Innovative Leak Test for Pavement Joint Seals

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Premature failure of concrete pavement contraction joint seals is an ongoing and costly problem for the Iowa Department of Transportation. Several joint seal test sections consisting of variations in sawing methods, joint cleaning techniques, sealant installation, and sealant types have been established over the past few years. Laboratory analysis and field inspections were done as a part of the tests, and core samples were taken for laboratory adhesion pull tests. Such methods often cover specifically small areas and may not expose hidden failures. Some tests are also labor-intensive and destructive, especially that of coring. An innovative, nondestructive, broad coverage joint seal tester that yields quick results has been designed and developed for evaluation of pavement joint seal performance. The Iowa vacuum joint seal tester (IA-VAC) applies a low vacuum above a joint seal that has been spray-covered with a foaming water solution. Any unsealed area or leak that exists along the joint will become quickly and clearly visible by the development of bubbles at the leak point. By analyzing the results from the IA-VAC tests, information on the number and types of leaks can be obtained; such information will help identify the source of the problem and direct efforts toward a solution.

Evaluation of pavement contraction joint seal performance has been under way for many years in search of better seal performance and reduced joint sealant life-cycle costs. A common method of field evaluation is the cold weather visual inspection. As a result of the visual inspection, leaks may sometimes be found by probing, pushing, or pulling the seal with an ice pick or knife. A method previously used to test sealant adhesion is based on taking a 10-cm (4-in.) core from over the sealed joint. The two halves of the core, bonded by the sealant, are then slowly pulled apart. This test method was applied to hot-poured and cold-applied field-molded sealants used in previous research projects. Joint sealant testing through the use of cores is very labor intensive, requires a lot of equipment, and covers a very small area.

A new method of field evaluation of joint sealants has been developed. The Iowa vacuum joint seal tester (IA-VAC) identifies a leaking seal nondestructively within seconds. After the test area is sprayed with a foaming shampoo-water solution, a low vacuum is applied over the area. Any unsealed area of the joint under the test chamber will immediately generate bubbles identifying the leaking or poorly performing sealed area. The IA-VAC test chamber is 122 cm (48 in.) long and 15 cm (6 in.) wide. Once the number and causes of leaks found are analyzed and understood, efforts can be more effectively directed toward finding a solution to the problem of joint sealant failures.

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OBJECTIVE

The objective of this research is to design and develop a low-cost, nondestructive, efficient system for field-testing and evaluating the performance of pavement contraction joint seals.

HISTORY OF FIELD EVALUATION OF PAVEMENT JOINT SEALS

The most common method of determining the performance of pavement contraction joint seals was to make a visual inspection during the coldest season of the year. A visual inspection in a warm season normally results in a better apparent sealant performance rating than would be found when the concrete thermal contraction has occurred. A pointed tool, such as an ice pick, is used to push or pull on the seal to determine its bond to the joint faces. This method was applied to the test section in a previous research project (*1*). A cold-season visual inspection rating was given to each joint in the test section annually for 5 years.

Another method of sealant evaluation is that of coring and performing adhesion pull tests in the laboratory to determine bonding and elongation properties of sealants from random joints within each test section (*2*). The testing temperatures used in the test are −29 and 21°C (−20 and 70°F). Evaluation by coring is labor-intensive and costly, and the results apply specifically to only a 10-cm (4-in.) length of a sealed joint (Figure 1). Coring is also destructive.

Results from the old method of testing (core samples) depend largely on individual judgment and opinion. There is a personal bias in selecting the location for the cores as well as in judging the failure of the sealant bond during laboratory tests. In addition, some of the personnel making the judgments or visual inspections may change over the years when the data are being collected. This makes the development of a quick, efficient, broad-coverage, objective method of field evaluation of joint seals essential. Therefore, out of the need for a better method to evaluate joint seals in the field, IA-VAC was initiated.

DEVELOPMENT OF VACUUM JOINT TESTING

As a result of less-than-satisfactory performance of many pavement contraction joint seals, especially with the high-cost silicone sealants, there was a need to improve evaluations to identify the cause of at least some of the many adhesion failure

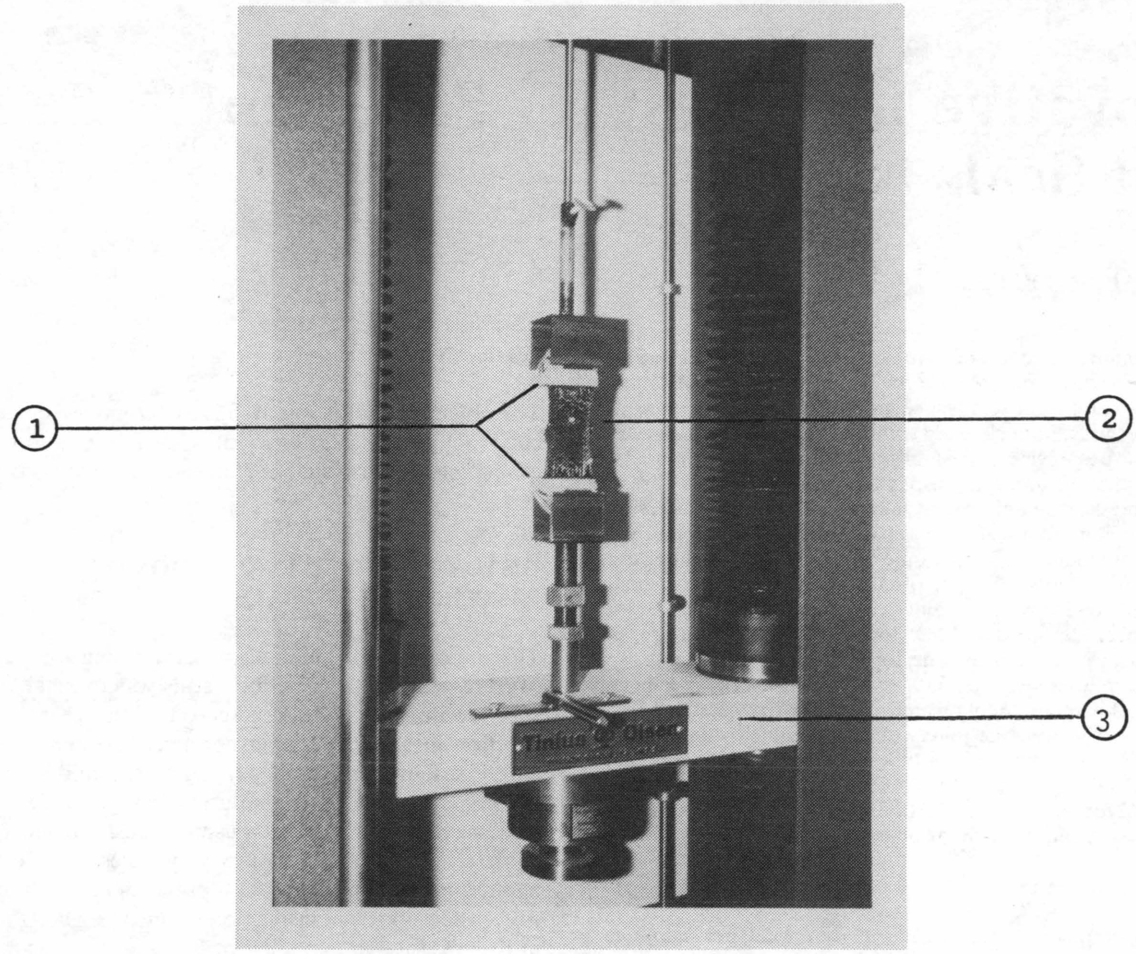

FIGURE 1 Laboratory sealant adhesion test: 1 = core sections, 2 = stretched sealant, 3 = Tinius Olsen testing machine.

problems. In most cases, sealant failures were not discovered until after one or more winter seasons after installation.

It was determined that any new test method should be applicable immediately after seal installation and should be nondestructive. With these conditions it would be possible to include in the evaluation the influence of the seal material as well as quality of the joint sawing, sealing procedures, and construction skills. It was considered essential to develop a good understanding of the sealed joint condition starting from day one. The IA-VAC method of testing applies to the performance of the end product. Test results can reflect problems with the seal material system as well as problems resulting from joint sawing, joint cleaning, backer rod, backer rod installation, sealing operations, and overall training or experience of construction personnel.

Standard tests for laboratory quality control, such as ASTM D3405 for hot-pour sealants, are used for preliminary sealant acceptance.

The development of the IA-VAC project was scheduled in three phases:

1. Developing and testing equipment,
2. Field testing and gathering field data, and
3. Analyzing field results and implementing standard test procedures and specifications.

When this paper was written, Phase 1 had been completed and Phase 2 was well under way.

PHASE 1: DEVELOPING AND TESTING EQUIPMENT

The first vacuum testing chamber built in this project was a metal frame 20 × 25 × 5 cm (8 × 10 × 2 in.) with a Plexiglas top and open bottom. The seal used between the bottom of the chamber and the pavement surface was 3M strip calk (Figure 2).

A second-generation test chamber was a metal frame 15 × 122 × 5 cm (6 × 48 × 2 in.) with a 6-mm (0.25-in.) clear acrylic top and a flanged open bottom. A Dow Corning 888 self-leveling silicone sealant molded into a triangular cross section with 13-mm (0.5-in.) sides was used for sealing between the bottom of the chamber flange and the pavement surface. After preliminary field testing, the seal was changed to a Dow Corning 890 self-leveling silicone molded into a triangular cross section with 19-mm (0.75-in.) sides. The size, shape, and quality of that seal was selected to provide an adequate airtight seal for testing on a variety of pavement surface textures, including those with transverse grooves 3 mm (0.12 in.) wide and 3 mm (0.12 in.) deep. A vacuum line

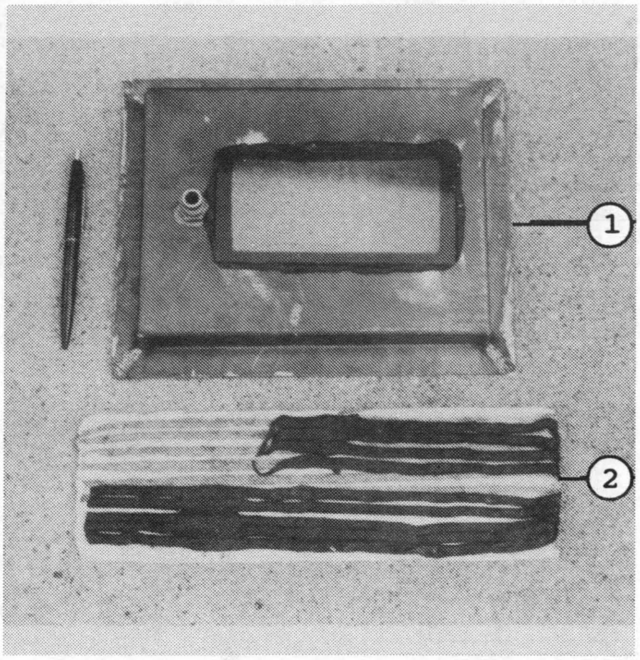

FIGURE 2 First-generation vacuum test chamber: 1 = test chamber, 2 = 3M strip chalk.

supply valve and a release valve were installed on one end of the IA-VAC chamber, and a vacuum gauge was installed on the other end (Figure 3).

A 14-L (0.5-ft^3) vacuum reserve tank was put into the vacuum supply line to help provide sufficient volume for a quick seal onto the pavement. The vacuum line from the reserve tank to the IA-VAC chamber was 6 mm × 3 m (0.25 in. × 10 ft) with quick-release couplings. A schematic of equipment used is shown in Figure 4.

A 246-W (0.33-hp) electric Fisher vacuum pump provided a free air delivery of 128 L/min (4.0 ft^3/min). A portable generator provided the electric power. The foaming shampoo-water solution was sprayed onto the test area and joint seal from an 11-L (3-gal) hand-pressurized sprayer. The sprayer capacity was enough for about 50 test locations.

PHASE 2: FIELD TESTING AND GATHERING FIELD DATA

Field Testing

Field testing was done from a small van. For a high rate of production testing, three people were required. One person drove the van and recorded joint location and test results. Another person sprayed the test area and joint seal with a foaming water solution, and a third person handled the IA-VAC chamber. The vacuum commonly applied for a test was approximately 8 cm (3 in.) of mercury (Hg) or negative 10 kPa (1.5 psi). Test results can usually be determined within seconds after applying the vacuum. About 100 tests can be completed in 1 hr if no time is used for a detailed analysis. The operation could be done by two people at a lower production rate. No personnel were required for traffic control because testing was done on new construction not yet opened to traffic.

In Phase 1, testing was usually on a random basis, on various roadways, selecting sites of special interest for each joint seal. The main objective was to test the design and performance of the equipment. A typical field-testing setup is shown in Figure 5.

The objective of Phase 2 was to develop a large amount of data on various types of sealants and from various sites. Normally, 20 consecutive joints were tested at a particular location, then 20 joints at another location. Identification of the type of leak allows the problem to be better analyzed. Leak test results or failures were recorded by type, such as joint spall, adhesion, cohesion, and bubble. Field-test results are given in Table 1 and Figure 6. It is important to note that all data in Table 1 are taken from new pavement projects and that all testing was done before the project was opened to traffic.

In tests on new seal installations, the leaks that are found are normally very short, that is, less than 13 mm (0.5 in.) long. Tests on older sealed joints showed longer failed sections and went as far as total failure with the seal falling to the bottom of the joint. The essential point here is that short sections of unbonded seals, with time, tend to grow to become long sections. IA-VAC is very sensitive to finding the initial

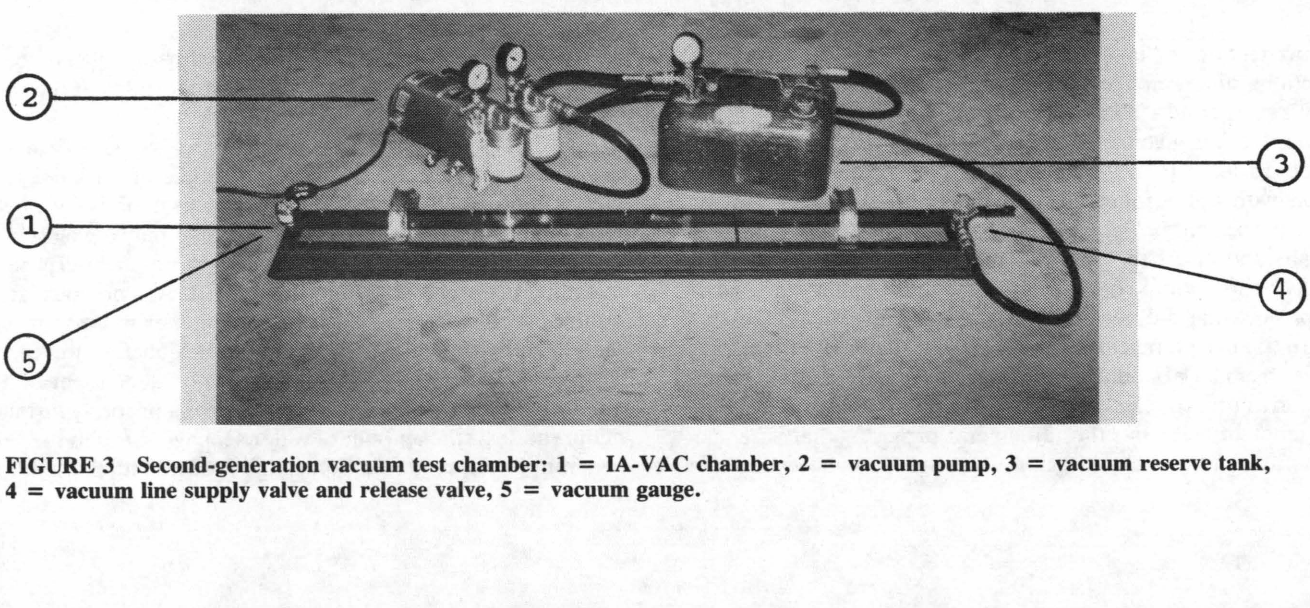

FIGURE 3 Second-generation vacuum test chamber: 1 = IA-VAC chamber, 2 = vacuum pump, 3 = vacuum reserve tank, 4 = vacuum line supply valve and release valve, 5 = vacuum gauge.

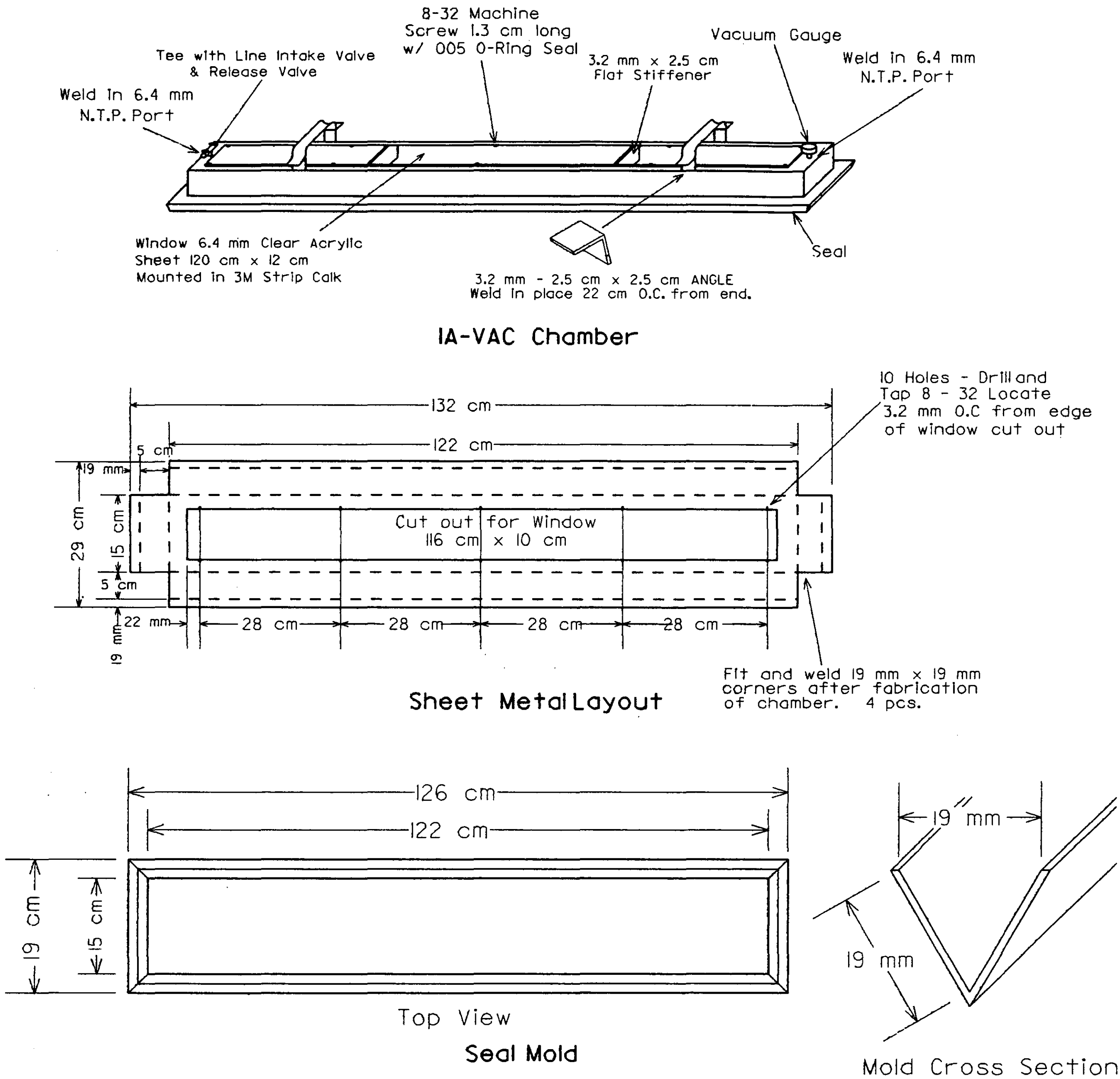

FIGURE 4 IA-VAC chamber schematic.

short sections of failure in new seal installations. Some predictions of seal longevity may be made on the basis of the initial test results obtained from a new project.

The results given in Table 1 show a major difference in the types of leaks found in hot-pour sealant projects in comparison with those found in a silicone sealant project. In the silicone sealant project, basically all of the leaks were through spalls and all of the spalls were at one end of the project. This clearly points to a sawing-related problem at one end of a project that did not exist at the other end.

In the hot-pour sealant projects, essentially all of the leaks were from lack of adhesion. Again, the leaks were sometimes found more concentrated in one area of the project. The absence of leaks in other areas of a project—that is, a successful bond—is encouraging. Through further testing and review of project records, the reasons for the difference in the number of leaking joints at different locations of the same project may become better understood.

Preformed neoprene joint seals (compression seals) are held in place strictly by their compressive force against the joint face. Theoretically, there is no adhesion as there is with field-molded sealants. However, some adhesion may develop from the lubricant adhesive that is used only for the purpose of installing neoprene seals into the joint. It was obvious, from bubbles seen during field tests, that some air passed through the interface of the neoprene seal and the concrete joint face. The amount of air passage appeared to be dependent on the amount of lubricant adhesive applied. For a properly installed neoprene seal, the amount of water seepage through the seal-concrete interface would be negligible. The anticipated ben-

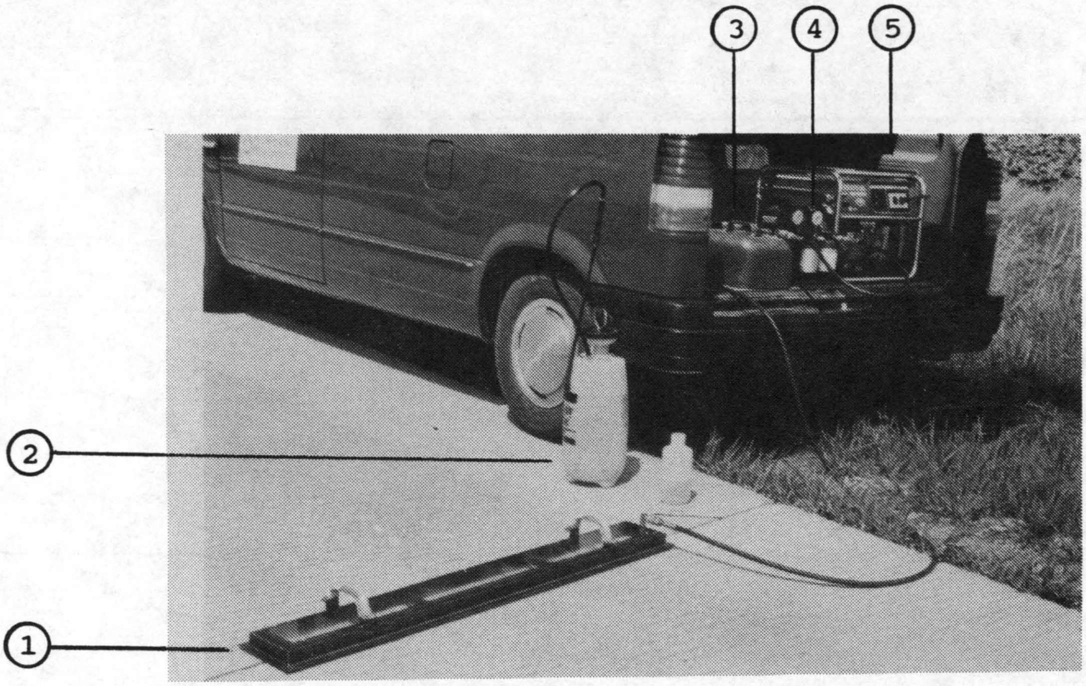

FIGURE 5 Field testing equipment: 1 = IA-VAC chamber, 2 = foaming water solution, 3 = vacuum reserve tank, 4 = vacuum pump, 5 = portable electric generator.

TABLE 1 IA-VAC Results from Field Testing

Test Location	Date of Test	# Joints Tested	Type of Sealant	Vac. kPa	Type of Leak					Total # Leaks
					Spall	Cohesion	Adhesion	Bubble	* Other	
Audubon Co. F-58 SBL	10-91	35	***** HP	10			39			39
Story Co. US 30 WBL	5-92	42	*** N	10	13		4		10	27
Hamilton Co. I-35 SBL	6-92	101	** S	10	27			1		28
Linn Co. US 151 SBL	7-92	49	**** HP	10	1		26		1	28
Boone Co. S. Linn St. NBL	7-92	40	***** HP	10			21			21
Cass Co. I-80 WBL	10-92	80	****** S	10	12		5		3	20

* Other includes pores, sand, and excessive joint width
** Dow Corning 890 Self Leveling Silicone
*** D. S. Brown 17 mm Preformed Neoprene
**** W. R. Meadows Sealtight Hot Pour #3405
***** Koch Hot Pour #9030
****** Crafco RoadSaver Silicone SL

Note: One test covers 122 cm of a joint
1 cm = 0.39 inch
1 kPa = 0.30 inch of Hg
1 kPa = 0.15 psi

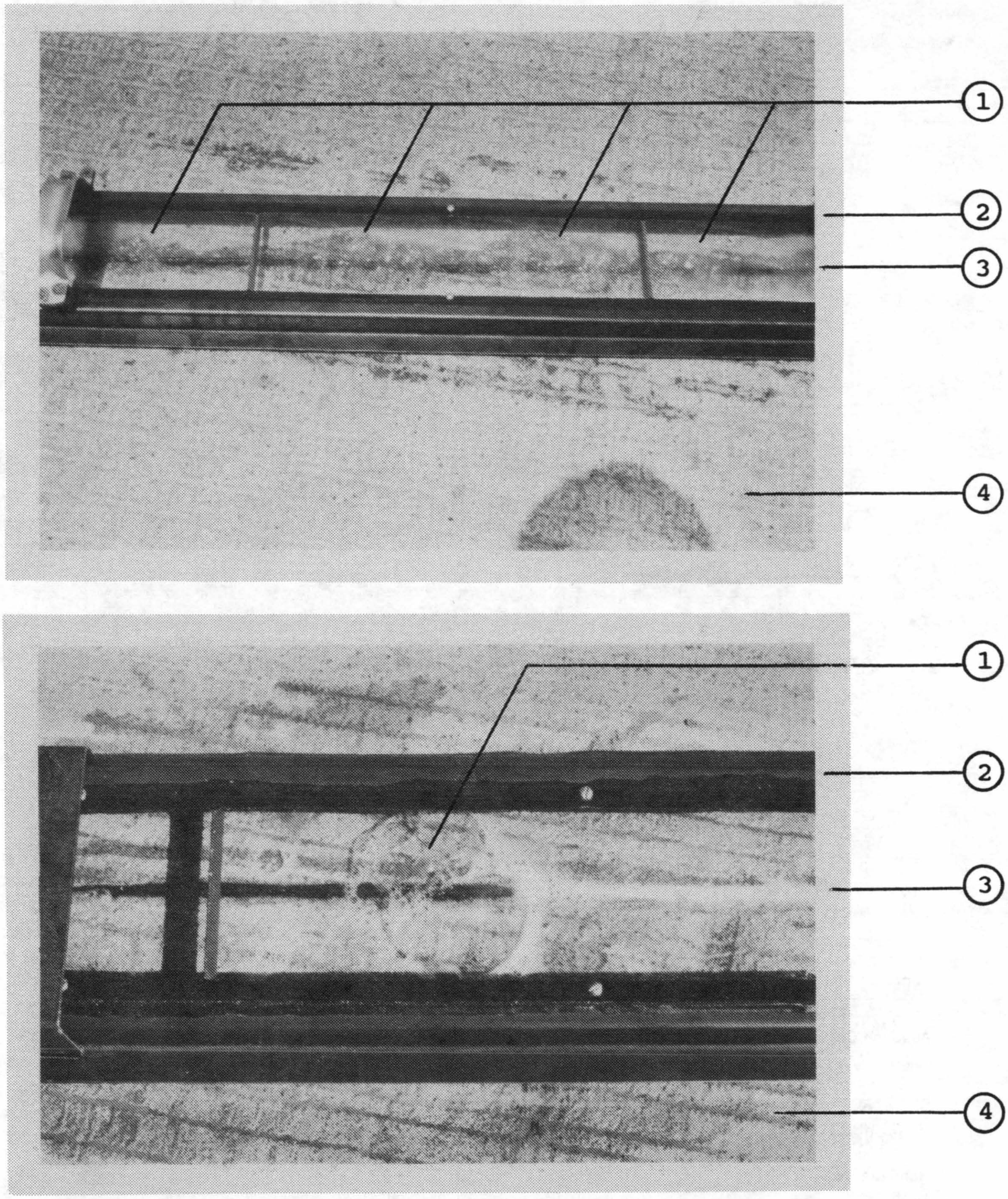

FIGURE 6 IA-VAC test results: 1 = bubbles from sealant leaks, 2 = IA-VAC chamber, 3 = sealed joint, 4 = grooved pavement surface.

efit from the high investment in preformed neoprene seals is their long-term performance.

Observations

The evaluation of test results on the basis of the limited data collected so far has led to several interesting observations. Some of the preliminary observations follow:

- The number of joints with leaks from adhesion failure was sometimes found to be high in one part of a project and low in another part of the same project.
- From results from random field tests, a preformed neoprene joint seal may show more leaks (air passage) initially than a silicone field-molded sealant. The amount of lubricant adhesive used with neoprene seals has a major influence, at least initially, on the amount of air passage.

• Field-test results have shown that the number of leaks due to concrete spalls may be minimal in one area of a project but can change and be significant in another area of the same project. The number of spall leaks appears to be affiliated with joint sawing and could be a function of time of sawing, blade type, operator skills, concrete mix, and so forth.

• Results from field tests have shown that poor quality control in joint sawing can harm the installation of a backer rod and in turn can result in poor joint seal performance if the backer rod is damaged or sheared.

• A very low vacuum, such as 8 cm (3 in.) of Hg or negative 10 kPa (1.5 psi) with IA-VAC, is sufficient to expose joint leaks. Higher levels of vacuum usually only make those existing leaks pass air at a higher rate.

PHASE 3: ANALYZING FIELD RESULTS AND IMPLEMENTING STANDARD TEST PROCEDURES AND SPECIFICATIONS

Implementation

Phase 3 of the IA-VAC project depends on evaluations and results determined in Phase 2. Some possibilities of implementation follow:

• Continue to use IA-VAC as an information-gathering device for research on joint seal performance.

• Continue to use IA-VAC as a postconstruction inspection tool and as a device for identifying problems of poor material or installation practices leading to undesirable seal performance. The observations would be distributed to design and construction departments for their consideration.

• After establishing a specification for sealant performance, on the basis of information obtained in Phase 2, IA-VAC might be used as a construction inspection device. It could be used to confirm compliance with a specification, limiting the maximum amount of leakage.

Benefits from Research

Since the development of IA-VAC and as more test data are accumulated, some of the underlying reasons for leakage along pavement contraction joints are becoming more evident. These reasons can be uniquely different from project to project. From the preliminary work with IA-VAC, some of the reasons for leakage along a joint seal that were observed were not generally expected. From six new projects covering three types of sealing material, the major reasons for leakage were as follows:

• For preformed neoprene seals: variable amount of lubricant adhesive used, and irregular sawed joint width.

• For self-leveling silicone sealant: joint spalls made from sawing.

• For hot-poured rubberized asphalt sealant: poor joint cleaning or no adhesion, and improper installation of backer rod, as a result of bad sawing.

IA-VAC can play an important role in predicting the longevity of pavement joint seals. By doing tests on seals on new construction, information on the initial condition will be obtained. With repeated nondestructive research testing performed annually on the same project, the rate and type of joint seal deterioration can be established over time. From the annual data obtained, joint seal longevity can be predicted.

Another benefit from this research is the improvement in quality of worker performance due to the awareness of the testing ability of IA-VAC. Contractors are very interested in IA-VAC test results and are now more concerned about providing high-quality sealed joints. They are aware that joint seal performance, which includes material and installation quality, can be easily tested by IA-VAC before the project is accepted.

This research project might be considered the first generation of IA-VAC. It is realistic to envision a second generation: an automated version of IA-VAC mounted across the rear of a van. It could be operated by hydraulic or air cylinders using the vehicle weight in assisting IA-VAC to seal onto the pavement and might cover a 2.4-m (8-ft) test span. The same principle of testing could also apply to certain bridge joint seals. Because of the simplicity of IA-VAC, equipment costs should be quite low.

CONCLUSIONS

IA-VAC offers a very sensitive, quick, simple, nondestructive method for testing leakage in pavement joint seals. It can detect many leaks that cannot be found by a visual inspection.

The development and use of IA-VAC brought a major increase in awareness of the problems of pavement contraction joint seal performance. Test results can be routinely obtained along consecutive joints, covering 122 cm (4 ft), during a period as short as 30 sec/joint.

The equipment cost of IA-VAC and accessories, excluding vehicle and portable generator, is less than $1,000.

RECOMMENDATIONS

It is recommended to continue IA-VAC testing to develop a sound data base of joint seal performance in Iowa. On specific projects or sites, testing should be repeated each year to determine the rate and type of deterioration. Contractors should be informed of testing techniques and results to assist them in their efforts toward improvements in joint seal performance. After completing Phase 2, consideration should be given to using IA-VAC in Phase 3 as an inspection device to ensure compliance with a joint seal performance specification.

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