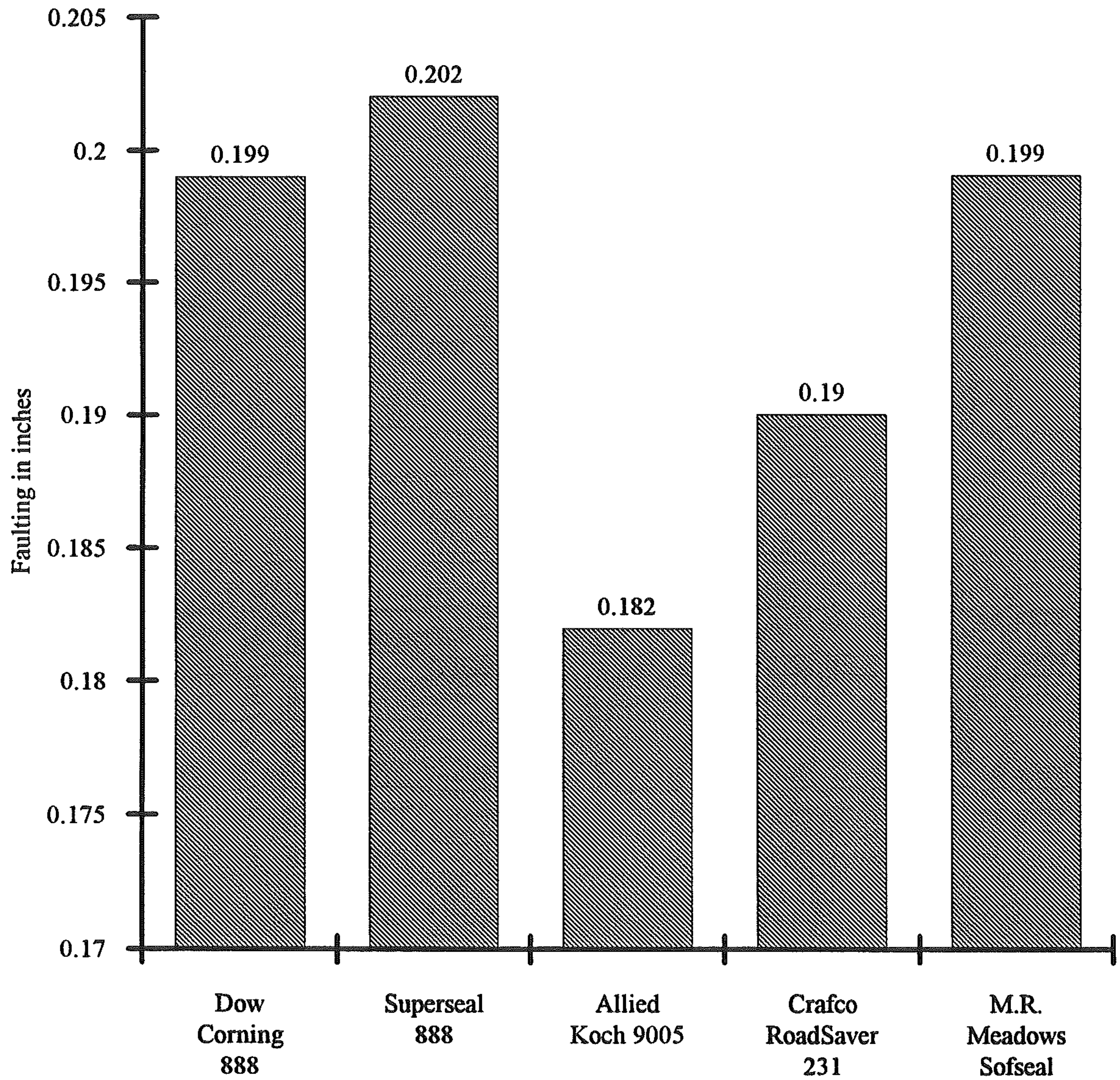

Figure 10: Average joint faulting measured near the shoulder and centerline

depth)rate of 65 to 80 percent along the joints. Allied Koch had an average adhesive failure rate of 40 percent.

4. Dow Corning 888, Superseal 888, Crafco Roadsaver and Meadow Soft-seal each experienced an average cohesive failure (partial and full depth) rate of less than five percent along the joints. Allied Koch had an average cohesive failure rate of 8.5 percent.
5. The average joint spalling was about 0.015 - 0.025 square feet for joints sealed with Dow Corning 888, Superseal 888, M. R. Meadows Sof-Seal; and approximately none for joints sealed with Allied Koch 9005 and Crafco Roadsaver 231.
6. Each of the silicones recessed an average of about 0.2 in. There was no significant recess for the asphalt based hot pour sealants.
7. Approximately 40 -- 60 percent of the Superseal 444 was missing from the joints in the surveyed half-mile roadway section.
8. Joint faulting at the outside edge of the travel lane was consistently higher than faulting near the centerline.

Non-destructive Structural Evaluation

A non-destructive structural evaluation was conducted to evaluate the deflection load transfer efficiency of the test joints and to determine whether voids were present beneath the slabs. A Falling Weight Deflectometer (FWD) was used to measure slab deflections near the joints. Deflections were measured at 35 joints (seven joints for each of the five sealants). Two deflection tests were conducted at each joint, one test applying the load on the leave slab (downstream slab), and the other on the approach slab (upstream slab). In each test, slab deflections were read from both sides of the joint. A complete FWD test at a joint consisted of measuring deflections at three load levels: 9 kips, 12 kips, and 16 kips. At each load level the loading was applied four times.

The load transfer efficiency was computed as the deflection ratio, expressed in percent, of the unloaded slab to the deflection of the loaded slab. A rapid void detection procedure (5) was used to determined the presence of voids beneath the slabs. The void detection analysis involved: (i) plotting of applied loads versus the measured deflections; (ii) drawing of best-fit line through the data points; and (iii) comparison of the best-fit line with the line formed by the simple connection of the data points. According to this method of analysis, marked differences between these lines would indicate presence of voids beneath the slab. In addition, if the best-fit line was satisfactory, the intercept value of the deflection axis was used to make a final determination of the support conditions beneath the slab. Locations where no voids exist generally have deflection intercept values of less than 0.002 inches (less than 2 mils). Thus, a deflection intercept larger than 0.002 inches indicates the presence of voids. It must be noted that the deflections were taken along the wheel path instead of at slab corners as suggested by the void detection procedure (5).

A summary of the data analysis for the five sealants is given in Table 4. A statistical analysis indicated that there was no significant difference in the maximum deflection, load transfer efficiency, relative deflection and void detection intercept values for the five sealants. Relative deflection is the difference between the maximum deflections of the loaded and the unloaded slabs at the joint. A tabulated report giving maximum deflection, relative deflection, load transfer efficiency and intercept value of deflection axis for each joint is included in Appendix D. Thirty-five individual plots made for the void detection analysis are included in Appendix E.

TABLE 4: SUMMARY OF FALLING WEIGHT DEFLECTOMETER TEST RESULTS

Description of test data item	Test Statistic	Dow Corning	Superseal 888	Allied Koch 9005	Crafco Roadsaver 231	W. R. Meadows Soft-Seal
Maximum deflection (mils)	Mean	6.45	6.42	6.39	6.53	6.55
	STD	0.46	0.75	0.76	0.27	0.43
Relative deflection (mils)	Mean	0.37	0.31	0.48	0.29	0.31
	STD	0.20	0.42	0.61	0.32	0.28
Load Transfer Efficiency (in percent)	Mean	94	95	93	96	95
	STD	3	6	8	5	4
Deflection intercept (mils)	Mean	0.19	0.24	0.20	0.17	0.27
	STD	0.23	0.16	0.15	0.19	0.21

7. CONCLUSION

Generally, it appeared that after eight years of service all five sealants had exhibited comparable performance level. Clearly, all test sealants performed better than Superseal 444 which was in ADOT standards and specifications for joint sealants when the test site was installed in 1986.

REFERENCES

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3. "Resealing Joints and Cracks in Rigid and Flexible Pavements". National Cooperative Highway Research Program Synthesis of Highway practice 98, Transportation Research Board, Washington, D. C., 1982.

4. Wolfe, T. M., and Tritsch, S. L.; Product Evaluation 86-18 Joint Sealant Study, Construction Report, Arizona Transportation Research Center, Phoenix, Arizona, 1987.

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APPENDIX A

JOINT SEALANT EVALUATION FORMS

ATRC JOINT SEALANTS EVALUATION FORM

PROJECT: ________ ROUTE: ________ Traffic Control? ________

Test Sec M.P.: ________ DIR: ________ Cores Taken? ________

ADT: ________ LANE: ________ OBSERVER: ________

Project Area : Flagstaff Pvmnt Type: ________ DATE: ________

Weather: ________ Pvmnt Temp: ________ TIME: ________

Gen. Pvmnt Cond: ________ Lane Width: ________

Joint Sealants

A: Dow Corning 888

B: Superseal 888

C: Allied Koch 9005

D: Crafco 231

E: Meadows Sofseal

JOINT NO.	SEALANT DISTRESS								Result of Destructive Test for Silicones	JOINT DISTRESS				
	FLEXIBILITY (Good/Med/Bad)	MISSING SEALANT (FT.)	ADHESIVE FAILURE (FT.)		COHESIVE FAILURE (FT.)		RECESS (IN.)	Intrusion of INCOMPRESSIBLES (FT.)		FAULTING (IN.)		JNT WIDTH (IN.)	SEALANT DEPTH (IN.)	SPALLING (SQ.FT.)
			Partial Depth	Full Depth	Partial Depth	Full Depth				Near Shldr	Near C/L			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

COMMENTS: ________

DATA ON JOINT SEALANT CORES

PROJECT: ____________ ROUTE: ____________ CORE DIA: ____________

Test Sec M.P.: ____________ DIR: ________ TOTAL CORES: ____________

LANE: ________

Project Area : ____________ DATE OF CORING: ____________

OBSERVER: ____________

Joint Sealants

A: Dow Corning 888

B: Superseal 888

C: Allied Koch 9005

D: Crafco 231

E: Meadows Sofseal

NOTE: Lineal Measurements should be average values of at least two data points.

CORE #	CORE LENGTH (IN.)	JNT WIDTH (IN.)	JNT DEPTH (IN)	SEALANT DEPTH (IN.)	RECESS (IN.)	BACKER ROD ADHERENCE	BACKER ROD GAP (IN.)	SEALANT CONTAMINATION	SEALANT FAILURES	CRACKING CONFIGURATION	AGRREGATE INTERLOCK	COMMENTS
1	2	3	4	5	6	7	8	9	10	11	12	13
1A												
7A												
29A												
6B												
8B												
36B												
15C												
18C												
32C												
9D												
12D												
22D												
4E												
16E												
23E												

NOTATION

BACKER ROD ADHERENCE: N = NO, P = PARTIAL, C = COMPLETE

SEALANT CONTAMINATION: N = NO, F = FINES AT JOINT WALLS, I = INCOMPRESSIBLES

SEALANT FAILURES: N = NO, STRONG BOND EXISTS, A = ADHESIVE, C = COHESIVE

CRACKING CONFIG.: F = FULL DEPTH CRACKING AT WEAKENED PLANE

P = PARTIAL DEPTH CRACKING AT WEAKENED PLANE

AGGREGATE INTERLOCK: G = GOOD, B=BAD

APPENDIX B

DATA FROM CORES EXTRACTED IN OCTOBER I990

PROJECT: IR-17-2(104)
M.P. Limits: 332.2 - 331.5
DIR + LANE: SB, TRAVEL

CORE DIA: 4"
TOTAL CORES: 15
DATE TAKEN: 10/10/89

CORE #	Core Length (in)	Joint Width (in)	Joint Depth (in)	Sealant Depth (in)	Recess (in)	Backer Rod Adherence	Backer Rod Gap (in)	Sealant Contamination	Sealant Failures	Cracking Config.	Aggregate Interlock G=Good B=Bad
1	2	3	4	5	6	7	8	9	10	11	12
1A	8.0	0.6	2.15	0.20	0.32	C	–	N	N	F	G
7A	8.0	0.5	1.95	0.30	0.16	C	–	N	N	P	B
29A	7.6	0.5	2.15	0.15	0.25	C	–	N	N	F	G
6B	8.0	0.5	1.90	0.18	0.22	N	0.35	N	N	F	G
8B	8.1	0.5	2.00	0.45	0.24	N	0.50	N	N	F	G
36B	8.0	0.5	1.65	0.40	0.22	P	–	N	N	F	G
15C	8.2	0.5	1.95	0.90	0.12	C	–	F, I	A	F	G
18C	8.3	0.5	1.90	1.03	0.10	C	–	I	N	F	G
32C	4.5	0.5	1.92	1.00	0.10	C	–	F, I	A	F	G
9D	8.2	0.5	1.95	1.00	0.05	C	–	F, I	A	F	G
12D	8.2	0.55	2.00	0.90	0.10	C	–	F	A	F	G
22D	8.2	0.56	2.00	1.00	0.10	C	–	F, I	A	F	G
4E	8.3	0.56	2.20	1.60	0.20	No Rod	No Rod	F, I	C, A	F	G
16E	8.2	0.58	2.20	0.95	0.06	C	–	F, I	A	F	G
23E	8.0	0.50	2.20	1.20	0.10	C	–	F, I	A	F	G

Notation: Backer Rod Adherence ⇒ N = No, P = Partial, C = Complete
Sealant Contamination ⇒ N = No, F = Fines @ Joint Walls, I = Incompressibles
Sealant Failures ⇒ N = No, Strong Bond exists, A = Adhesive, C = Cohesive
Cracking Config ⇒ F = Full Depth Crack @ Weakened Plane
P = Partial Depth Crack @ Weakened plane.

APPENDIX C
SEALANT CONDITION DATA COLLECTED IN APRIL 1994

I-17 JOINT SEALANT DATA COLLECTED ON APRIL 11, 1994

JOINT ID NUMBER	SEALANT FLEXBILITY	SEALANT MISSING FT	ADHESIVE FAILURE ALONG JOINT (FT) PARTIAL DEPTH	FULL DEPTH	TOTAL LENGTH	COHESIVE FAILURE IN JOINT (FT) PARTIAL OR FULL DEPTH PARTIAL	FULL	TOTAL	SEALANT RECESS	PRESENCE OF SOLIDS (FT)	SLAB FAULTING (IN 0.1 INCHES) NEAR SHOULDER/CENTER LINE SHOULDER	CENTER LINE	MEAN	JOINT WIDTH
1C	2	0.5	2	4	6	2	0	2	0	5	2.4	1.6	2.00	0.625
1D	3	0	2	0	2	0	0	0	0	1	2	2	2.00	0
2A	3	0.5	0.4	1.5	1.9	0	0	0	0.13	1	1.8	1.5	1.65	0.625
2B	3	1.5	2.5	4.5	7	1	3	4	0.125	8	2.3	1.5	1.90	0.625
2C	2	0	0	0	0	0	0	0	0	0	2	1.5	1.75	0
3D	3	0	6	0	6	0	0	0	0.06	1.5	1.6	1.6	1.60	0.5
3E	3	0	8	0	8	1	0	1	0	4.5	2.5	1.2	1.85	0.5
4C	2	0.5	6	0	6	1	0	1	0	6	1.7	1.7	1.70	0.5
4E	3	0	8	0	8	0	0	0	0	6	2	2	2.00	0.5
5D	3	0	9	0.5	9.5	0.5	0	0.5	0	3	2.4	1.8	2.10	0.5
6A	3	0.3	8	0	8	0	0	0	0.125	1.5	2.6	2	2.30	0.5
6B	3	0.9	3	3	6	0.5	0	0.5	0.125	4.5	2.6	2.2	2.40	0.5
6C	2	0	8	0	8	1	0.5	1.5	0	5	2.5	2.7	2.60	0.5
6D	3	0.5	9	0.5	9.5	0.5	0.5	1	0	4	2	1.8	1.90	0.5
6E	3	0	8	1	9	1.5	3	4:5	0	4	2.9	2.6	2.75	0.5
7B	3	1	6	3	9	0	1.5	1.5	0.125	10	2.7	2.4	2.55	0.5
7C	2	0	4	0	4	1	1	2	0	7	2.3	2.2	2.25	0.5
7E	3	0	10	1	11	0	0	0	0	5	1.9	1.9	1.90	0.5
8B	3	0	3	1	4	0	1	1	0.125	4	2.4	2	2.20	0.5
8D	3	0	10	0.5	10.5	0	0	0	0	3	1.5	1.3	1.40	0.5
8E	3	0	8	0	8	1	0	1	0	3	1.2	1.4	1.30	0.5
9A	3	0	10	1	11	0	0	0	0.125	2	2.8	2.2	2.50	0.5
9D	3	0	10	0	10	0.5	0	0.5	0	2	2	1.6	1.80	0.5
9E	3	0	7	0	7	2	0	2	0	4	2.2	1.7	1.95	0.5
10B	3	0.3	11	1	12	4	1	5	0.125	9	2.4	1.2	1.80	0.5

JOINT ID NUMBER	SEALANT FLEXBILITY	SEALANT MISSING FT	ADHESIVE FAILURE ALONG JOINT (FT)			COHESSIVE FAILURE IN JOINT (FT) PARTIAL OR FULL DEPTH			SEALANT RECESS	PRESENCE OF SOLIDS (FT)	SLAB FAULTING (IN 0.1 INCHES) NEAR SHOULDER/CENTER LINE			JOINT WIDTH
			PARTIAL DEPTH	FULL DEPTH	TOTAL LENGTH	PARTIAL	FULL	TOTAL			SHOULDER	CENTER LINE	MEAN	
11A	3	0.3	7	0	7	0	0	0	0.125	4	1.6	1.5	1.55	0.5
11C	3	0	6	0	6	0	0	0	0	3	2.1	1.4	1.75	0.5
11E	3	0	8	0	8	0	0.5	0.5	0	5	1.6	1.3	1.45	0.5
12A	3	0	9	0	9	0	0	0	0.125	2.5	0.8	0.9	0.85	0.5
12B	3	0	10	2	12	0	0	0	0.125	4	2.3	1.4	1.85	0.5
12D	3	0	11	0	11	0.5	0	0.5	0	2	1.5	1	1.25	0.312
12E	3	0	10	0	10	0	0.5	0.5	0	2	2.7	1.7	2.20	0.5
13B	3	0.3	8	3	11	2	0	2	0.125	5	1.5	1.3	1.40	0.5
13E	3	0	11	0	11	0	0	0	0	6	2.2	1.4	1.80	0.5
14A	3	0	8	0	8	0	0	0	0.125	3	1.5	1.7	1.60	0.5
14B	3	0.5	8	1	9	1	0	1	0.125	7	2.2	1.7	1.95	0.5
14D	3	0	9	0	9	0	0	0	0	3	1.7	1.5	1.60	0.5
14E	3	0	8	0.5	8.5	0	0	0	0	2	2.1	1.9	2.00	0.5
15D	3	0	10	0	10	0	0	0	0	2.5	2.3	1.4	1.85	0.5
15E	3	0	11	0	11	0	0	0	0	5	1.5	1.6	1.55	0.5
16B	3	0	7	3	10	0	0	0	0.25	4	1.7	1.7	1.70	0.5
16C	3	0	6	0	6	0	0	0	0	1.5	2	1.5	1.75	0.5
16D	3	0	10	0	10	0	0	0	0	1.5	2	1.8	1.90	0.5
17A	3	0	4	4.5	8.5	0	0	0	0.25	5	1.4	1.2	1.30	0.5
17B	3	0.3	3	2	5	0	0	0	0.25	5.5	1.2	1	1.10	0.5
17C	3	0	1	0	1	0	0	0	0.25	1	1	0.9	0.95	0.5
18B	3	0.3	8.5	1.5	10	0	0	0	0.25	4	1.2	1.4	1.30	0.5
19A	3	0	6	1	7	0	0	0	0.25	1.5	1.9	1.3	1.60	0.5
19C	3	0	4	0	4	0	1	1	0	2	0.9	1.1	1.00	0.5
20A	3	0	4	4	8	0	0	0	0.25	6	1.6	1.3	1.45	0.5
20C	3	0	9	0	9	1	1	2	0	4	2	1.8	1.90	0.5
20E	3	0	10	0	10	0.5	0	0.5	0.25	4	1.2	1.2	1.20	0.5

JOINT ID NUMBER	SEALANT FLEXBILITY	SEALANT MISSING FT	ADHESIVE FAILURE ALONG JOINT (FT)			COHESSIVE FAILURE IN JOINT (FT)				PRESENCE OF SOLIDS (FT)	SLAB FAULTING (IN 0.1 INCHES) NEAR SHOULDER/CENTER LINE			JOINT WIDTH
						PARTIAL OR FULL DEPTH			SEALANT RECESS					
			PARTIAL DEPTH	FULL DEPTH	TOTAL LENGTH	PARTIAL	FULL	TOTAL			SHOULDER	CENTER LINE	MEAN	
21C	3	0	6	1	7	0	1	1	0	1	1.8	1.5	1.65	0.5
21D	3	0	9	0	9	0	1	1	0	3	1.7	1.4	1.55	0.5
22A	3	0.5	2	7	9	0	0	0	0.25	8	1.9	2	1.95	0.5
22C	3	0	4	0	4	0.5	0	0.5	0	0.5	1.2	1	1.10	0.5
22D	3	0	7	0	7	0.5	0	0.5	0	1	1.7	1	1.35	0.5
22E	3	0	11	0	11	0	0	0	0	6	1.8	1.6	1.70	*
23B	3	0	8	1	9	0	0.5	0.5	0.375	6	1.1	0.9	1.00	0.5
23D	3	0	8	0	8	0	0.5	0.5	0	3	1.7	1.4	1.55	0.5
24C	3	0	3	0	3	1	0	1	0	2	2	1.5	1.75	0.5
24D	3	0	8	0	8	0.5	0	0.5	0	1.5	2.6	2	2.30	0.5
25A	3	0	5	4	9	0	0	0	0.25	4.5	1.8	1.1	1.45	0.5
26E	3	0	7	0	7	0.5	0	0.5	0	1	1.8	1.4	1.60	0.5
27A	3	0	4	7	11	0	0.5	0.5	0.25	8	1.6	1.3	1.45	0.5
27B	3	0	10	1	11	0	0	0	0.25	6	1.6	1.8	1.70	0.5
27C	3	0	3	0	3	0	1	1	0	0.5	1.7	1.4	1.55	0.5
27D	3	0	5	0	5	0	0.5	0.5	0	2	2.4	2.1	2.25	0.5
27E	3	0	8	0	8	0.5	0	0.5	0	2	2.4	2.2	2.30	0.5
28B	3	0.3	7.5	1.5	9	0	1	1	0.25	7	3.2	2.2	2.70	0.5
28D	3	0	5	0	5	0.5	1	1.5	0	2	3	1.7	2.35	0.5
29A	3	4	4	2	6	0	0	0	0.25	8	2.2	2.2	2.20	0.5
29B	3	0.3	6	1.5	7.5	0	1	1	0.25	6	2.1	2.3	2.20	0.5
30A	3	0	7	2	9	0	0	0	0.25	5	2.3	2.1	2.20	0.5
30C	3	0	4	0	4	0	1	1	0	2	2	1.7	1.85	0.5
30D	3	0	9	0	9	0	0	0	0	4	2.1	1.8	1.95	0.5

JOINT ID	SEALANT	SEALANT	ADHESIVE FAILURE ALONG JOINT (FT)			COHESSIVE FAILURE IN JOINT (FT)				PRESENCE OF	SLAB FAULTING (IN 0.1 INCHES)			JOINT
						PARTIAL OR FULL DEPTH			SEALANT		NEAR SHOULDER/CENTER LINE			
NUMBER	FLEXBILITY	MISSING FT	PARTIAL DEPTH	FULL DEPTH	TOTAL LENGTH	PARTIAL	FULL	TOTAL	RECESS	SOLIDS (FT)	SHOULDER	CENTER LINE	MEAN	WIDTH
31E	3	0	10	1	11	0	0	0	0	5	2.3	1.9	2.10	0.5
32A	3	0	5	3	8	0	0	0	0.25	6	2.8	2.5	2.65	0.5
32B	3	0.2	9	0	9	0	0	0	0.25	8	3.4	2.6	3.00	0.5
32C	2	0	2.5	0	2.5	0	0	0	0	1.5	1.8	1.8	1.80	0.5
33A	3	0.5	5	3	8	0	0	0	0.25	7	2.5	2.3	2.40	0.5
33B	3	0	6	1	7	0	0.5	0.5	0.25	5	2.2	1.8	2.00	0.5
33E	3	0	10	0	10	0	0	0	0	5	2.9	2.9	2.90	0.5
34B	3	0	8	0	8	0	0.5	0.5	0.25	4	2.4	1.8	2.10	0.5
34C	2	0	2	0	2	0	1	1	0	1	3.4	2.2	2.80	0.5
34E	3	0	10	0	10	0	0	0	0	5	2	2.2	2.10	0.5
35C	3	0	9	0	9	1.5	0	1.5	0	4	2.1	2	2.05	0.5
35E	3	0	11	0	11	0	0.5	0.5	0	4	2	2.1	2.05	0.5
36A	3	0	5	3	8	0	0	0	0.25	7	2.8	2.2	2.50	0.5
36E	3	0	10	0	10	0	0	0	0	4	3.3	2.8	3.05	0.5
37A	3	1	4	6	10	0	1	1	0.25	9	3.3	2.9	3.10	0.5
37B	3	0	6	1	7	0	0	0	0.25	4	4	2.6	3.30	0.5
37C	2	0	0	6	6	0	3	3	0	7	2	2.1	2.05	0.5
37D	3	0	11	0	11	0	0	0	0	7	2.9	3	2.95	0.5
38A	3	0	4	5	9	0	0.5	0.5	0.25	8	2.8	2.7	2.75	0.5
38B	3	0	8	1	9	0	0	0	0.25	5	2.5	2	2.25	0.5
38D	3	0	7	0	7	1	0	1	0	3	2.8	2.4	2.60	0.5
39A	3	0	4	5	9	0	1.5	1.5	0.375	9	2.5	2.3	2.40	0.5
39C	2	0	6	0	6	1	0	1	0	2.5	2.1	2	2.05	0.5
39D	3	0	6	0	6	0.5	0	0.5	0	2	1.9	1.6	1.75	0.5

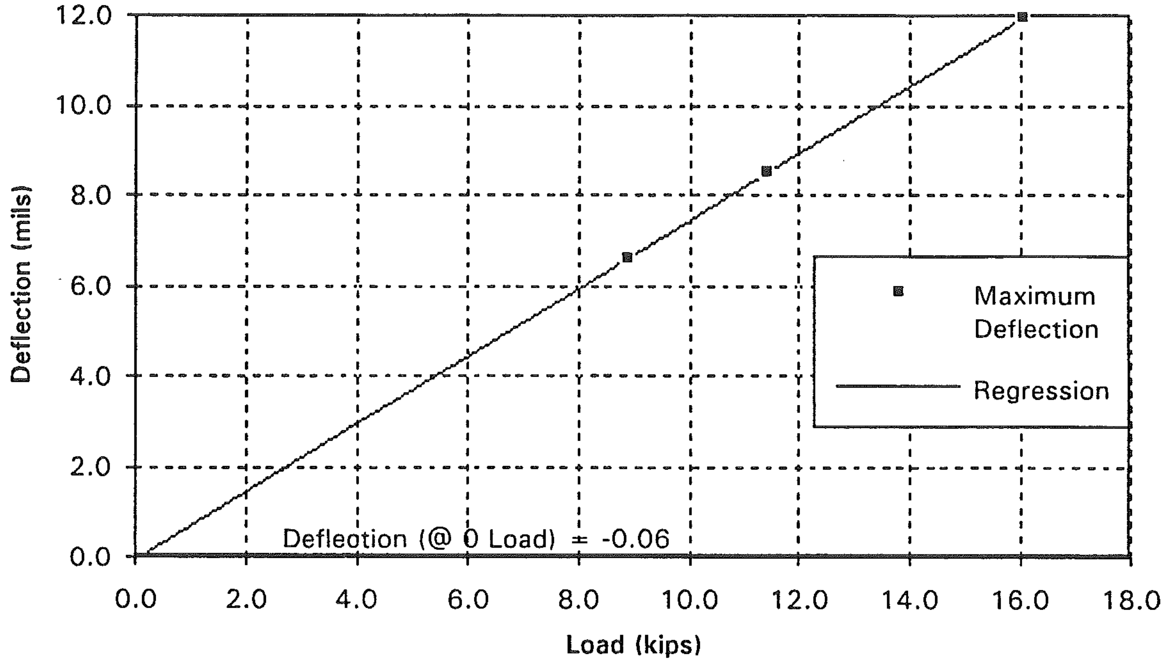
APPENDIX D
ANALYSIS RESULTS OF THE FALLING WEIGHT DEFLECTOMETER (FWD) TEST DATA

Individual FWD Test Results

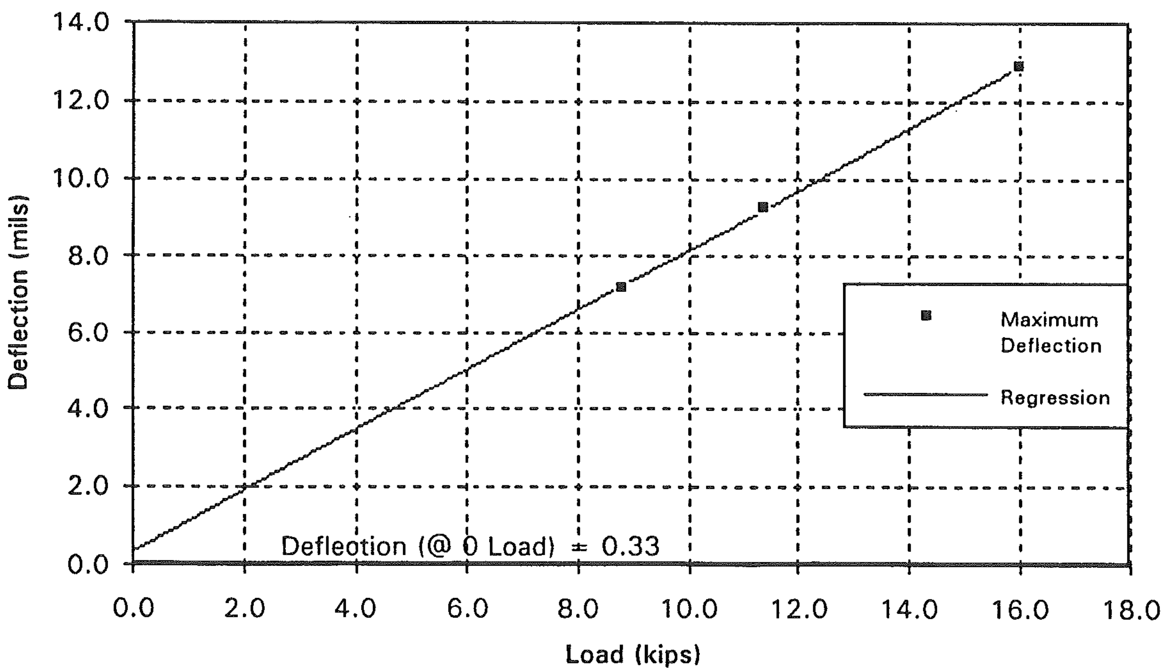
Joint	Direction	Max. Defl. (mils) *	Load Transf. (%)	Rel. Defl. (mils) *	Voids Detect. (mils) *
11 A	A	6.48	99%	0.07	-0.24
11 A	B	6.80	94%	0.43	0.13
11 B	A	7.18	106%	-0.42	0.07
11 B	B	7.58	96%	0.29	0.58
11 C	A	7.11	91%	0.66	0.05
11 C	B	6.90	93%	0.45	0.23
11 D	A	6.53	96%	0.29	0.09
11 D	B	6.27	97%	0.18	0.18
11 E	A	6.14	98%	0.13	0.20
11 E	B	5.80	97%	0.20	0.27
12 A	A	5.64	97%	0.19	0.04
12 A	B	5.76	90%	0.60	0.04
12 B	A	6.13	99%	0.05	0.15
12 B	B	6.12	92%	0.47	0.23
12 C	A	5.52	92%	0.43	0.19
12 C	B	5.22	89%	0.55	0.07
12 D	A	6.71	90%	0.68	0.16
12 D	B	6.38	82%	1.15	0.39
12 E	A	6.53	95%	0.35	-0.05
12 E	B	5.75	89%	0.61	-0.05
13 A	A	6.95	98%	0.13	-0.09
13 A	B	6.25	89%	0.66	0.36
13 B	A	6.18	97%	0.20	-0.01
13 B	B	5.58	94%	0.32	0.32
13 C	A	7.26	68%	2.33	0.13
13 C	B	6.62	86%	0.91	0.62
13 D	A	7.14	97%	0.19	0.24
13 D	B	6.50	99%	0.09	0.19
13 E	A	7.12	101%	-0.05	0.24
13 E	B	7.10	89%	0.77	0.12
14 A	A	6.91	99%	0.07	0.31
14 A	B	6.76	94%	0.38	0.18
14 B	A	7.82	81%	1.49	0.21
14 B	B	7.07	92%	0.57	0.17
14 C	A	7.18	101%	-0.05	0.28
14 C	B	7.41	92%	0.57	0.30
14 D	A	6.68	101%	-0.04	0.17
14 D	B	6.75	97%	0.19	0.38
14 E	A	6.57	101%	-0.04	0.19
14 E	B	6.91	95%	0.34	0.38
15 A	A	6.68	96%	0.25	0.09
15 A	B	6.46	94%	0.37	0.18
15 B	A	6.61	101%	-0.06	0.09
15 B	B	6.50	94%	0.40	0.25
15 C	A	6.80	100%	-0.03	0.22
15 C	B	6.44	98%	0.12	-0.03
15 D	A	6.45	97%	0.19	-0.24
15 D	B	6.37	96%	0.24	0.01
15 E	A	6.31	98%	0.11	0.09
15 E	B	6.77	87%	0.87	0.34
16 A	A	6.01	92%	0.46	0.14
16 A	B	5.95	91%	0.55	0.31
16 B	A	5.87	100%	0.02	0.25
16 B	B	6.13	94%	0.37	0.53
16 C	A	5.46	96%	0.22	0.20
16 C	B	5.67	92%	0.43	0.19
16 D	A	6.19	97%	0.16	0.53
16 D	B	6.15	92%	0.49	0.16
16 E	A	6.71	97%	0.22	0.69
16 E	B	6.37	93%	0.42	0.56
17 A	A	6.96	92%	0.54	0.65
17 A	B	6.52	92%	0.51	0.53
17 B	A	5.47	96%	0.21	0.21
17 B	B	5.60	94%	0.36	0.29
17 C	A	5.76	98%	0.14	0.15
17 C	B	6.10	101%	-0.04	0.17
17 D	A	6.44	102%	-0.16	0.06
17 D	B	6.84	94%	0.38	0.09
17 E	A	6.78	98%	0.16	0.36
17 E	B	6.85	96%	0.29	0.40

APPENDIX E
PLOTS MADE FOR THE VOID DETECTION ANALYSIS

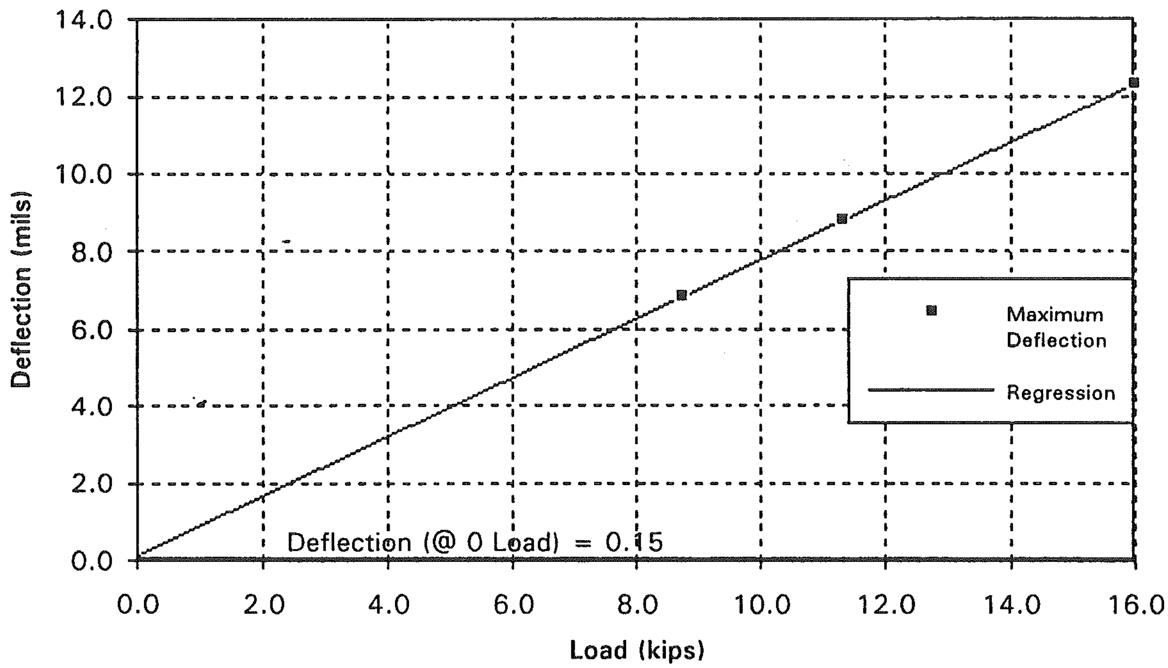
Joint: 11A - Sealant Type : Dow Corning



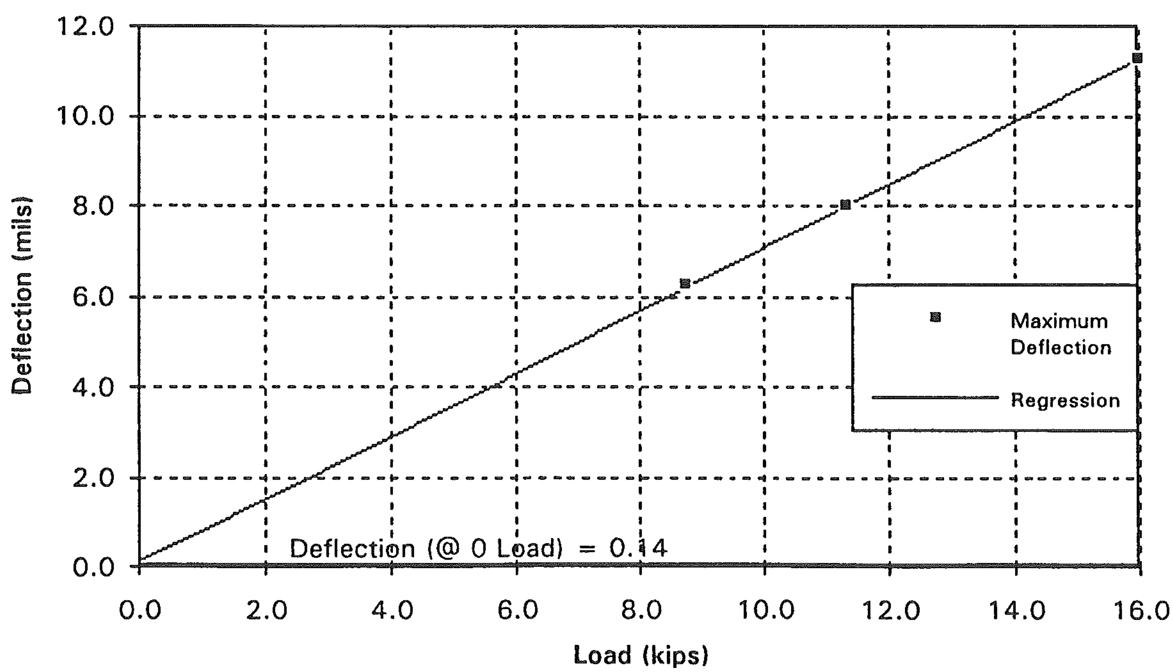
Joint: 11B - Sealant Type : Superseal 888



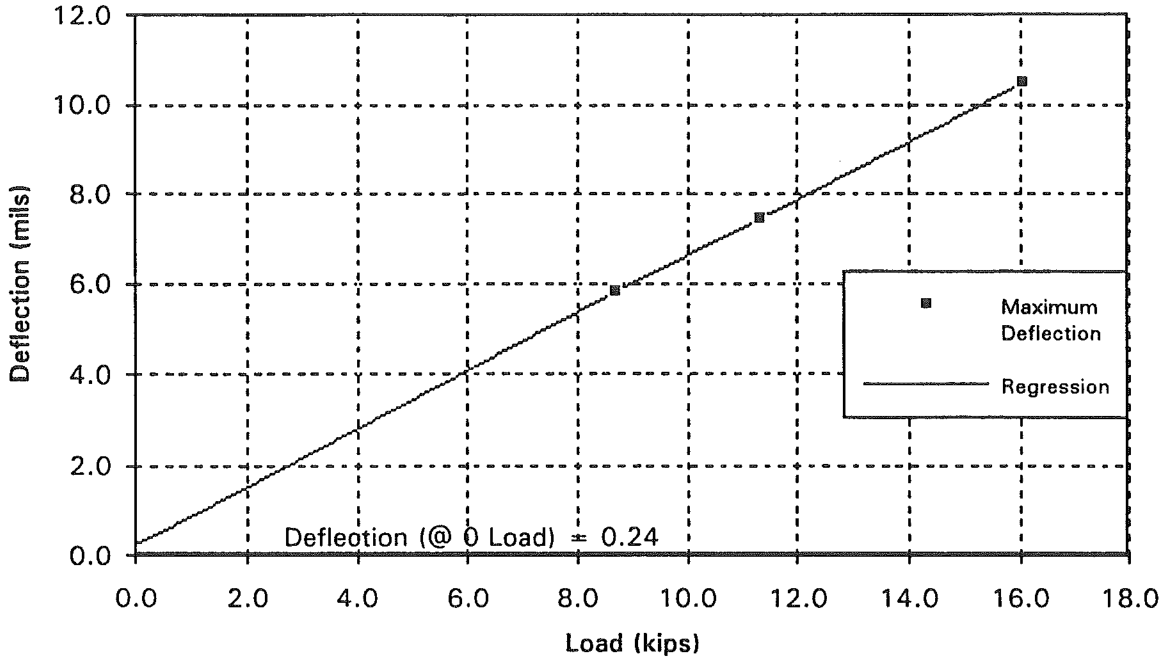
Joint: 11C - Sealant Type : Allied Koch 9005



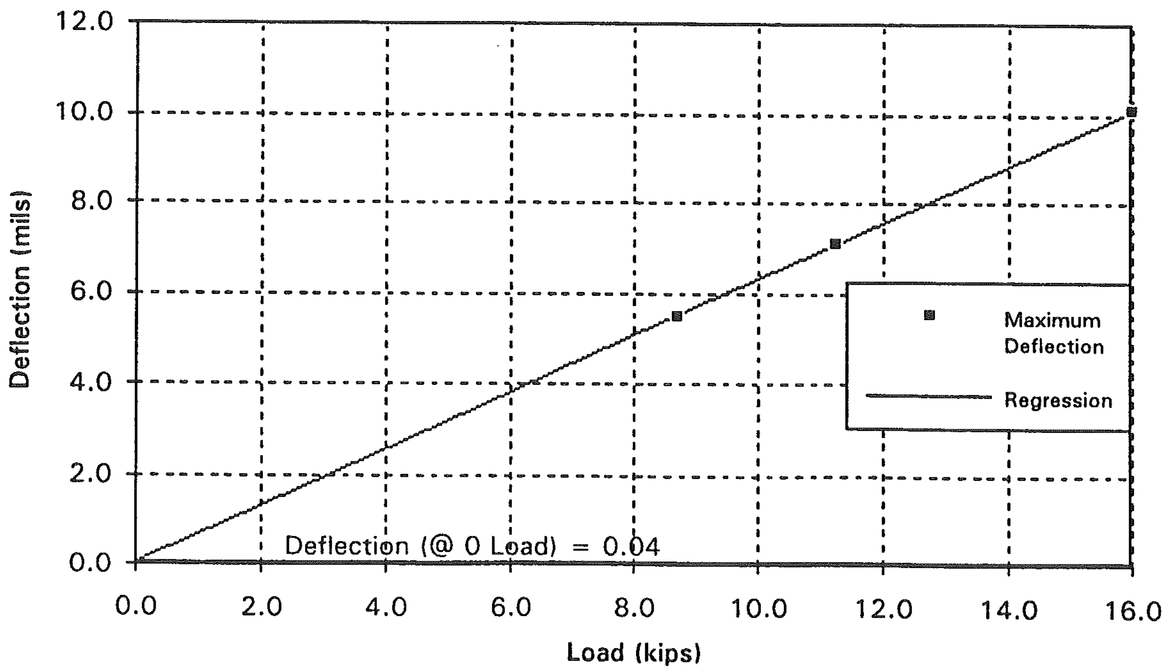
Joint: 11D - Sealant Type : Crafco Roadsaver 231



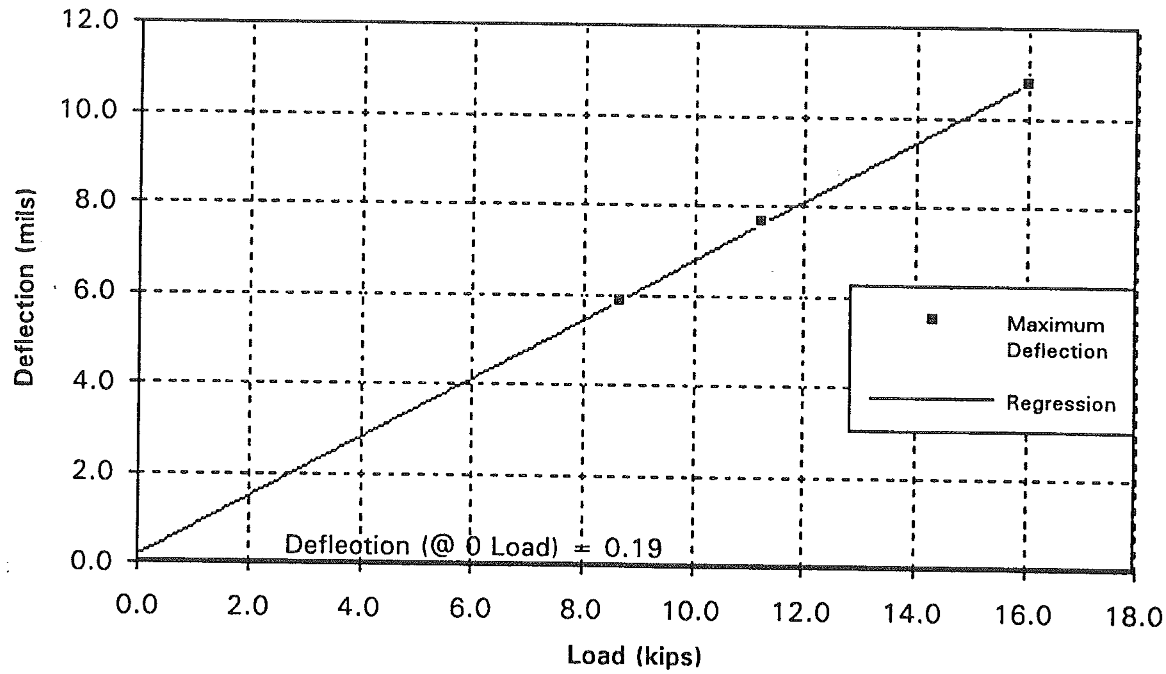
Joint: 11E - Sealant Type : W. R. Meadows Soft-Seal



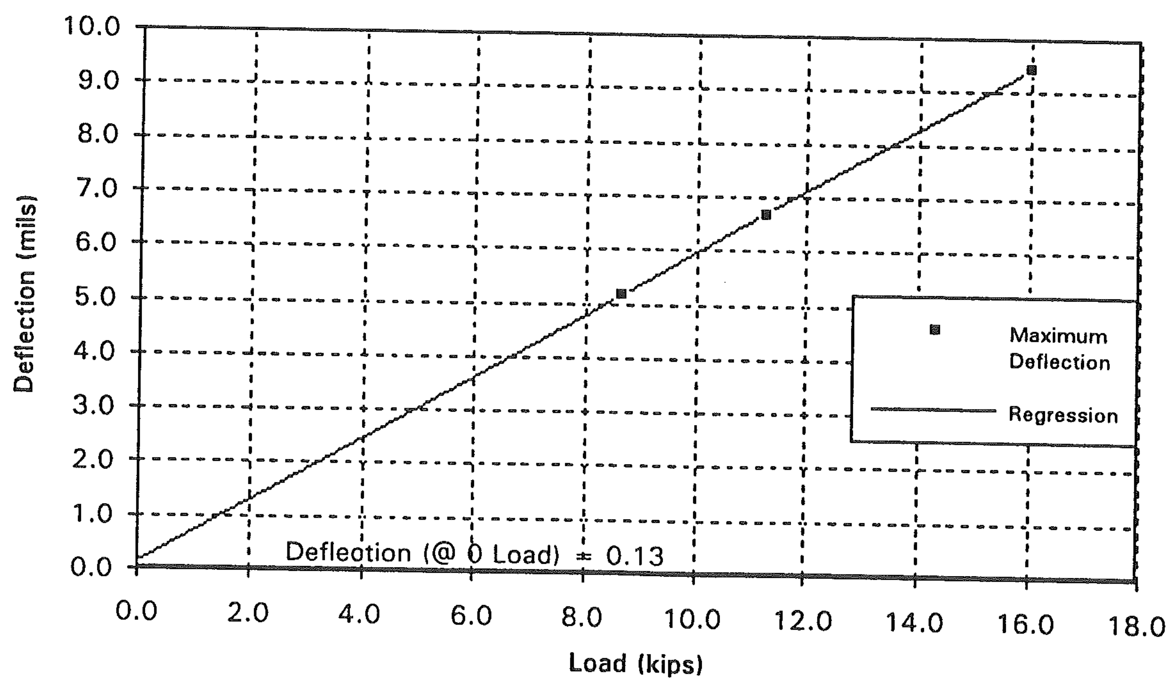
Joint: 12A - Sealant Type : Dow Corning



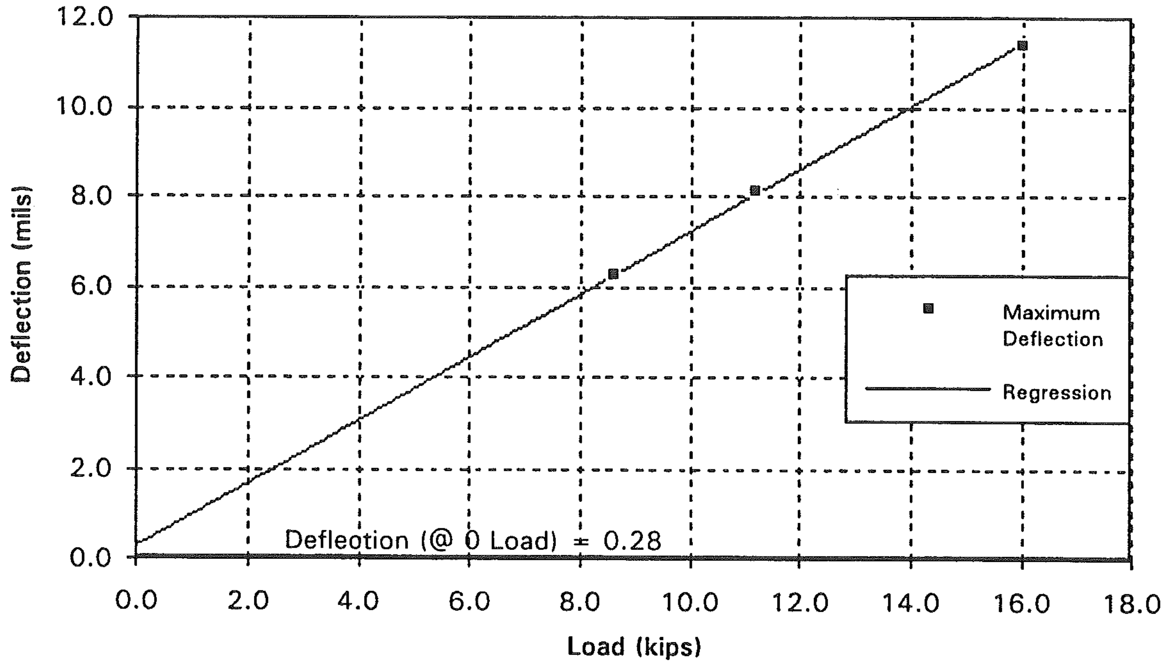
Joint: 12B - Sealant Type : Superseal 888



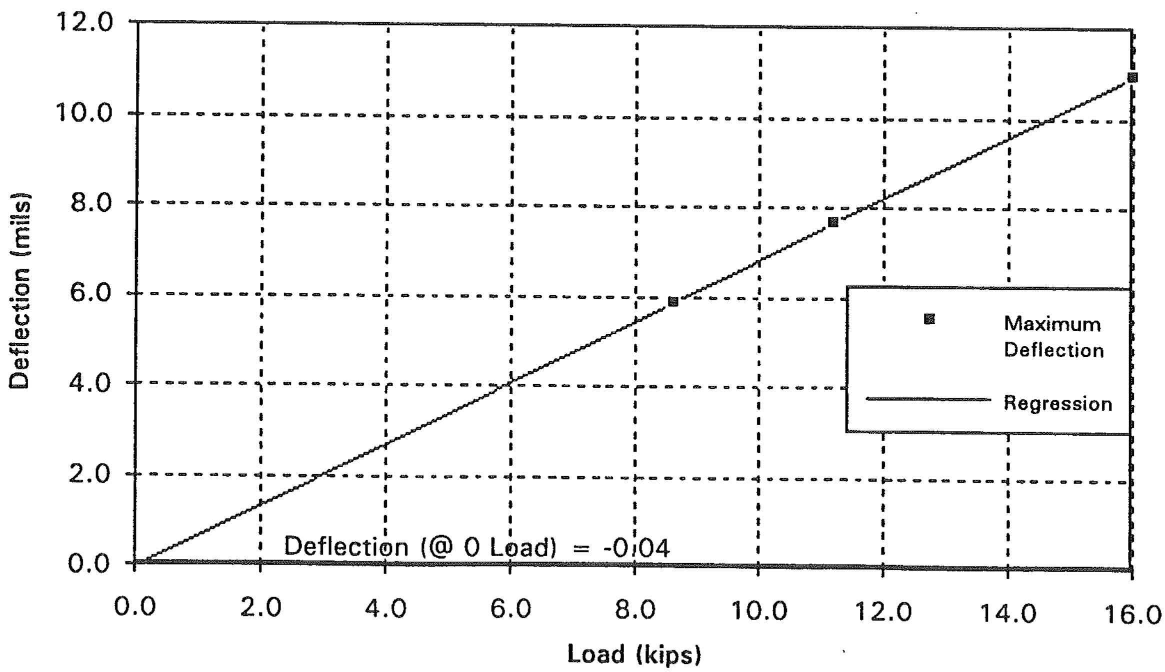
Joint: 12C - Sealant Type : Allied Koch 9005



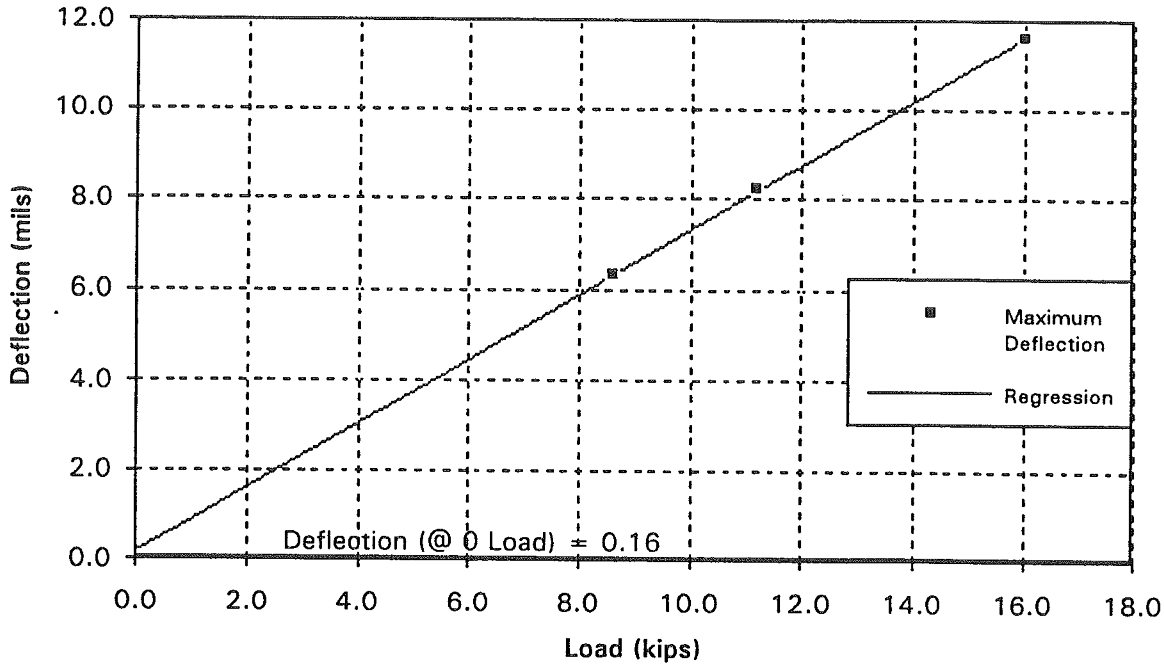
Joint: 12D - Sealant Type : Crafco Roadsaver 231



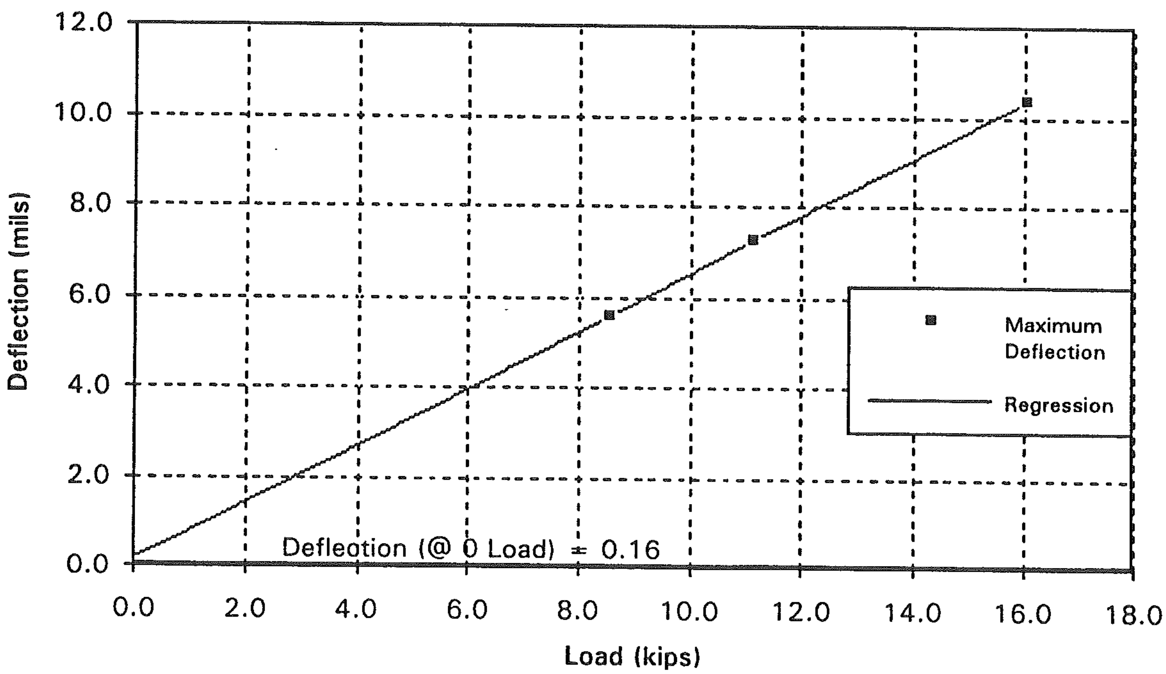
Joint: 12E - Sealant Type : W. R. Meadows Soft-Seal



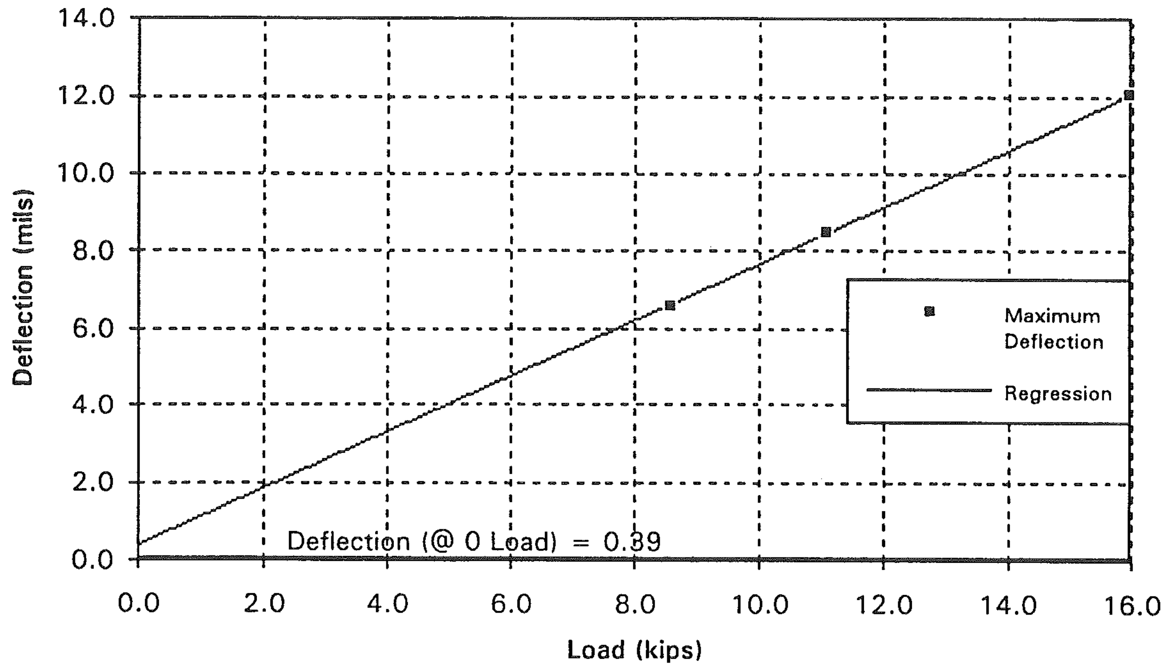
Joint: 13A - Sealant Type : Dow Corning



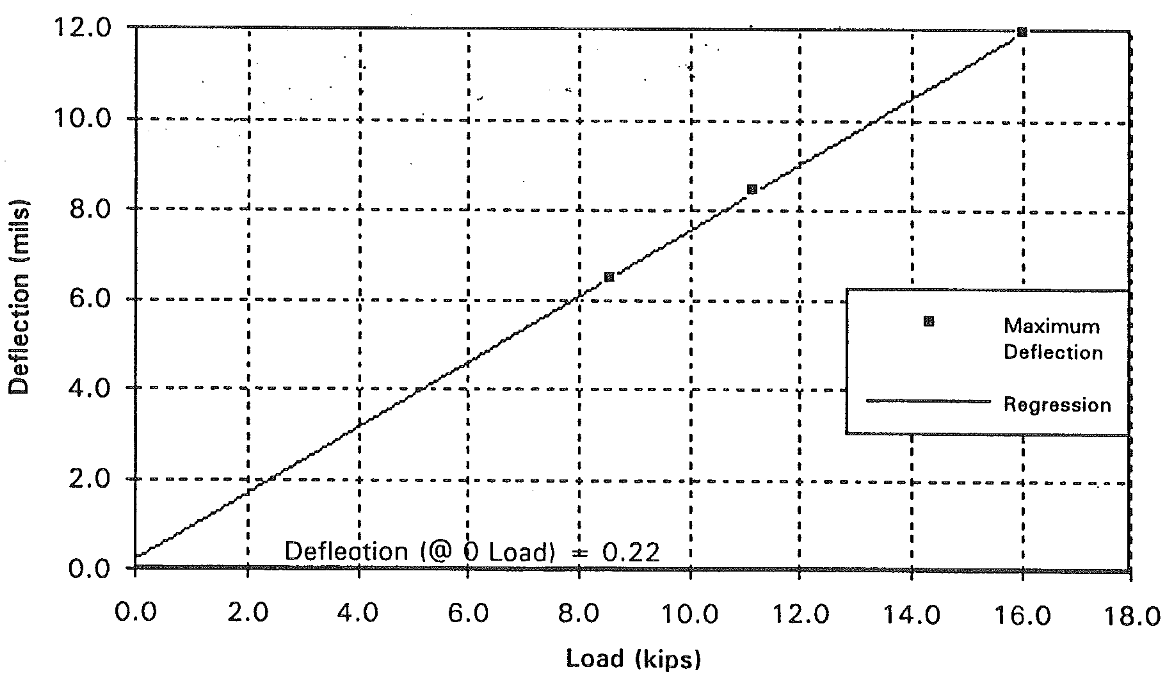
Joint: 13B - Sealant Type : Superseal 888



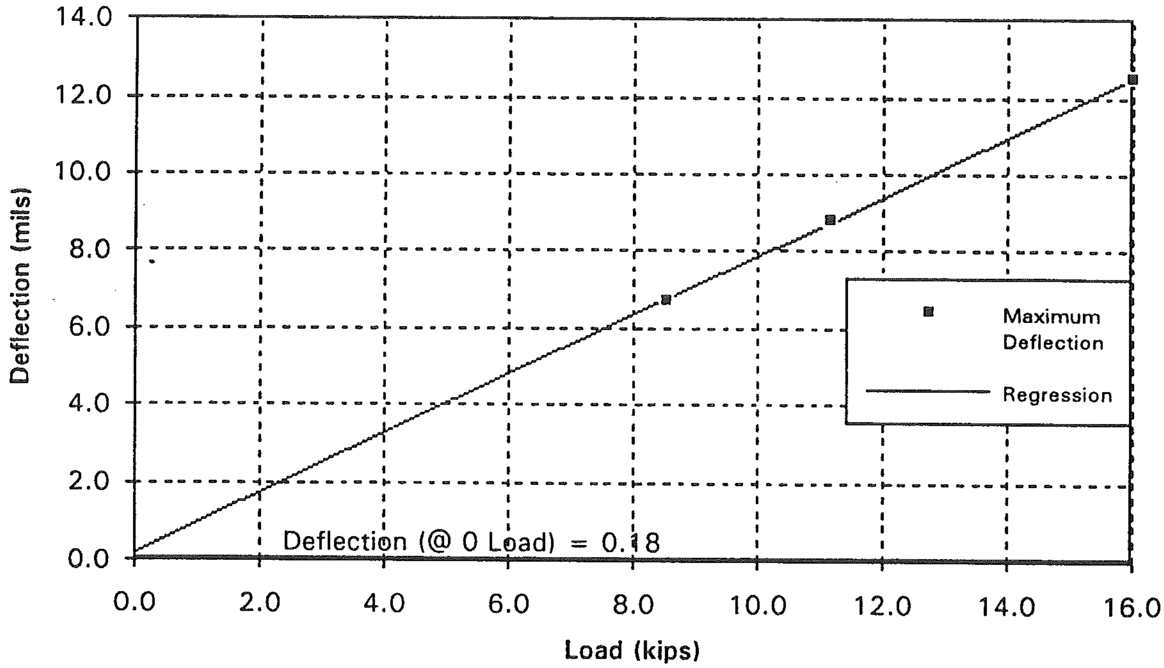
Joint: 13C - Sealant Type : Allied Koch 9005



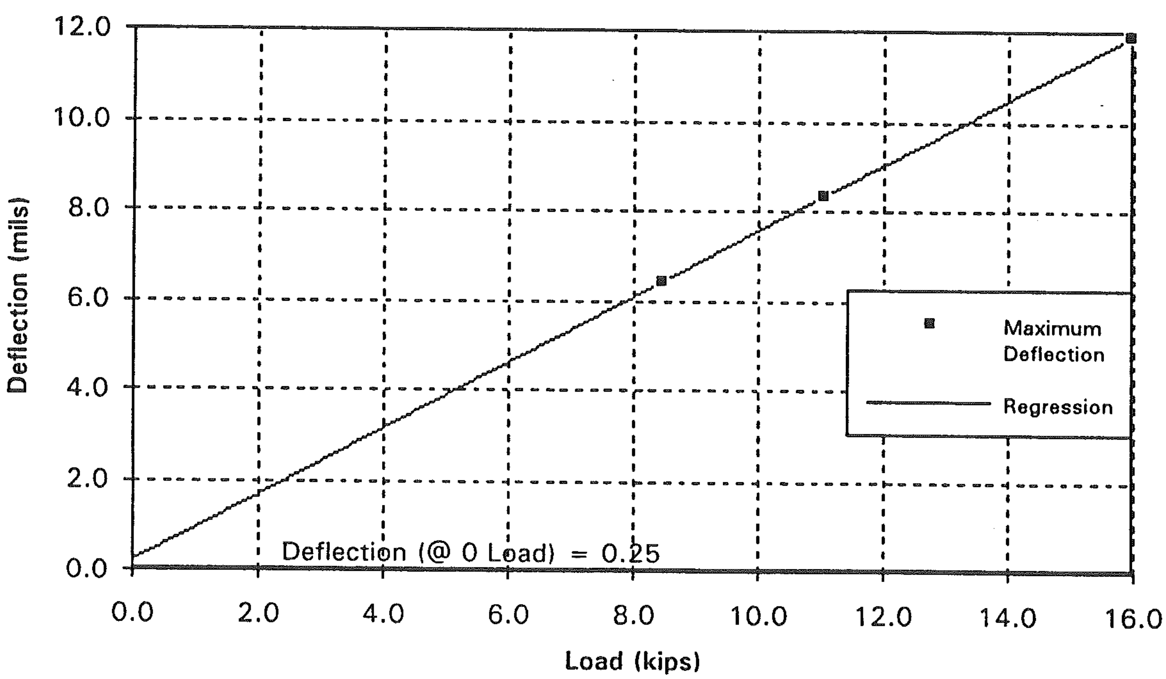
Joint: 13D - Sealant Type : Crafco Roadsaver 231



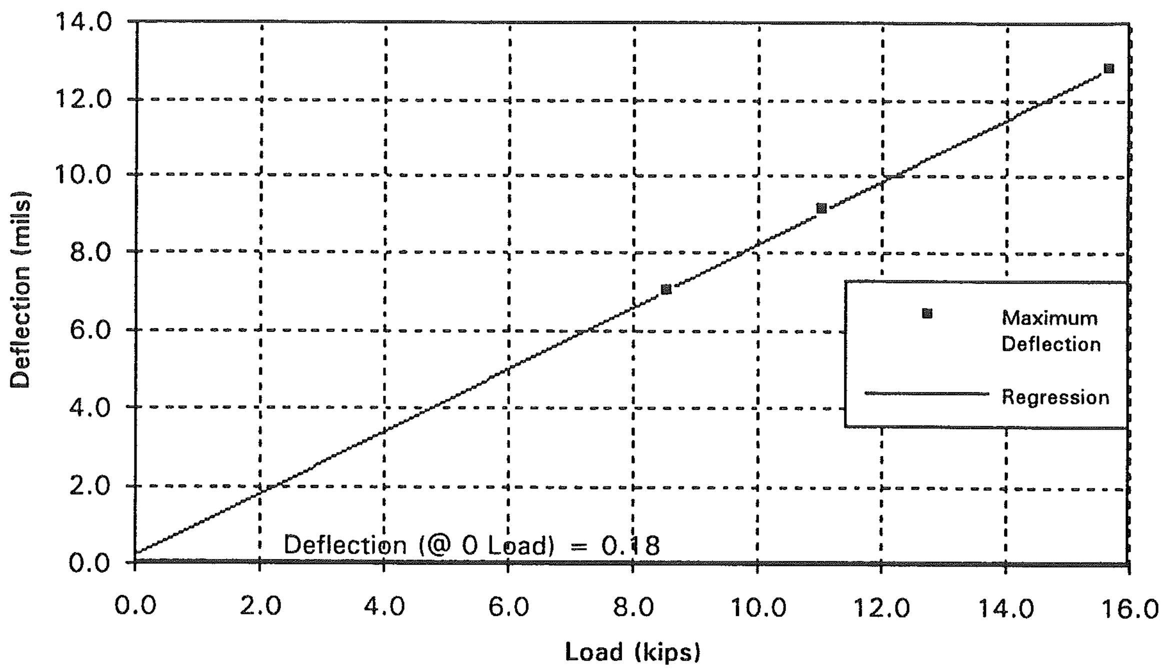
Joint: 13E - Sealant Type : W. R. Meadows Soft-Seal



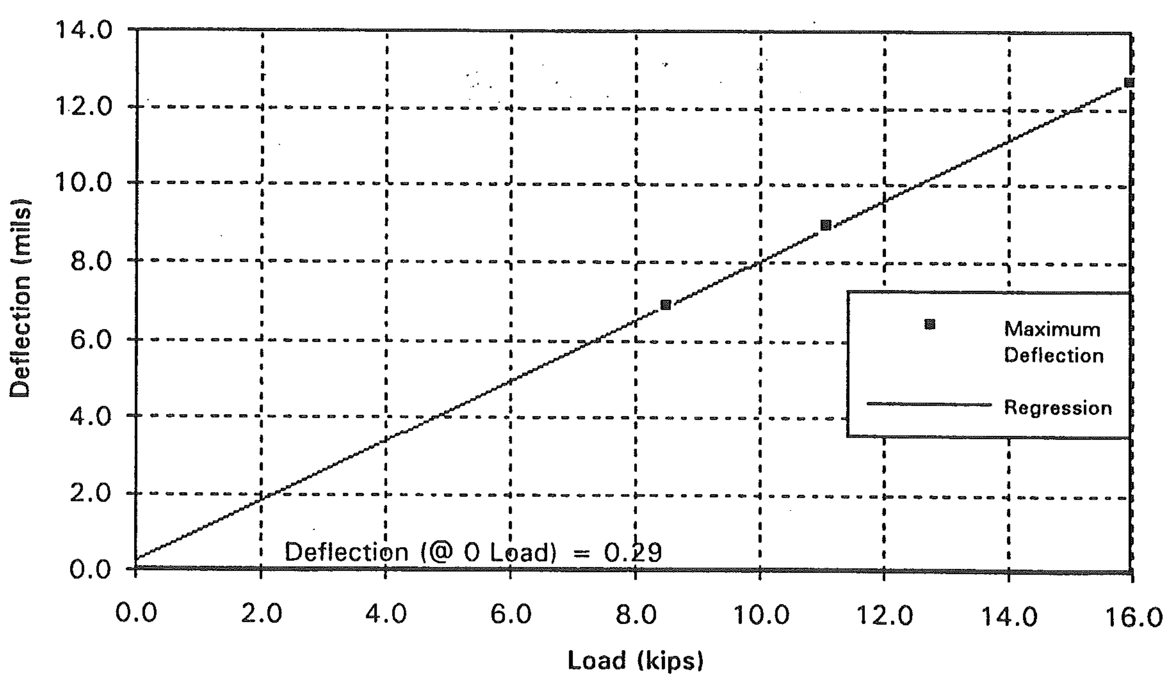
Joint: 14A - Sealant Type : Dow Corning



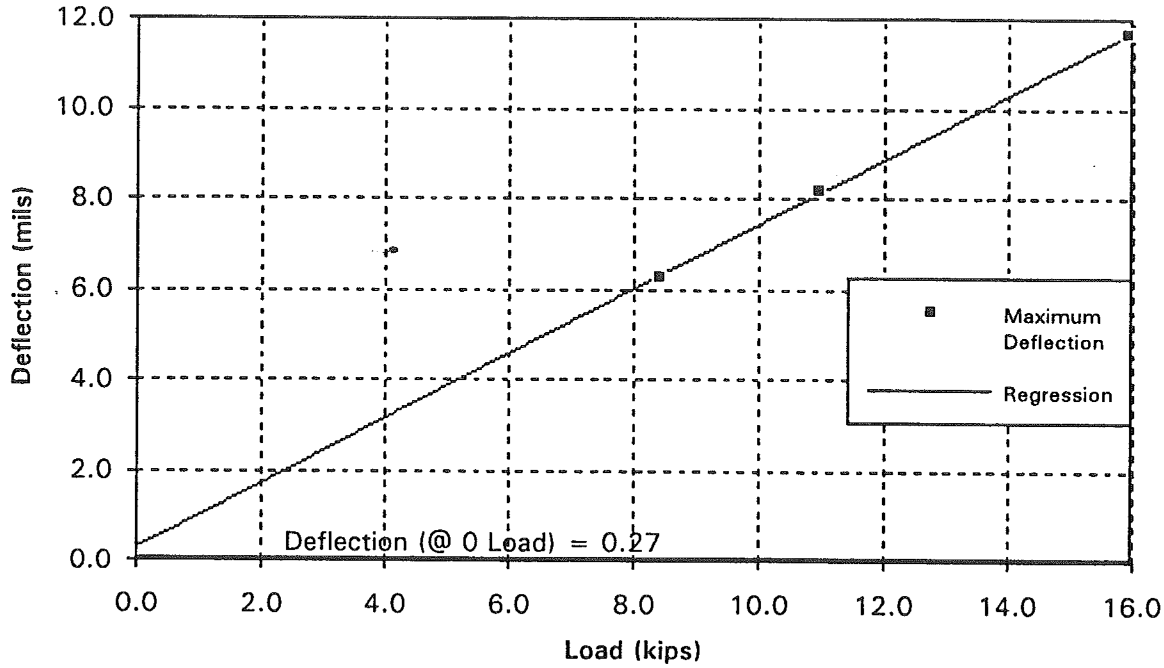
Joint: 14B - Sealant Type : Superseal 888



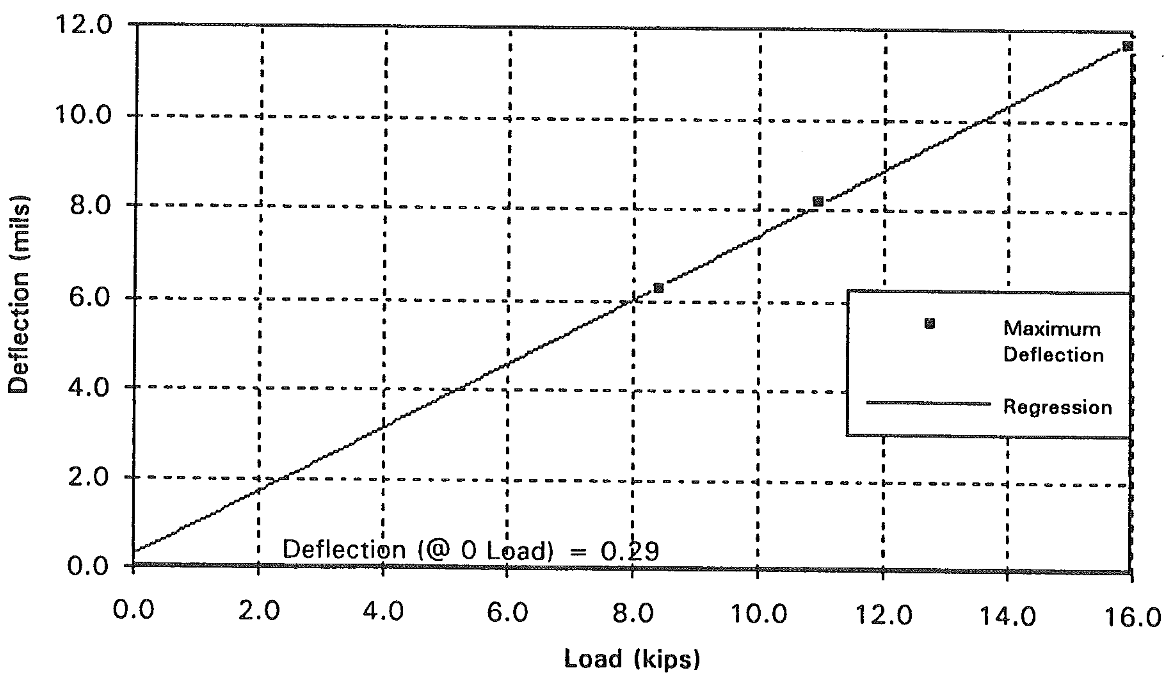
Joint: 14C - Sealant Type : Allied Koch 9005



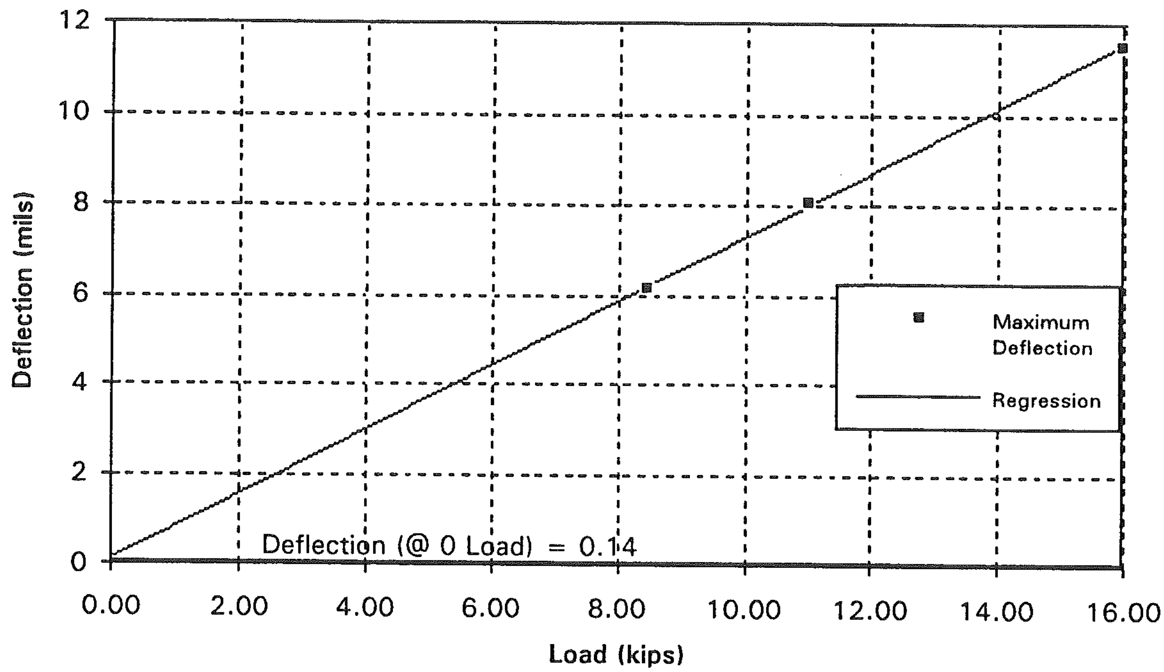
Joint: 14D - Sealant Type : Crafco Roadsaver 231



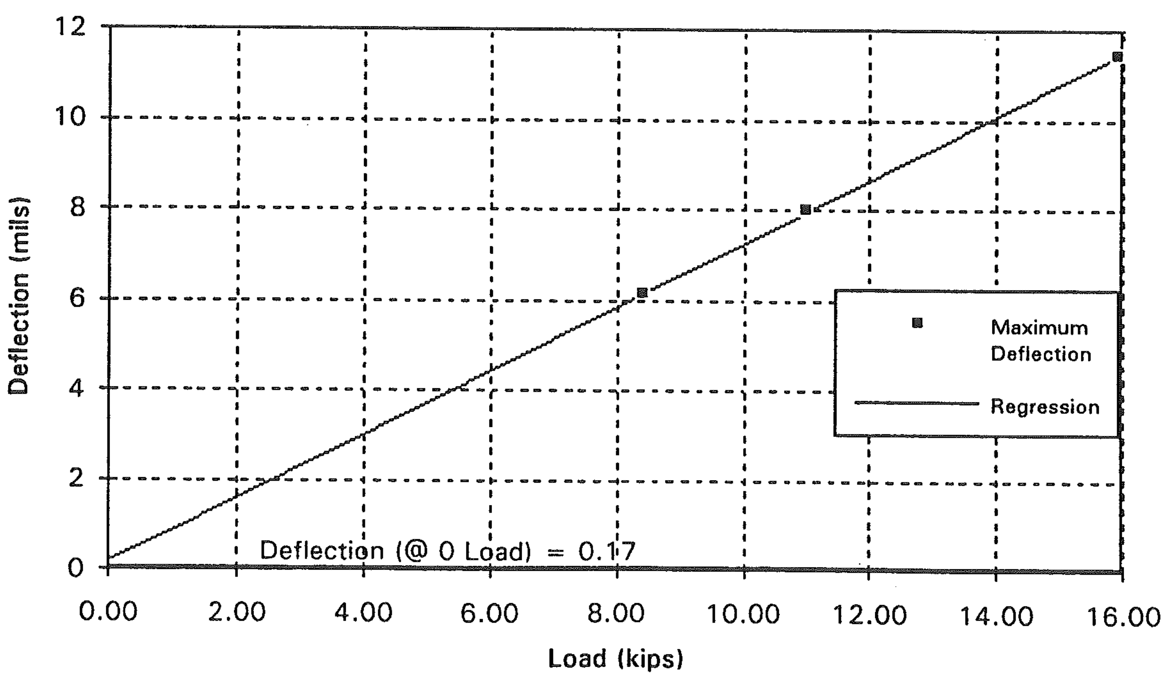
Joint: 14E - Sealant Type : W. R. Meadows Soft-Seal



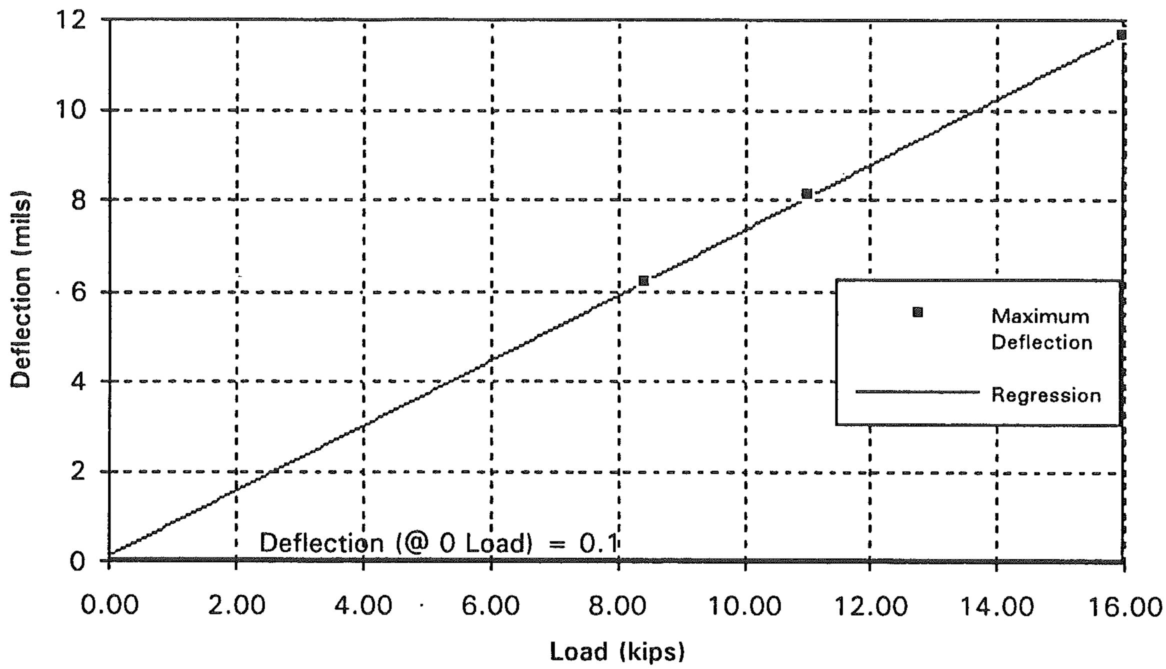
Joint: 15A - Sealant Type : Dow Corning



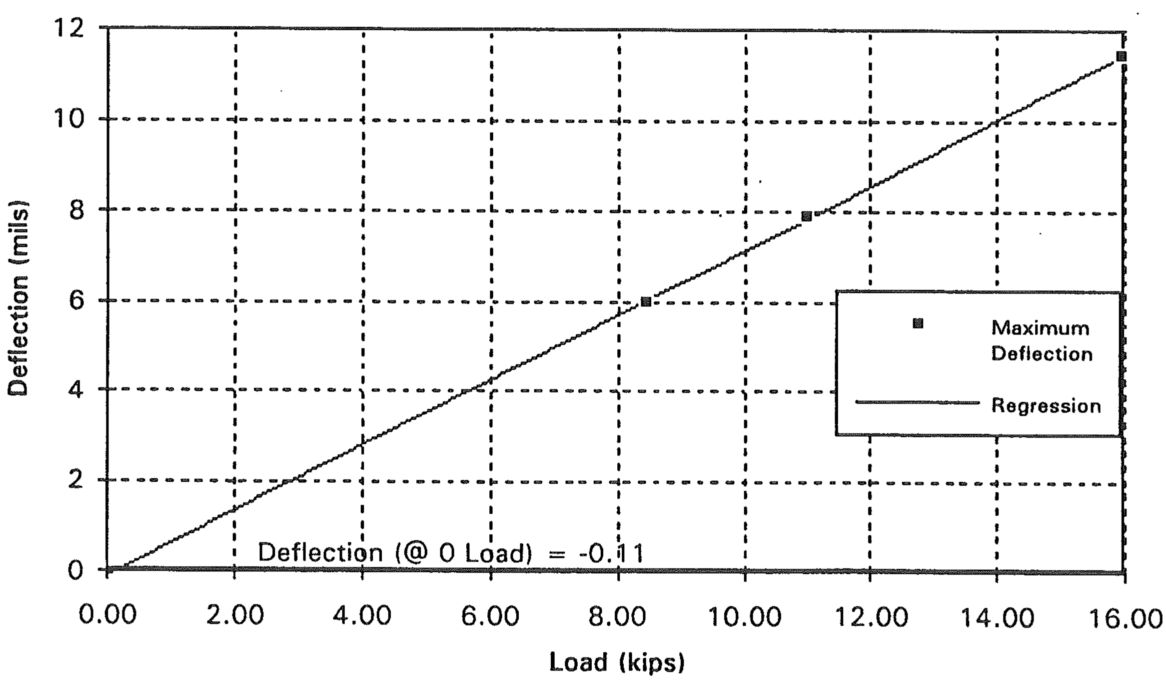
Joint: 15B - Sealant Type : Superseal 888



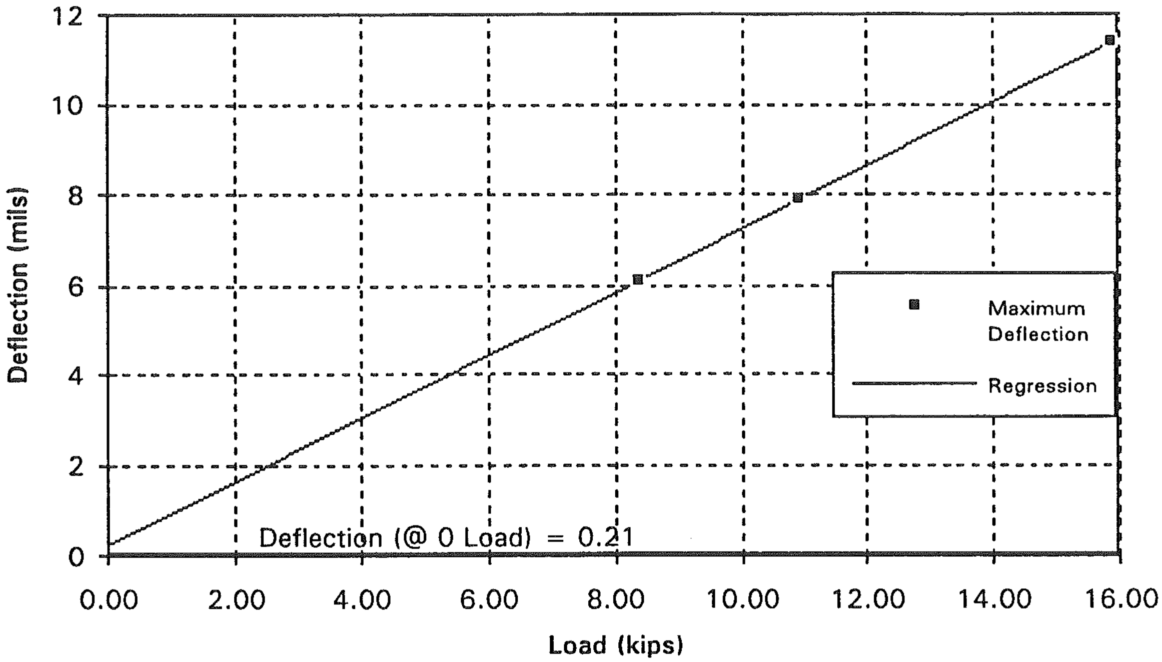
Joint: 15C - Sealant Type : Allied Koch 9005



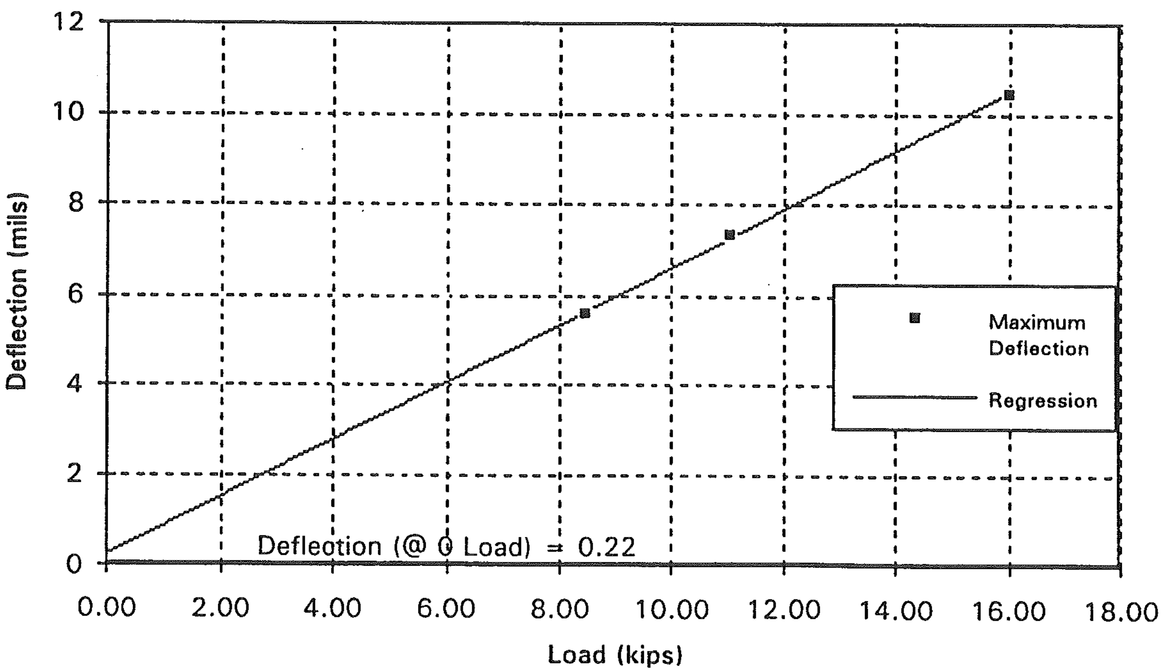
Joint: 15D - Sealant Type : Crafco Roadsaver 231



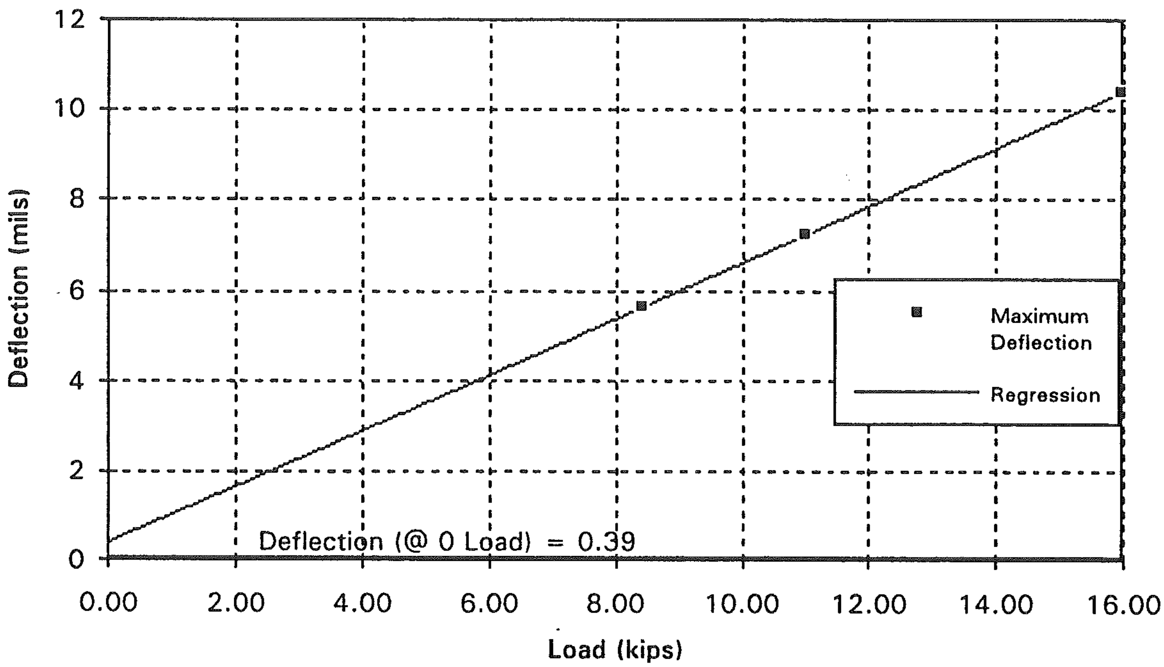
Joint: 15E - Sealant Type : W. R. Meadows Soft-Seal



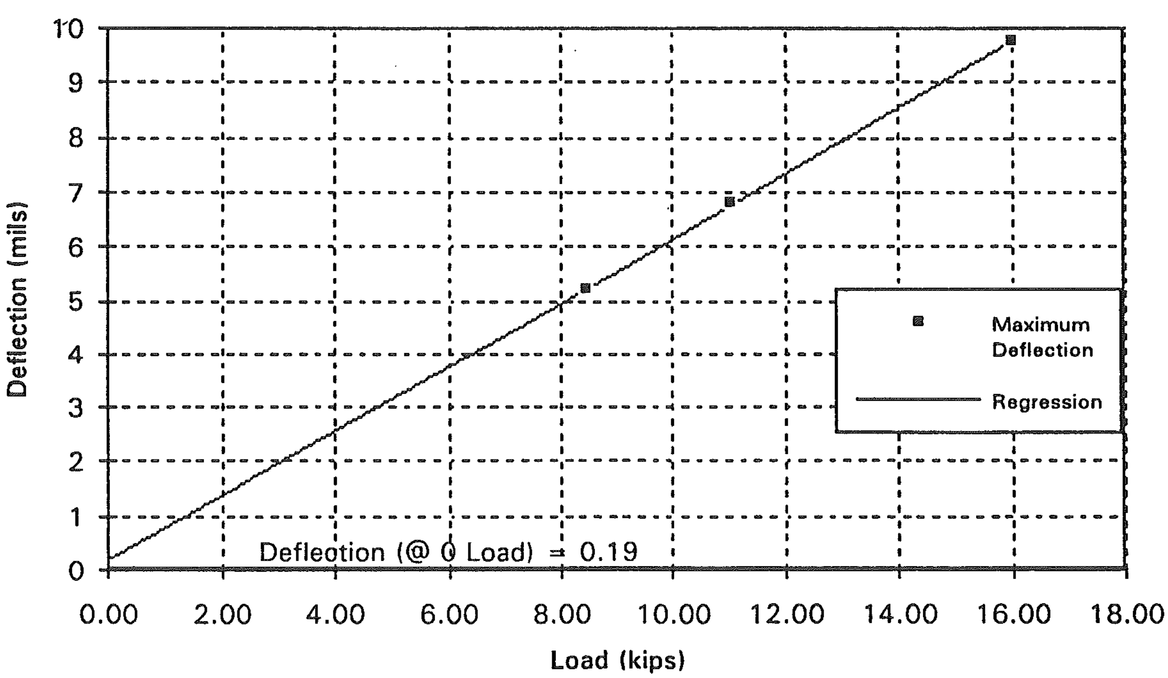
Joint: 16A - Sealant Type : Dow Corning



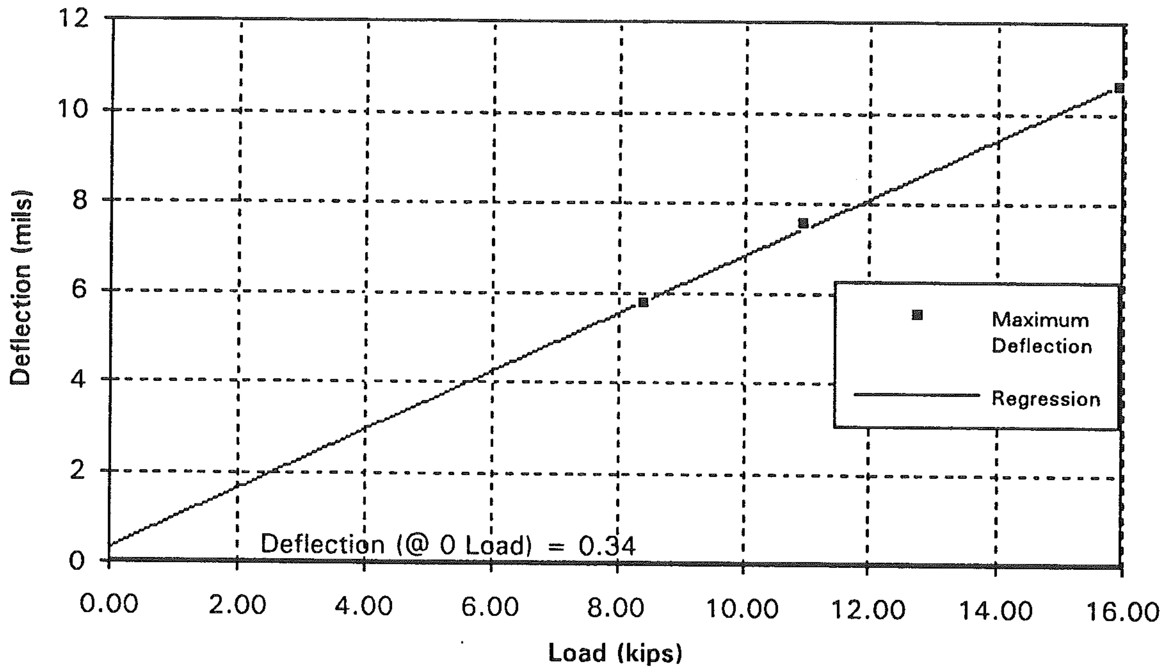
Joint: 16B - Sealant Type : Superseal 888



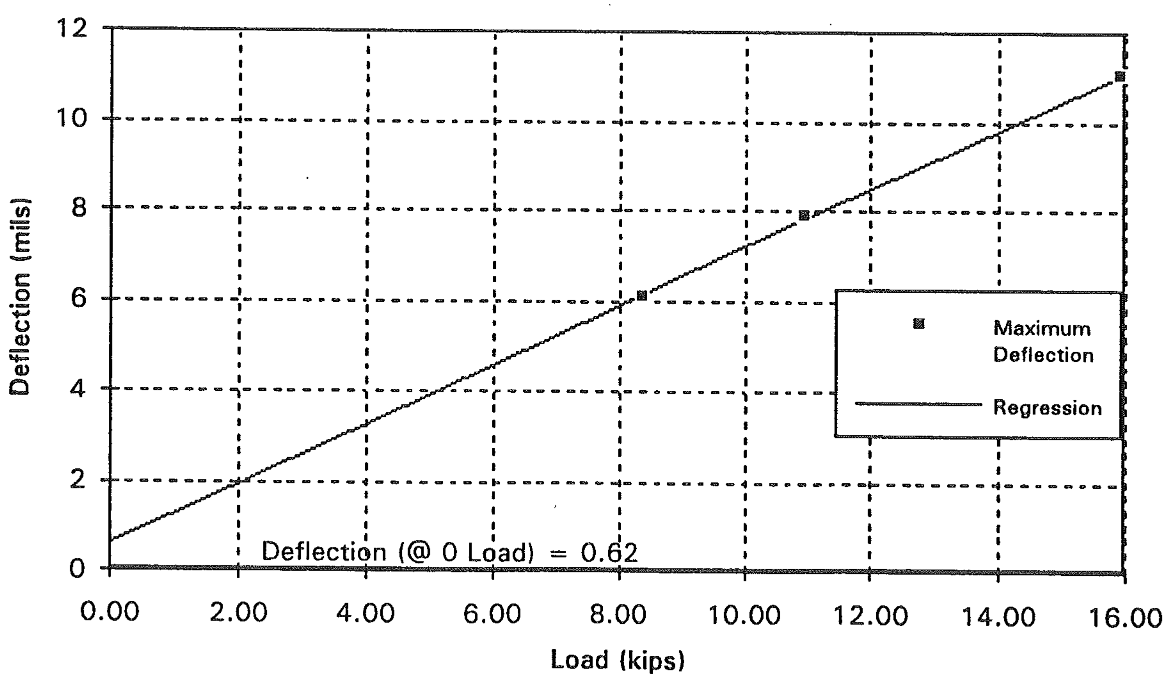
Joint: 16C - Sealant Type : Allied Koch 9005



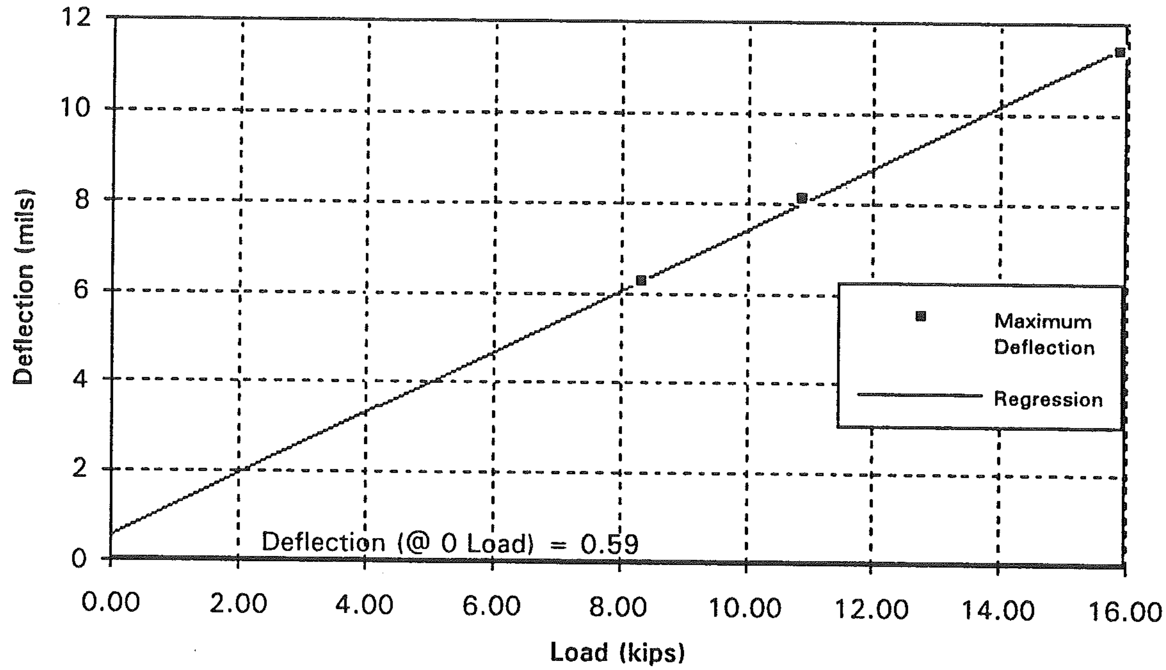
Joint: 16D - Sealant Type : Crafco Roadsaver 231



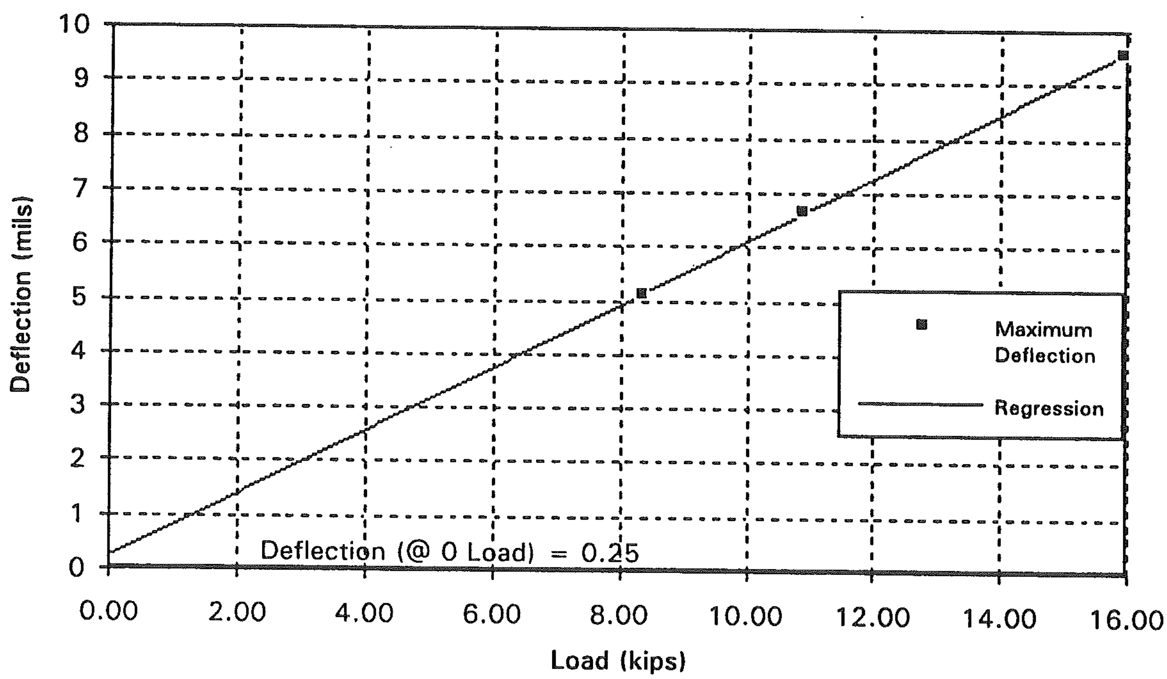
Joint: 16E - Sealant Type : W. R. Meadows Soft-Seal



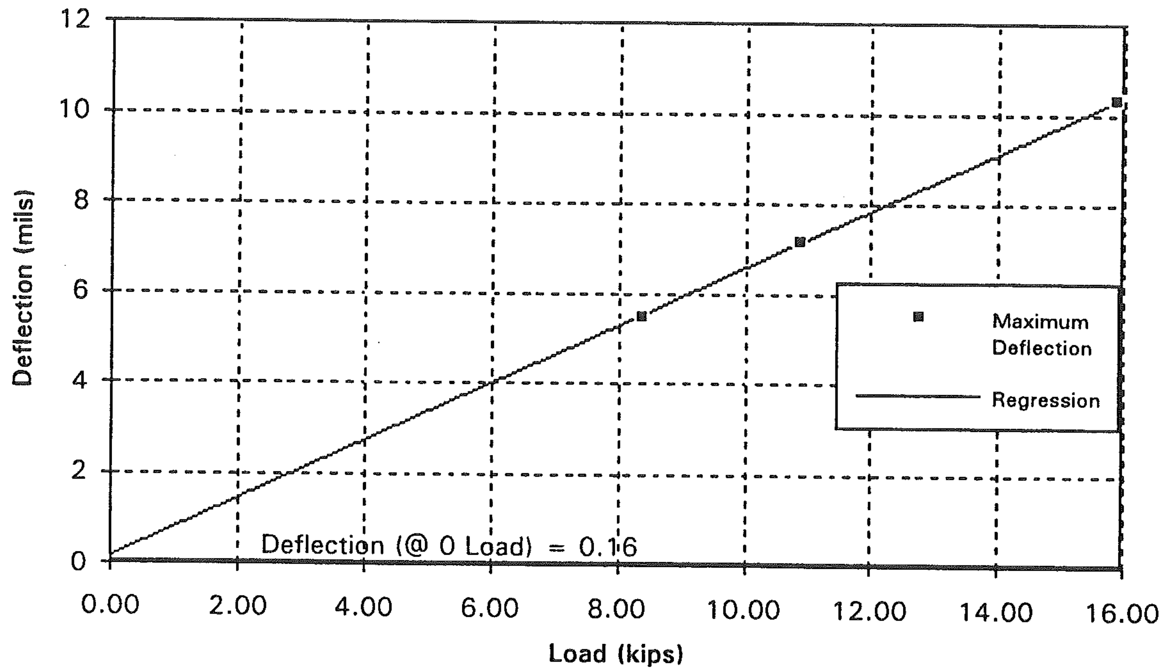
Joint: 17A - Sealant Type : Dow Corning



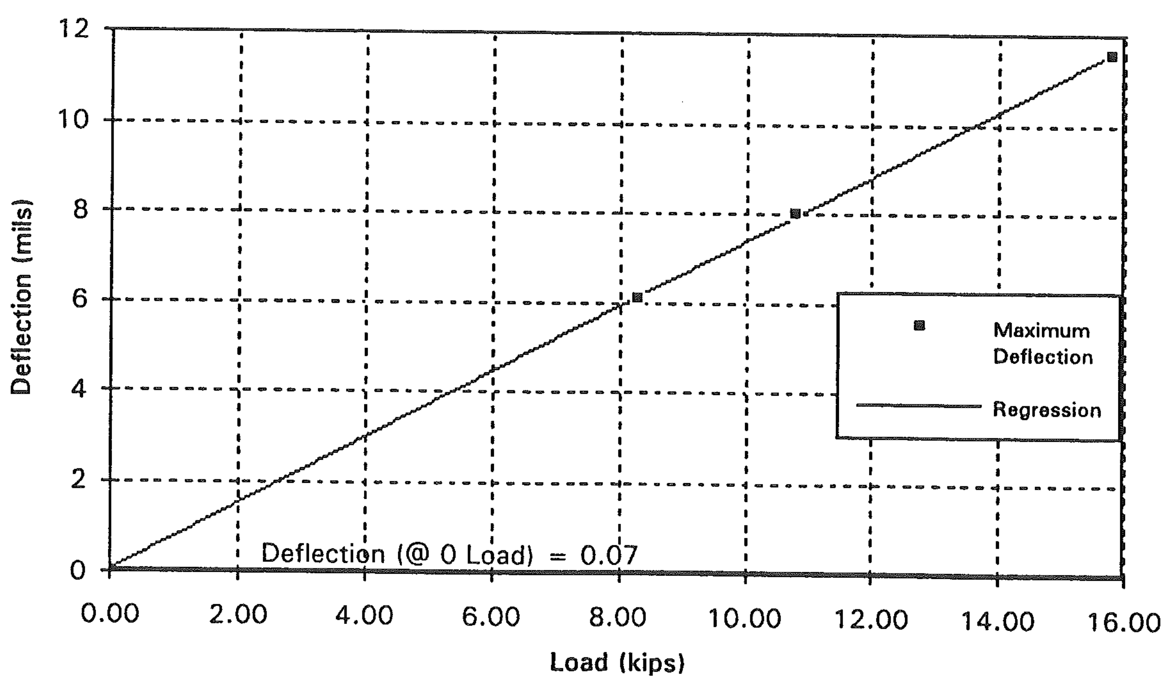
Joint: 17B - Sealant Type : Superseal 888



Joint: 17C - Sealant Type : Allied Koch 9005



Joint: 17D - Sealant Type : Crafco Roadsaver 231



Joint: 17E - Sealant Type : W. R. Meadows Soft-Seal