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16. Abstract

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RAPID REPAIR OF WET ASPHALT
USING COMMERCIAL MIXTURES

by

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Research Report Number 359-1

Rapid Repair of Wet Asphalt
Research Project 3-18-83-359

conducted for

Texas State Department of Highways
and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

May 1985

PREFACE

This report describes methods studied to effect the repair of potholes in asphalt concrete pavements during cold and wet weather.

The authors wish to thank the members of the Advisory Panel from the Texas State Department of Highways and Public Transportation: Larry Butler, Darren Hazlett, Gary Graham, and Joe Duran.

David Whitney, Jim Anagnos, Pat Hardeman, and Eugene Betts were instrumental in the laboratory and field evaluations and their assistance is greatly appreciated, as is the assistance of Lyn Gabbert and Rachel Hinshaw, who typed the drafts of this manuscript, and Ahlam Barakat and Michele Mason Sewell, who prepared all the figures.

LIST OF REPORTS

Research Report 359-1, "Rapid Repair of Wet Asphalt Using Commercial Mixtures," by Brian Osterndorf, Alvin H. Meyer, and David W. Fowler, presents the results of laboratory and field evaluations of three commercially available pothole repair materials for use in inclement weather.

ABSTRACT

Based on a survey of the districts, three commercially available, prepackaged pothole repair materials were selected for a series of field and laboratory tests.

The laboratory tests included a modified Marshall Stability test, an indirect tensile test, and a shear bond strength test. Specimens were exposed to various moisture and temperature environments, including dry-freeze cycling. The laboratory tests were inconclusive in identifying parameters that would predict performance in the field. Recommendations are made that might improve the laboratory testing procedure.

Test repairs were made in four distinct geographical and climatic regions of Texas. All but two of the repairs survived the duration of the project. Hence, no conclusive statements concerning performance can be made. Recommendations are made for documenting the continued performance of the repairs and other repairs made with the materials.

SUMMARY

Conventional asphalt materials used effectively for pothole repairs during warm dry weather have not provided long-term repairs when used in inclement (cold and/or wet) weather. Labor and material costs increase because these potholes have to be continually re-repaired. The increasing user costs and damage to vehicles which also result makw a long-term, economical solution to pothole repair in inclement weather desirable.

Several pre-packaged, commercially manufactured projects are currently available. Three were selected for analysis to determine their potential for repair of potholes in inclement weather. Sylvax U.P.M., Traffix, and Instant Road Repair were evaluated, both in the field and the laboratory, to determine their effectiveness for these types of repairs.

These products were evaluated at four sites which reflect the diversity of climatic conditions in Texas. These climates are typically identified as cold/dry, cold/wet, warm/dry, and warm/wet.

While these materials are all asphaltic-based materials, they do not lend themselves to standard asphalt tests. That is, they seem to work even though they often do not satisfy the material requirements specified by standard asphalt tests. Therefore, an attempt was made to develop modified standard tests or new tests to identify some material characteristics that would predict differences in performance.

The relative strength of the repair material and the material's ability to bond with the surrounding pavement were identified by the districts as the most important characteristics of a repair material. The relative strength was evaluated in terms of a modified Marshall Stability Test, and a test was developed to evaluate bond effectiveness. Both laboratory evaluations were conducted under conditions that attempted to simulate the presence of water and of freeze-thaw conditions. The results of the laboratory tests were inconclusive in predicting the performance of the repair materials.

Of the 23 repairs made in the field, 21 remained in service at the conclusion of this study.

IMPLEMENTATION STATEMENT

While the laboratory phase failed to produce tests that conclusively predict field performance, the field tests did demonstrate that these materials work under the conditions stated and should be considered among alternatives for pothole repairs in inclement weather.

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CHAPTER 1. INTRODUCTION

THE POTHOLE PROBLEM

Travelling the highways and roads of Texas, one invariably confronts a jarring reality -- potholes. Several factors have exacerbated the problem drastically. The phenomenal population growth in many parts of Texas has subjected the road system to traffic for which it was never designed, both in terms of volume and magnitude of the loads. Fatigue failure occurs long before the pavement attains its design life. Also, the unusually harsh winters experienced in Texas the past couple of years have aggravated the situation. The cold temperatures stiffen the asphalt concrete, making it more susceptible to cracking. More significantly, the presence of water in the base material supporting the surface layer weakens the supporting soil. As the pavement flexes under traffic loads, failures in the form of potholes occur at the weakest points.

It is this combination of traffic loads and water that causes potholes. Adequate drainage design and maintenance are instrumental in preventing water from infiltrating the pavement and weakening the base material. However, standing water in drainage ditches, the seepage of water through permeable surface layers, and freezing and thawing of the pavement all allow water to gain access to the base material.

Potholes are more than minor nuisances. They constitute a significant safety problem and cause immeasurable damage to vehicles. Potholes in wet weather are especially hazardous because visibility is reduced and water in the hole "hides" it from the driver.

Repair of potholes is expensive. Material and labor costs can strain budgets for most districts. Making the repairs in the lane adjacent to moving traffic is hazardous, and closing traffic lanes in order to effect the repair inconveniences motorists and increases user costs. Unfortunately, most pothole repairs are temporary, lasting as little as a few weeks or months, and require constant attention.

Scheduling pothole repairs for the summer is the way to insure that the proper repair materials will be available and the repair can take place under the best possible weather conditions. However, pothole incidence increases in the winter, and their repair is most urgent then. Delaying repairs is not practical or often possible.

Typically, district maintenance personnel use cold-mixed asphalt concrete or hot-mixed asphalt concrete that is stockpiled cold to repair potholes during those months in which hot-mix batching facilities cannot be operated because the outside temperature is too low. Although the latter material appears to work better than the former, neither is the ideal solution in that repairs last only a short time. Other repair methods utilizing various materials have had varying degrees of success but have not been comprehensively evaluated on a state-wide basis.

SCOPE

The problem of repairing potholes in asphalt pavements during rainy weather, especially when it is also cold, has not yet been solved by methods currently practiced in Texas. The generally accepted repair method, filling the hole with hot-mix asphalt concrete, cannot be used during the winter, because hot-mix patch plants are not in operation. Moreover, in rainy weather, the hot-mix does not adhere well to the existing pavement. The problems of effecting the repairs with alternative materials, cold-mixed asphalt and hot-mixed asphlat that is stockpiled cold, are discussed in the previous section.

Throughout Texas, various districts of the State Department of Highways and Public Transportation (SDHPT) have tried several alternate methods of repair with mixed results; the most effective methods are prohibitively expensive for wide-scale use. These methods involve the use of pre-packaged, commercially produced materials that have not yet been thoroughly investigated (independently) in the laboratory and have been applied too infrequently in the field for definitive conclusions to be reached about their relative effectiveness.

The Center for Transportation Research of The University of Texas in cooperation with the SDHPT initiated a study to investigate various methods of pothole repair to find a reliable method that can be used in wet weather and provide a reasonable life expectancy at a moderate cost.

Initial efforts involved a literature search for possible alternatives and a survey of the SDHPT districts to determine the methods currently used and their effectiveness. Included in the survey was a questionnaire, the purpose of which was to determine the physical characteristics and properties considered most desirable in a pothole repair material. A copy of the questionnaire and a summary of the results are included in Appendix A.

At this point, two avenues of investigation presented themselves. First, the literature review revealed one very promising repair material, fly ash; and a separate investigation of a solution involving fly ash in a mix by itself or combined with other natural materials (sand, gravel) or synthetic materials (glass or steel fibers) was initiated.

Second, the summary also revealed that several commercially produced products have been used throughout Texas. Three of these products were rated more favorably than others, and it was decided that these products should be investigated under more controlled conditions to determine their relative effectiveness. This report deals exclusively with the latter avenue of investigation. A companion report dealing with the fly ash investigation is being prepared.

CHAPTER 2. MATERIALS

MATERIAL SELECTION

The three commercially produced materials rated most favorably by the SDHPT districts were Sylvax U.P.M., Traffix, and Instant Road Repair. Table 2.1 summarizes the survey results. The three materials were evaluated on a scale of 1 to 5, with a rating of one being the least favorable.

Most of the comments indicated that these materials were easy to use and performed well but were too costly.

The Advisory Committee recommended that Sylvax U.P.M., Traffix, and Instant Road Repair be evaluated in this study.

DESCRIPTIONS

These descriptions of the materials that were evaluated are taken from the literature provided by the manufacturers.

SYLVAX U.P.M., manufactured by the Sylvax Corporation, New York. "The patching material shall be composed of a suitable aggregate, plant-mixed with U.P.M. Liquid Asphalt Blend, from the Sylvax Corporation. The bituminous material shall be capable of coating approved wet aggregates without stripping, and shall be available in various grades so that one such grade will enable a stockpile to remain pliable and workable at a temperature of −15°F (−26°C). The patching material shall be capable of maintaining adhesive qualities in patched areas which are damp or wet at time of application, and also after remaining in an uncovered stockpile for up to 12 months."

TABLE 2.1. MATERIAL EVALUATIONS

	Material		
	Instant Road Repair	Sylvax	Traffix
No. of Responses	7	1	1
Mixing	4.9	5	5
Placing	4.9	5	5
Compaction	4.9	5	5
Appeal to Workers	4.7	5	5
Bond to Existing Pavement	4.7	5	5
Durability	4.6	5	4
Appearance	4.6	5	5
Overall Performance	4.7	5	5
Effect of Hot Temperature	4.0	5	4
Effect of Cold Temperature	4.7	5	4
Effect of Moisture	3.4	5	5
Cost	1.7	2	1

INSTANT ROAD REPAIR, manufactured by Safety Lights Co., Houston. "... A premixed patching material which shall be ready for immediate use without the addition of primers, catalysts or activators of any kind. It shall consist of a liquid adhesive mixed at room temperature, by an approved method, with select aggregate to effect a permanent type repair to concrete, asphalt or masonry pavement surfaces. The patching mix shall have good workability at placement temperatures ranging from 20°F to 140°F (-7° to 60°C) without the addition of heat. It shall have good adhesion to wet surfaces and be resistant to water damage."

TRAFFIX, manufactured by Pace Products, Kansas City. "... A fast, all-weather patch for chuckholes, ruts, etc., in asphalt, brick and cement, with application possible whether area is wet or dry ... carefully selected and graded aggregate, angular in dimensions so interlocking occurs under compaction. The aggregate is coated with a specially formulated asphalt adhesive ... can be used under the most adverse conditions..."

Each manufacturer claims that its repair material is easily applied and that the repaired area could be opened to traffic immediately after the repair is concluded.

All these materials are bituminous based mixtures. The Sylvax has a blacker, slicker, shinier appearance than the other two. All are black or very dark brown in color. The Instant Road Repair has a coarser appearance and does not flow as well as the Sylvax and Traffix. After placement the materials look very similar, particularly from a distance. The surface of the Instant Road Repair has a duller appearance and looks more open than the others.

COSTS

Quantities of the three materials were purchased for the testing. Due to the small quantities required, the products were purchased in 5-gallon pails. Large scale use of these materials would require purchases of larger unit quantities for ease of storage/stockpile and would reduce unit costs. Table 2.2 presents price and quantity information current as of February 14, 1985.

GRADATION OF AGGREGATES

The SDHPT is currently developing a specification for repair materials and is interested in how closely the aggregate gradations used in these three materials coincide with their specification.

A sieve analysis of a sample of each of the materials was performed. Two samples of each product were tested. Results are presented in Table 2.3.

These results are presented on gradation charts in which the sieve sizes are raised to the 0.45 power (Figs 2.1 - 2.3). A perfectly well-graded mixture would graph on a straight line between the lower left and upper right corners of the chart.

The results show that Sylvax and Traffix have almost identical gradations of aggregate, while Instant Road Repair uses a somewhat coarser mix.

SHELF-LIFE OF MATERIALS

No actual tests of shelf-life characteristics of the materials were performed. The manufacturers claim indefinite storage life for the materials in an airtight (unopened) container.

Sylvax and Instant Road Repair claim the effectiveness of material is retained for up to one year when purchased in bulk and stored in stockpile. However, during field tests conducted in cold temperatures, as explained in Chapter 3, Instant Road Repair was unworkable until heated. Instant Road Repair stored in stockpile had a tendency to stiffen upon exposure to cold temperatures (below 40°F, 4°C). Sylvax remained workable at temperatures between 35° and 40°F (2°-4°C). Effects of colder temperatures on the workability of Sylvax were not determined.

Traffix is not sold in bulk quantities.

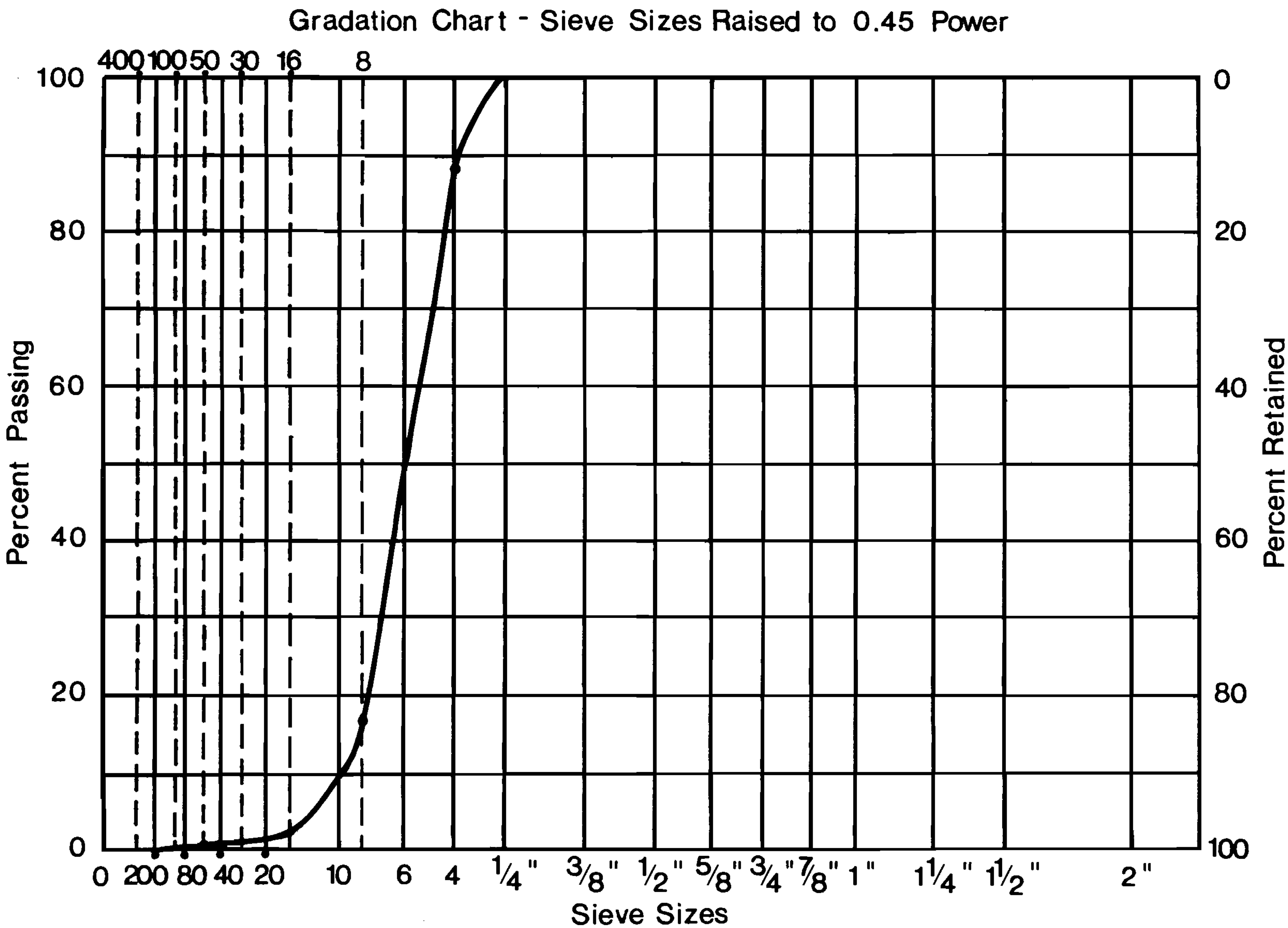

Fig 2.1. Gradation Chart for Sylvax.

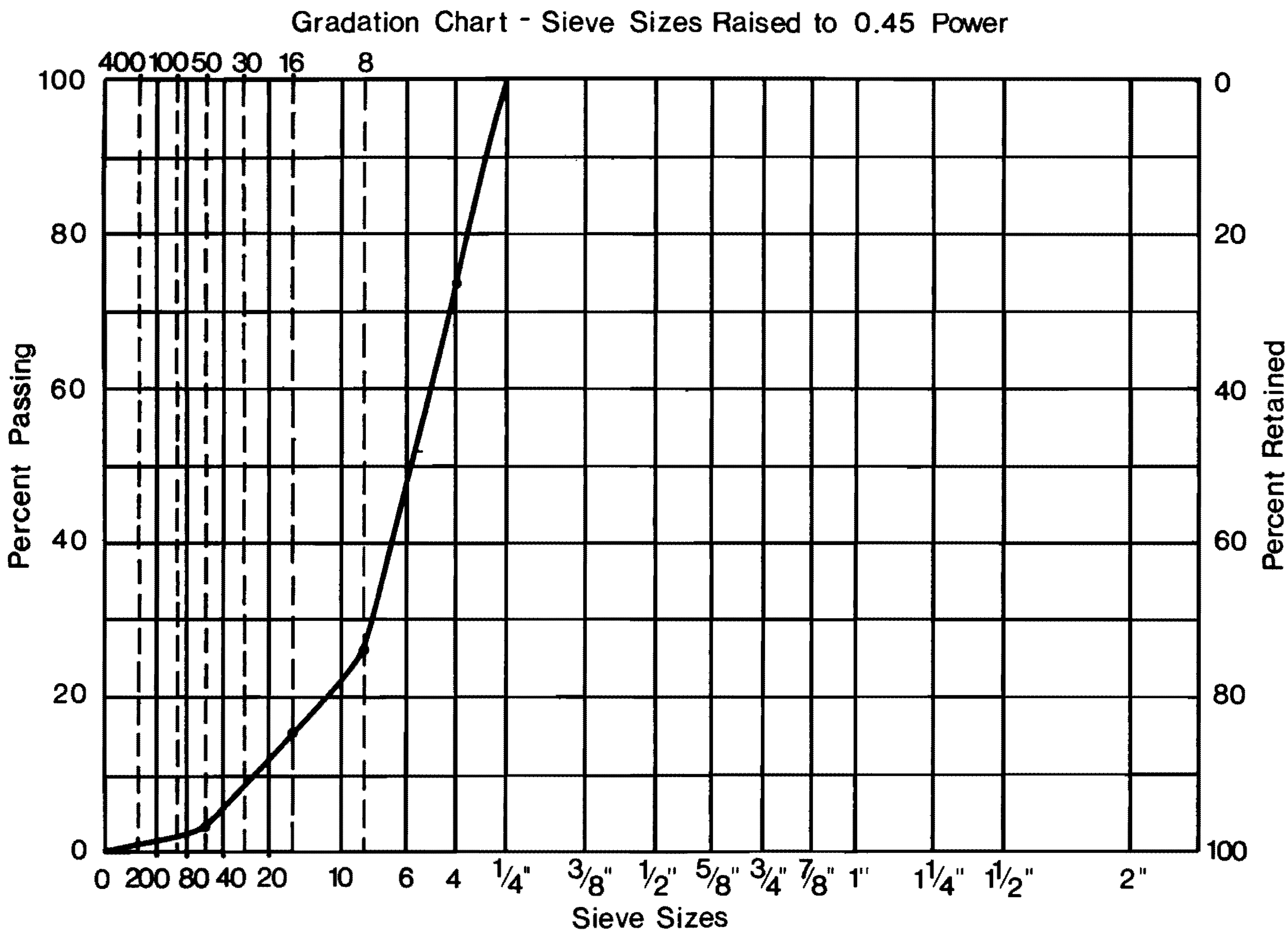

Fig 2.2. Gradation Chart for Instant Road Repair.

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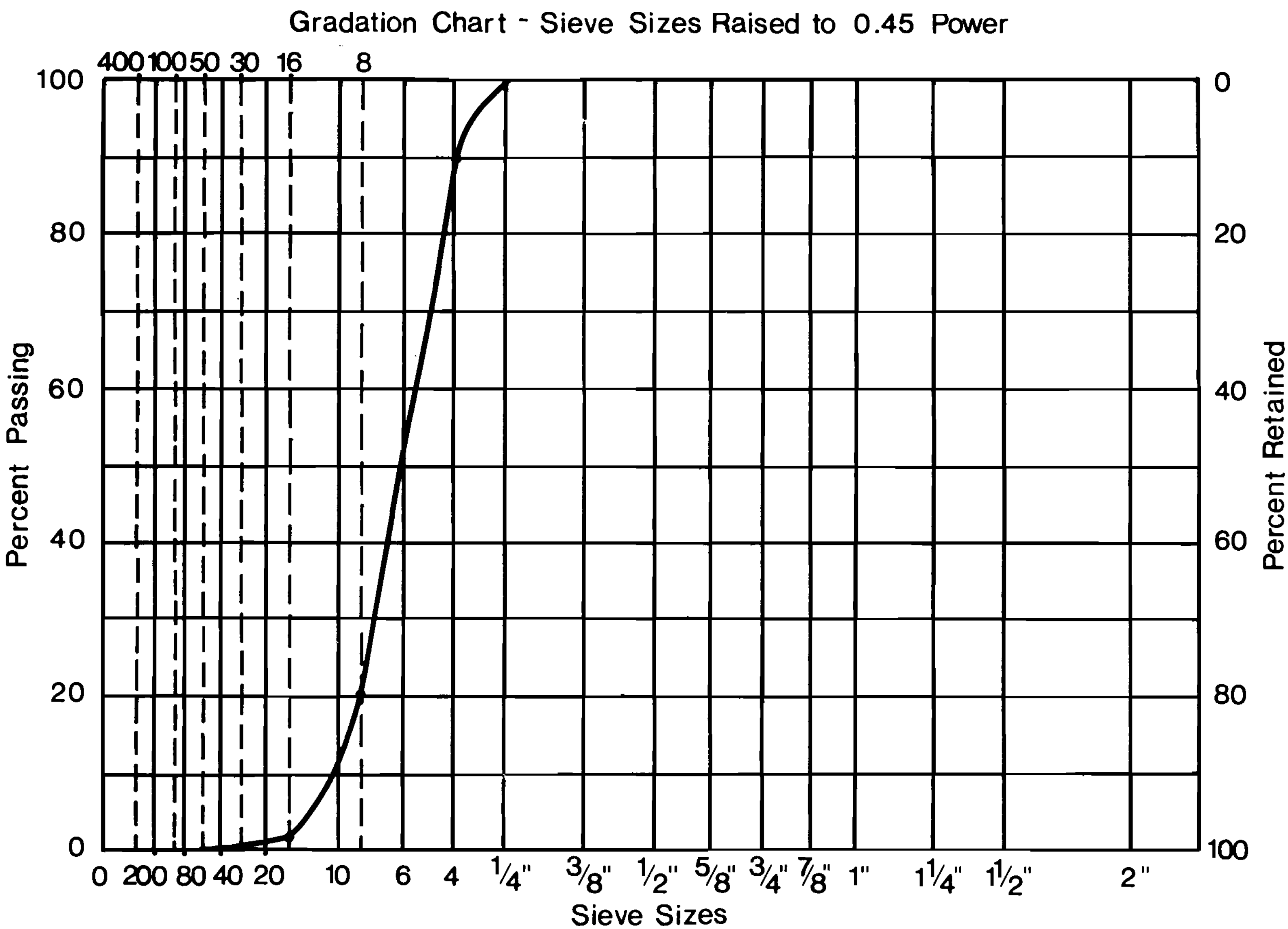


Fig 2.3. Gradation Chart for Traffix.

TABLE 2.2. QUANTITY/PRICE DATA (AS OF FEBRUARY 14, 1985)

Material	Quantity	Bulk Cost	Unit Cost (per lb)
Instant Road Repair	5-gallon (50-lb) pail	Less than 10 pails: $15.00 each	$ .30
Distributor:		10 or more pails: $13.75 each	.28
Safety Lights Co.			
Houston, Texas	55-gallon (667-lb) drum	1-3 drums: $180.00 each	.27
		4 or more drums: $166.75 each	.25
	Bulk -- in hopper		
	FOB at factory		
	2000 lb.		.25
	6000 lb.		.24
Traffix	5-gallon (50-lb) pail	$45.15 each	.90
Distributor:	55-gallon (approx. 650 lb.) drum	$473.55 each	.73
G. S. Stockton	5 drums	5% discount	.69
Amarillo, Texas	10 drums	10% discount	.66
	20 drums	15% discount	.62
	50 drums	20% discount	.58
Sylvax[1]	55-gallon (675-lb) drum	$ 75.00 each	.11
Distributor:	FOB Cleveland, Ohio		
Whitis Mfg.			
Weatherford, Texas	Bulk: FOB plant in Weatherford, Texas	$ 69.00/ton	.035

[1] Liquid asphalt binder is available separately to districts desiring to use their own aggregates and to do their own batching.

TABLE 2.3. SIEVE ANALYSIS (PERCENT RETAINED)

Sieve Size	Sylvax 1	Sylvax 2	Average	IRR 1	IRR 2	Average	Traffix 1	Traffix 2	Average
#4	11.96	10.59	11.28	26.22	26.20	26.21	9.72	9.15	9.44
#8	71.20	73.01	72.11	47.93	49.04	48.49	69.56	70.87	70.22
#16	15.56	14.99	15.28	10.24	9.40	9.82	18.67	17.93	18.30
#50	1.05	1.08	1.07	12.05	12.07	12.06	1.70	1.72	1.71
#100	0.11	0.13	0.12	2.23	2.13	2.18	0.15	0.11	0.13
pan	0.12	0.20	0.16	1.33	1.16	1.25	0.20	0.23	0.22

CHAPTER 3. FIELD TESTING

PLACEMENT

Sites

The intent of the field testing program was to evaluate the repair materials under actual traffic and climatic conditions. Trips to several locations in Texas were planned so that the various climatic conditions that Texas experiences could be included as test variables in the evaluation. Extremely dry and hot regions of Texas (southwest Texas) were not included in the program because of the parameters of the project; a material was being sought that performed well in a cold, wet environment. For this reason, field testing was conducted during the winter.

Four sites were chosen in which to conduct the tests. The first installation of test repairs was made in Amarillo. Winter temperatures there are relatively low and the region is relatively dry, although Amarillo did experience several snow storms during the evaluation period. Repair materials were placed on October 25, 1983. Traffic volumes, placement techniques, and other observations are detailed in Appendix B. Only two materials, Instant Road Repair and Sylvax, were evaluated in Amarillo.

The second field installation was made in Lufkin on December 20, 1983. Lufkin is in east Texas, and, although it experiences only moderate temperature extremes, it does receive fairly heavy annual precipitation. All three materials were placed. See Appendix B for a detailed description of the procedures used.

A third set of test repairs was made in San Angelo, in west Texas. All three materials were placed on January 6, 1984. San Angelo has a dry climate and moderate temperatures.

The final series of test repairs was made in New Boston, in the northeast corner of Texas. Annual precipitation is relatively high and temperatures are slightly lower than in Lufkin. The materials were placed on February 17, 1984.

Method of Placement

The method of application of each product was identical for each test site, with the exception of the distinction between "wet" and "dry" holes.

It did not actually rain any of the days on which repairs were made, so the repair materials were placed in dry potholes and in potholes into which water had been poured to a depth of about one-half inch (1.25 cm). The sides of the potholes were also wet. Excess, standing water was then broomed out of the "wet" potholes, leaving their surfaces wet. The repair materials were placed immediately afterwards, while the hole was still wet.

It can be reasonably argued that this "wet" pothole did not represent the saturated condition that would develop in the pavement if the water were left standing and the entire pavement exposed to water for several hours or days. However, the presence of water does not typically impede the placement or compaction process but has the most significant influence on the bonding of the new material to the existing pavement. Prevention of bonding requires only a film of water and hence the method used to wet the pothole was deemed adequate for the purpose.

Manufacturers' recommendations for application are quite similar and were followed as much as was practical. Specific hole preparation methods and methods of placement are detailed in Appendix B, but the general method of placement was quite simple.

It should be understood that no material can overcome poor repair techniques. Whenever practical, the well documented, proven techniques for repair should be used. However, in this project we attempted to use the techniques that would most likely be used in inclement conditions.

The procedure involved "squaring off" the damaged area into a rectangularly shaped hole, cleaning loose debris out of the hole, placing the material in one or more lifts, and compacting. Striking the repaired area with the back of a shovel provided sufficient compaction to allow for the passage of a truck. A 2-1/2 ton dump truck (unloaded) was then driven over the repaired area 10 to 15 times before the area was opened to traffic.

Enough material was placed in the hole to allow approximately one-half inch (1.25 cm) to remain above the surface of the original pavement before compaction. The passage of the dump truck over the repaired area caused the material to compact to the extent that after, 10 to 15 passes, the level of the repaired area was essentially at grade with the original pavement.

At each test site, the maintenance supervisor of that district was asked to monitor the results during the course of his usual pavement evaluations and inform the CTR of any problems that developed.

RESULTS

General

All of the repair materials performed quite well. As of March 8, 1985, only two of the repaired potholes had failed. In some cases, the repaired areas had outlasted the surrounding original pavements.

However, the field tests failed to establish which is the best repair material. The results do not substantially differentiate between the performances of any of the three materials.

All the products are easy to work with. The placement method described is simple, quick, and, apparently, effective. The packaging of the materials makes them convenient to use. The time required to effect the repairs when traffic lanes had to be closed was minimal.

Workability/Stability

The workability of Instant Road Repair and Traffix decreases as temperatures drop. At temperatures of about 40°F (4°C) and below, these materials, especially Instant Road Repair, stiffen. The stiffness increases to the point that the material is no longer workable. During one of the field trips, heat had to be applied to containers before the materials could even be removed. Additional heat was required before the materials could be placed. Sylvax U.P.M. remained very workable in all the tests.

Storage of these materials, then, may present a problem. A heated storage area would be required for the materials with workability problems during cold periods.

Pothole Size

All of the potholes repaired could be termed moderate in size, falling generally in the range of 4 to 10 square feet (0.38 to 0.95 square meters). The largest area repaired measured 12.3 sq. feet (1.15 sq. meters).

The depths of the potholes were 4 inches (10 cm) in Amarillo and 1-1/2 inches (3.8 cm) at the other field test sites. The method of placement varied slightly in the case of the deeper potholes. The repair materials were placed in two lifts in Amarillo; the first lift was partially compacted by striking the area repeatedly with the back of a shovel.

Pothole size did not influence the field test results. The two failures occurred on repaired potholes that were relatively small. The two potholes measured 4 square feet in area and were 1-1/2 inches deep.

Failures

All of the repairs settled slightly within a month after placement. More precisely, the materials in the potholes underwent further compaction due to the traffic. This further densification caused the level of the repaired area to drop slightly below the level of the surrounding pavement. Settlements were on the order of 1/8 to 1/4 inches (0.31 to 0.62 cm). In no case did the settlement become excessive; that is, although the dips could be perceived from a passenger car travelling over the repaired area, they did not cause discomfort. The repaired areas were judged satisfactory in this regard by the maintenance personnel of the districts in which the repairs were made.

The two failures occurred in San Angelo. They were reported by the district maintenance personnel on May 29, 1984, as having occurred within the week prior to that date. The potholes repaired with Instant Road Repair and Traffix and placed dry "punched out" in the middle of the repaired area. Ths was somewhat surprising in several respects.

First, it was thought that if a failure were to occur, it would be as a result of a failure of the bond between the repair material and the existing pavement, and that the failure would manifest itself along the edges of the repaired area, not the middle.

Second, the weather and traffic conditions associated with the failed potholes were the most favorable of all the conditions associated with the repaired potholes. Temperatures in San Angelo were warmer, and there was less precipitation, than in the other test sites. Traffic conditions were not unlike those for the other sites.

Finally, it was the holes repaired "dry" that failed; holes repaired "wet" with the same materials, under identical traffic and weather conditions, performed well. It had been thought that potholes repaired in the rain without measures taken to completely dry the hole would represent the results of the more adverse conditions.

The failures do not substantiate the conclusion that Sylvax out-performed the other two materials, even though Sylvax did not have any field test failures. There certainly could have been factors, unaccounted for and unrelated to the repair materials themselves, that might have caused failures in these two areas. For example, although in all sites the base material underneath the damaged pavement surfaces appeared to be in good condition, failure in these two cases might have been as a result of the base or subbase having been weaker in these two spots than in the others.

On the other hand, it would not be proper to dismiss these two incidents of failure as statistically insignificant anomalies. These two repairs did not perform as required, for whatever reason, and should be considered in evaluating the effectiveness of the materials. Certainly, test results should not be accepted or rejected based on how well they correspond to a priori performance expectations.

No further failures of any of the potholes appeared at the San Angelo site through August 28, 1984, when the entire site was resurfaced by the SDHPT.

CLIMATIC SUMMARY

The following table, Table 3.1, summarizes the severity of the climatic conditions to which each test site was subjected during the evaluation period. The evaluation period, for purposes of this summary, is from the date of installation at each respective repair site until the end of August 1984. The data are presented in terms of the constraints stipulated in the research problem statement: cold and wet conditions.

The degree to which the site was subjected to cold temperatures is expressed in terms of the number of days in which the ambient temperature dropped below freezing (32°F, 0°C).

The degree to which the site experienced wet conditions is quantified by the number of days on which precipitation occurred at the site and the total amount of precipitation that did occur. No distinction is made between rain, sleet, snow, etc.

SUMMARY OF FIELD TEST RESULTS

No conclusive determinations can be made as a result of the field testing, other than that all three products performed well. Certainly, given the duration of the repairs, all three products are viable alternatives to repair materials currently used.

Table 3.2 presents a summary of the field test results. Photographs depicting the placement method used appear in Appendix C.

A final check, made on March 18, 1985, with the maintenance departments of the districts in which the field tests were conducted revealed that all repairs were intact except for the failures in San Angelo. The maintenance supervisors unanimously felt that all three products have proved to be effective.

TABLE 3.1. CLIMATIC SUMMARY (THROUGH AUGUST 1984)

Site	Installation Date	Number of Freezing Days	Number of Precipitation Days	Total Precipitation (inches)
Amarillo	10/25/83	123	58	13.97
Lufkin	12/20/83	38	65	21.98
San Angelo	1/6/84	34	25	7.76
New Boston	2/17/84	7	41	16.13

Source: Climatological Data, Texas, Natural Oceanic and Atmospheric Administration

TABLE 3.2. FIELD TEST RESULTS: SUMMARY

Site	Date	Materials	Results (3/18/85)
Amarillo	10/25/83	Sylvax UPM IRR	Repairs intact, no signs of any distress, 1/8 - 1/4 inch settlement.
Lufkin	12/20/83	Sylvax UPM IRR Traffix	Repairs intact, no signs of any distress, slight settlements.
San Angelo	1/6/84	Sylvax UPM IRR Traffix	Traffix, dry and IRR, dry, pounded out May 1984, other repairs intact. Resurfaced August 1984.
New Boston	1/17/84	Sylvax UPM IRR Traffix	Repairs intact, no signs of any distress, raveling of old pavement at edges.

CHAPTER 4. LABORATORY TESTING

FORMULATION

Several of the commercially produced products used in pothole repairs do not lend themselves to standard laboratory tests. However, they appear to perform better in the field under certain conditions than do traditional pothole repair materials. The need exists to determine a laboratory test or series of tests that would predict the performance of these materials without having to use a trial and error method in the field. If such laboratory tests could be identified, new products could be better judged prior to their use in the field.

The most difficult aspect of this research project was formulating the laboratory testing program. Although basically bituminous mixtures, these repair materials were unique, not only in terms of the products themselves, but also of the method of application. It was possible that laboratory tests designed to evaluate standard hot-mix asphalt concrete would not be strictly suitable for evaluating these materials. Performance under the climatic conditions specified in the problem statement had to be included in any test method. Finally, laboratory tests had to support field test programs. That is, if field test results identified a particular problem condition or situation, a laboratory test method had to allow for testing under those conditions.

Several considerations guided the formulation of the laboratory program. Tests had to be relatively quick and easy to run. The tests had to be consistent; they had to repeatedly produce the same results, and variability associated with the test method had to be minimal. Laboratory conditions had to simulate conditions under which the materials would actually be used. Finally, the laboratory tests had to "measure" what was important to the evaluation. That is, if a test was to be used to evaluate a material property, the property had to be a property that is fundamentally related to the performance of the material.

This latter consideration led to the choices of the nature of the tests to be conducted. Primarily as a result of a survey sent to the various districts of the SDHPT, two principal characteristics of a repair material were selected as representing how well the material performs. The first was the strength. The material needed to be strong in its own right. It should be able to withstand expected traffic loads. Second, the combination needed to behave as one unit; a repaired area subjected to wheel loads should respond as an integral part of the surrounding pavement. A repaired area that is more or less rigid than the surrounding original pavement will deform differently under the wheel load, accelerating failure along the interface of the two materials. A repair material with poor adhesive qualities, one that does not form a strong bond with the original pavement, is that much more susceptible to failure.

Table 4.1 presents a summary of the characteristics of a repair material that are considered the most important by the SDHPT districts. Appendix A contains a more complete report and analysis of the survey.

The next step in the formulation process was to identify currently accepted test methods, perhaps in modified form, that "measure" one or both of the principal characteristics mentioned above. Several methods are currently practiced by various agencies to determine the strength or stability of a material; Hveem Stability, Marshall Stability, and the Indirect Tensile Test are just a few methods that could be selected. The methods used and results obtained in the determination of material strength are detailed below.

No current test method seemed suitable for determining the effectiveness of the bond between the repair material and the existing pavement. Consequently, a new method was developed to evaluate that bond. The methodology and results of that test are detailed below.

THEORETICAL SPECIFIC GRAVITIES

Prior to performing laboratory evaluations of strength and bond effectiveness, more information about the repair materials was desired.

TABLE 4.1. MOST IMPORTANT CHARACTERISTICS OF MATERIALS TO BE USED FOR WET POTHOLE REPAIR: SUMMARY

		AVERAGE	*SCALED (1-10)
CHARACTERISTICS OF MATERIALS	COST	4.00	3.33
	WORKING TIME	3.15	4.75
	CURING TIME	2.58	5.70
	EASE OF MIX, PLACE, FINISH	3.55	4.08
	PERFORMANCE	1.25	7.92
	COLOR	5.94	0.10
MECHANICAL PROPERTIES	STRENGTH	2.16	6.40
	BOND TO A.C.C.	1.35	7.75
	SHRINKAGE	4.11	3.16
	WEAR RESISTANCE	3.55	4.08
	DUCTILITY	3.85	3.58
	COEFF. OF THERMAL EXP.	5.78	0.37

* $\left[10 - 10/6 \text{ (Ave)}\right]$

The higher the number, the more important the item.

The theoretical specific gravity of each material was obtained by methods specified in ASTM D 2041-78, Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures. The results are shown in Table 4.2.

Additionally, this method was slightly modified by measuring the surface dry weight of the sample and using this value in the denominator of the specific gravity calculation instead of the air dry weight. The results were virtually identical.

PERCENTAGE OF AIR VOIDS

Preparation of specimens for evaluation of strengths required information about the density of the material in place in the field. Attempts to remove cored samples of the repair materials immediately after placement in the field were unsuccessful; the samples fell apart in the core bit. Later attempts, after the material had been in place several months, were similarly unsuccessful.

It was apparent that the field densities of these repair materials were quite low. Consequently, it was considered improper to compact the laboratory specimens with a gyratory compactor that would compact the specimen so that only 3 to 5 percent air voids remained in the specimen.

Instead, a Marshall compactor hammer was used to compact specimens, with 50 blows per side used to simulate moderate vehicle traffic volumes. The degree of compaction would not be the same as when the repair is opened to traffic but is intended to represent the repair after some traffic has further densified the repair material. A description of this method is given in ASTM D1559-82, "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus." However, specimens were made at room temperature.

Specimens were tested to determine the air void content of the repair materials compacted in this manner. The evaluation was conducted according to ASTM D 1188-71, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens," with one modification. Specimens dipped into the paraffin wax fell apart. To prevent this, specimens were frozen for

TABLE 4.2. THEORETICAL SPECIFIC GRAVITIES

Material	G.S. (ASTM 2041)	G.S. (Modified)	Average
Traffix	2.50	2.49	2.49
Sylvax	2.41	2.41	2.41
Instant Road Repair	2.42	2.42	2.42

two days prior to coating with the wax in order to stiffen the specimen sufficiently.

The percentage of air voids and bulk specific gravities for the repair materials compacted with a Marshall drop hammer at room temperature, 50 blows per side, are presented in Table 4.3.

These values are considerably higher than the values for standard hot-mix asphalt cement, but are predictable in view of the looseness of the materials that fell apart in the core bit. This looseness is no doubt due in part to the gradation of the aggregates used in the mixes. The uniformly graded mixtures do not allow for an effective aggregate interlock.

Specimens prepared in the manner described were determined to most closely represent the degree of compaction obtained in field placements of the repair materials.

MODIFIED MARSHALL STABILITY

Initially, two methods were considered for evaluating the strength of the repair materials. However, it became obvious early in the testing process that the two methods yielded similar results -- the hierarchies of relative strengths were the same for both methods -- and it was decided to continue the testing using one method only.

The Indirect Tensile Test and a modified Marshall Stability Test were the two methods initially considered. The methods of preparation of the test specimens were identical for the two tests and were as described above. The specimens were prepared and tested at room temperature because that most nearly simulates how the repair materials are actually utilized; no heat is applied during any stage of the application.

Test specimens were evaluated under three conditions. Specimens were tested after being soaked in water, after having undergone freeze-thaw cycling, and after being cured at room temperature. Time intervals between preparation and testing were varied in order to determine strength gain or loss with time.

TABLE 4.3. PERCENTAGE OF AIR VOIDS AND BULK SPECIFIC GRAVITIES

Material	Percent Air Voids	Bulk Specific Gravity
Traffix	19.7	2.000
Sylvax	18.2	1.980
Instant Road Repair	18.0	1.976

In order to test the effects of water on stability, prepared specimens were allowed to stand for one day at room temperature and were then soaked in a water bath for an additional day before testing. Water in the water bath, at room temperature, completely covered the specimens.

Considerable difficulty was experienced in evaluating Sylvax under these conditions. Sylvax specimens placed in the water bath completely fell apart in a few hours. As a result, Sylvax U.P.M. could not be evaluated under wet conditions.

The responses of materials to cold temperatures were evaluated by subjecting specimens to freeze-thaw cycling immediately after preparation. The freeze portion of the cycle consisted of placing the specimens in a freezer unit where they were cooled by the air temperature (0°F). It was not practical to place the specimens in a freezing medium, such as water, because the Sylvax specimens deteriorated when placed in water. Specimens were allowed to thaw at room temperature. Each material was tested after eleven and twenty-five such cycles. In each case, specimens were left an additional six days at room temperature before testing.

Another problem developed in testing newly prepared Sylvax specimens. These specimens did not have sufficient stiffness to allow them to be placed in the loading apparatus. Sufficient strength for testing purposes did not develop until the specimens had been allowed to cure at room temperature for four days.

Marshall Stability testing was conducted as described in ASTM D 1559. Specimens were loaded at a rate of 2 inches (5 cm) per minute. Marshall Stability and flow were recorded. The results are presented in Tables 4.4 to 4.6. Graphical representations of the data are shown in Figs 4.1 to 4.6.

Stability values presented are corrected for specimen volumes. Only the average values are represented.

In order to compare these results with the more familiar results obtained by testing specimens at 140°F, three specimens of each material were prepared at room temperature and allowed to stand for nine days. Specimens then were placed in an oven and warmed to 140°F (60°C) and tested as before. The results are presented in Table 4.7.

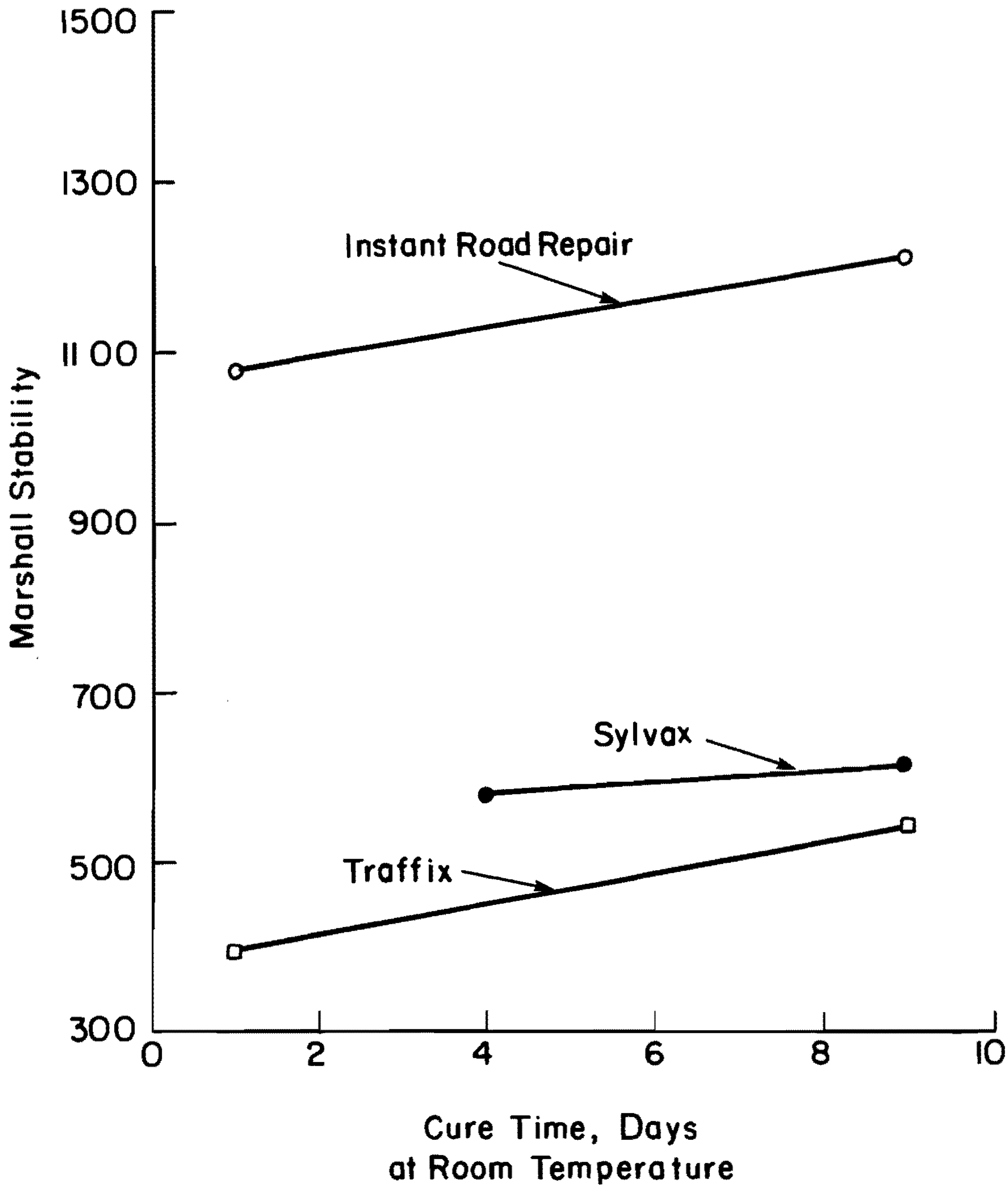


Fig 4.1. Effect of curing time on Modified Marshall stability.

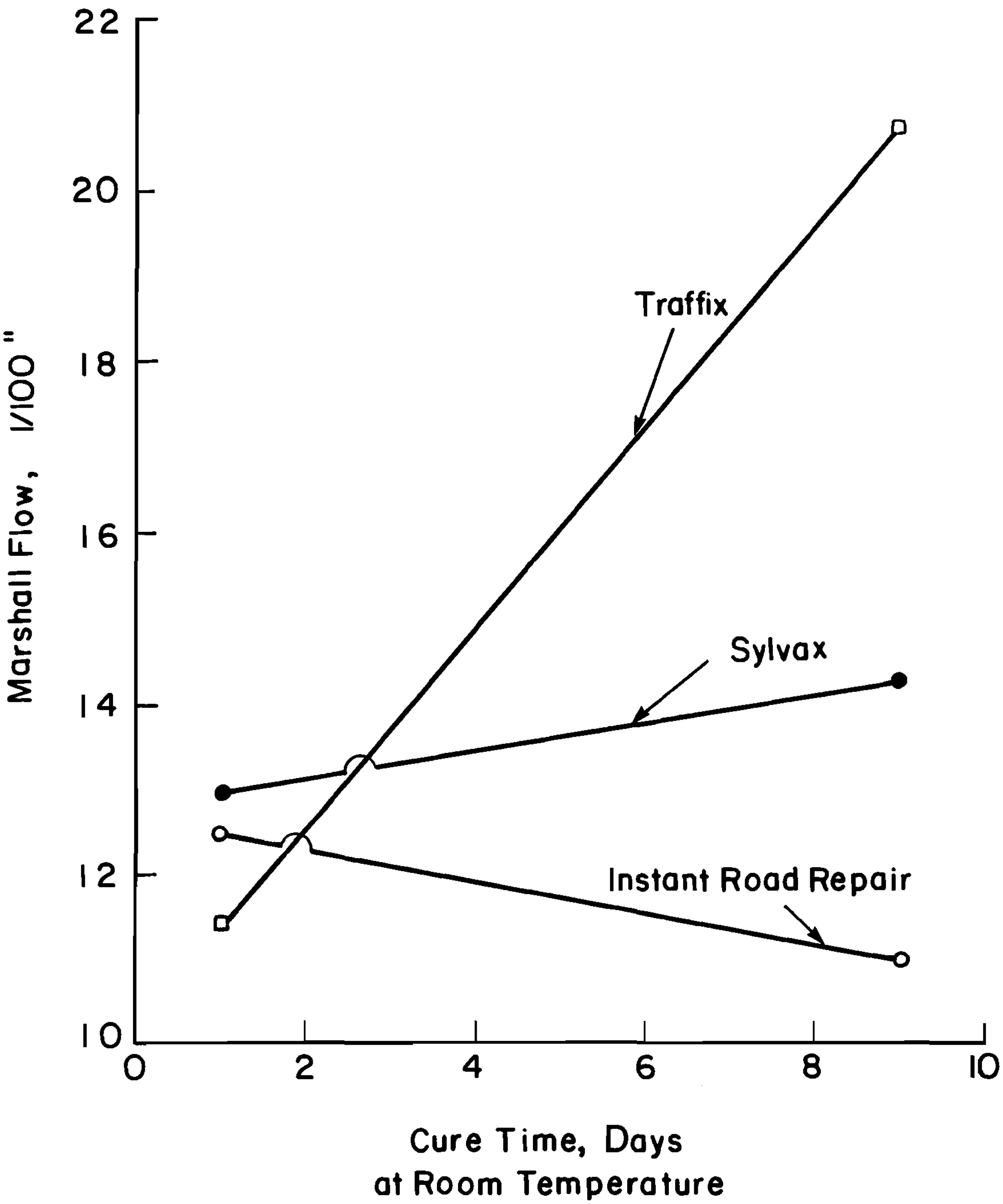


Fig 4.2. Effect of curing time on Modified Marshall flow.

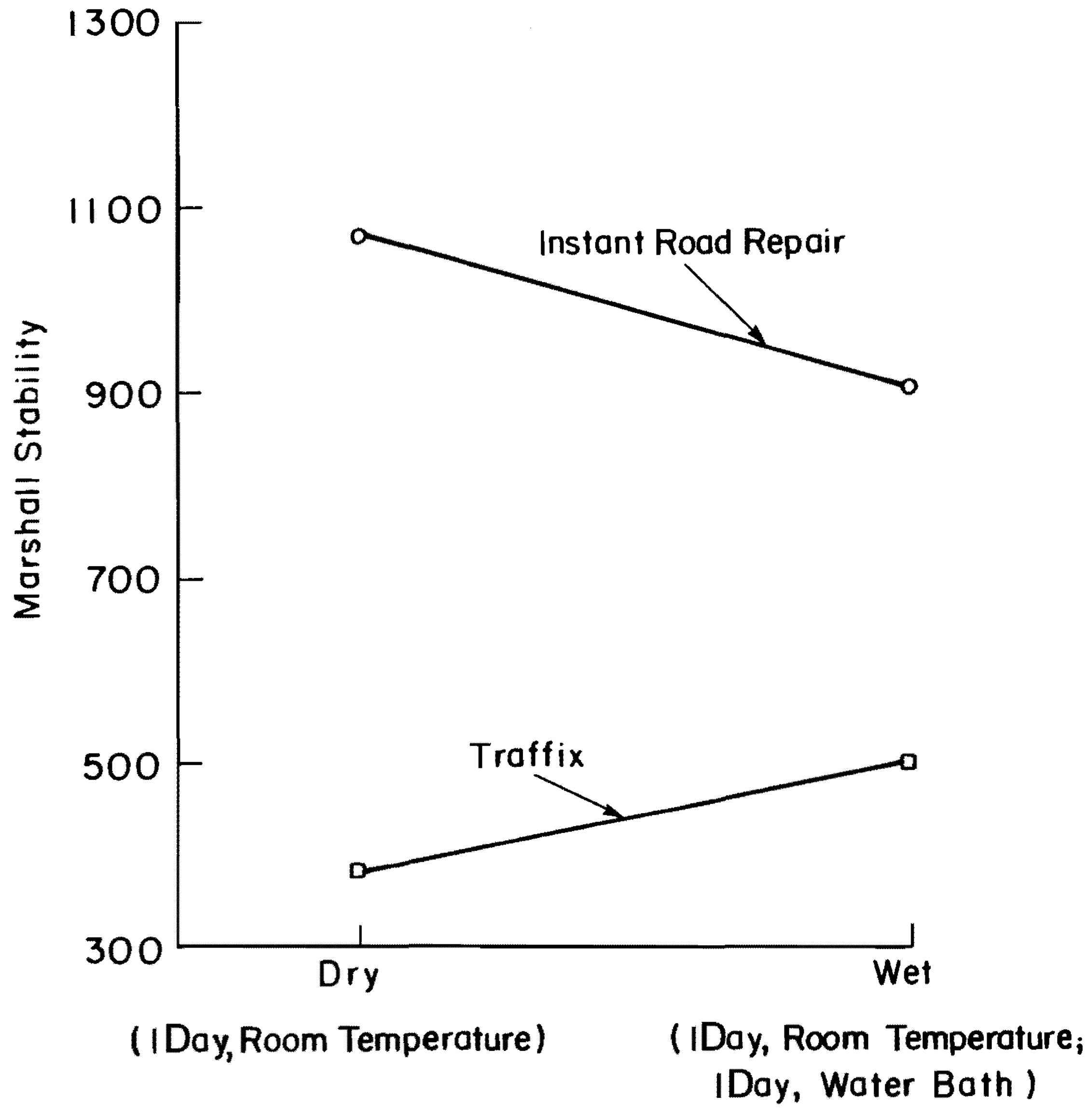


Fig 4.3. Effect of water on Modified Marshall stability.

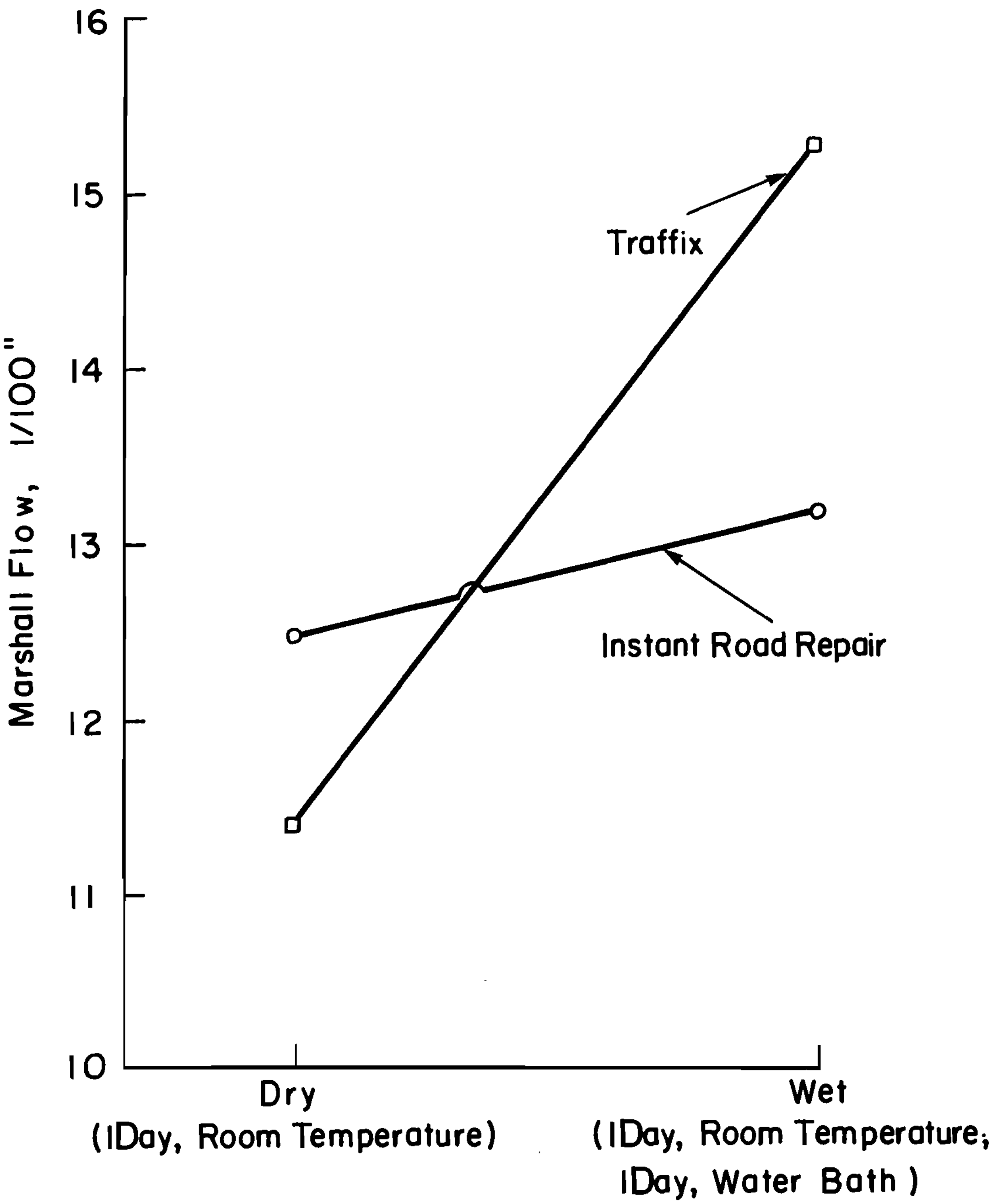


Fig 4.4. Effect of water on Modified Marshall flow.

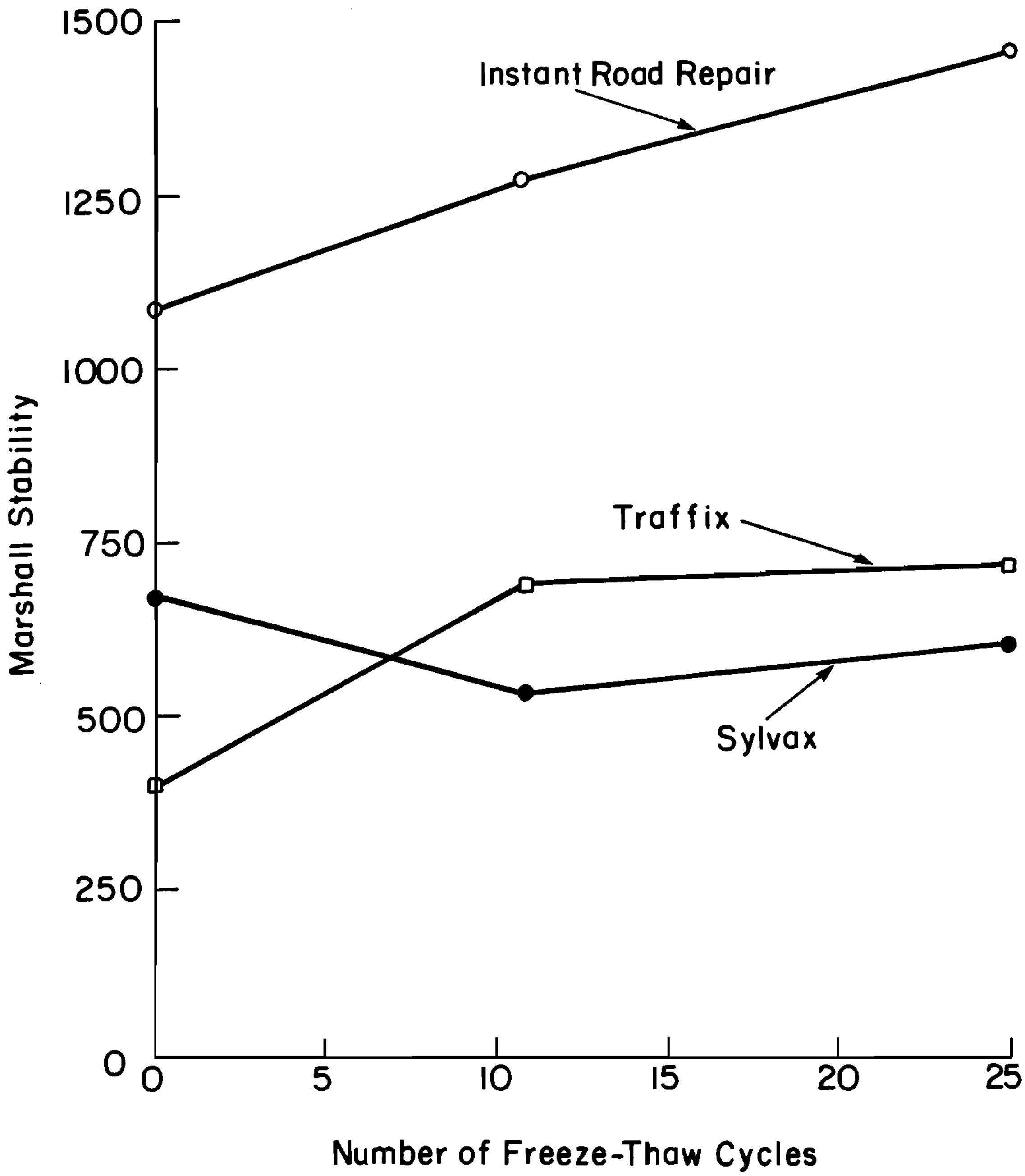


Fig 4.5. Effect of freeze-thaw cycling on Modified Marshall stability.

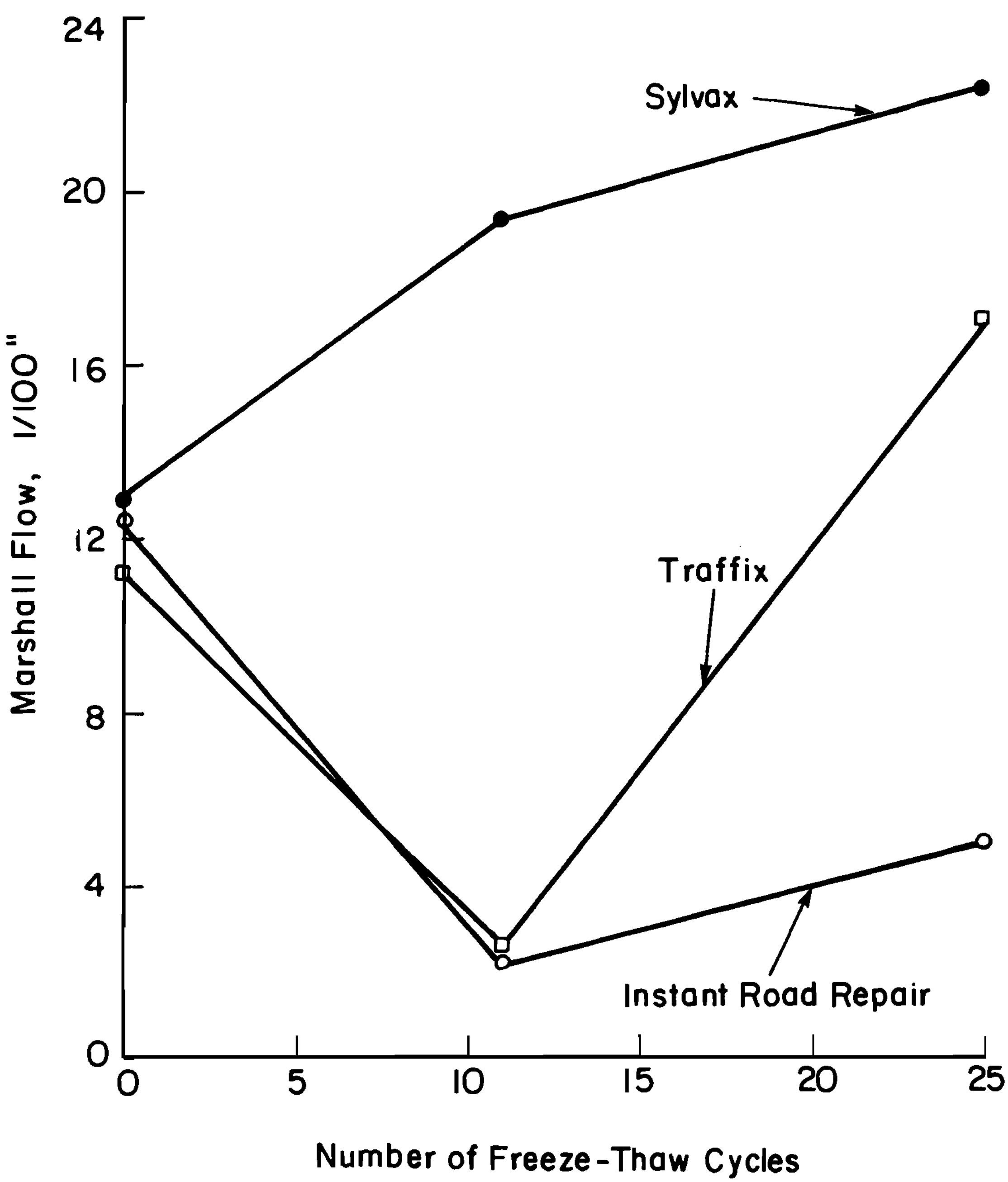


Fig 4.6. Effect of freeze-thaw cycling on Modified Marshall flow.

TABLE 4.4. MODIFIED MARSHALL STABILITIES AND FLOW, TRAFFIX

Specimen No.	Test Condition	Uncorrected Stability	Flow	Average Uncorrected Stability	Average Flow	Average Corrected Stability
T_1	1-Day Cure,	450	10.4			
T_2	Room Temperature	475	11.6	458.3	11.4	394.1
T_3		450	12.2			
T_4	9 Days Cure,	675	22.8			
T_5	Room Temperature	625	21.0	628.3	20.8	540.3
T_6		585	18.6			
T_7	1 Day Cure,	625	17.6			
T_8	Room Temperature,	575	13.4	592.0	15.3	509.1
T_9	1 Day in Water Bath	575	15.0			
T_{10}	11 Freeze-Thaw Cycles,	838	2.2			
T_{11}	6 Days,	862	2.6	787.7	2.6	677.4
T_{12}	Room Temperature	663	3.0			
T_{13}	25 Freeze-Thaw Cycles,	763	24.8			
T_{14}	6 Days,	900	10.4	832.0	17.6	715.5
T_{15}	Room Temperature					

TABLE 4.5. MODIFIED MARSHALL STABILITY AND FLOW, INSTANT ROAD REPAIR

Specimen	Test Condition	Uncorrected Stability	Flow	Uncorrected Average Stability	Average Flow	Average Corrected Stability
R_1	1 Day Cure,	1275.0	13.4			
R_2	Room Temperature	1350.0	12.4	1300.0	12.5	1079.0
R_3		1275.0	11.8			
R_4	9 Days Cure,	1425.0	10.4			
R_5	Room Temperature	1475.0	11.6	1466.7	11.0	1217.4
R_6		1500.0	11.0			
R_7	1 Day Cure,	1150.0	13.2			
R_8	Room Temperature,	925.0	12.9	1091.7	13.2	906.1
R_9	1 Day Water Bath	1200.0	13.6			
R_{10}	11 Freeze-Thaw Cycles	1550.0	2.2			
R_{11}	6 Days,	1512.5	2.2	1525.0	2.2	1265.8
R_{12}	Room Temperature	1512.5	2.2			
R_{13}	25 Freeze-Thaw Cycles	1825.0	5.2			
R_{14}	6 Days,	1625.0	6.0	1733.3	5.1	1438.7
R_{15}	Room Temperature	1750.0	4.0			

TABLE 4.6. MODIFIED MARSHALL STABILITY AND FLOW, SYLVAX

Specimen	Test Condition	Uncorrected Stability	Flow	Uncorrected Average Stability	Average Flow	Average Corrected Stability
S_1	4 Day Cure,	750	13.0			
S_2	Room Temperature	637.5	12.0	675.0	13.0	580.5
S_3		637.5	14.0			
S_4	9 Day Cure,					
S_5	Room Temperature	655	14.0	712.5	14.3	612.8
S_6		765	14.6			
No Data on Sylvax in water -- specimens disintegrated						
S_{10}	11 Freeze-Thaw	600	18.4			
S_{11}	Cycles, 6 Days,	650	20.4	619.3	19.5	532.6
S_{12}	Room Temperature	608	19.6			
S_{13}	25 Freeze-Thaw	712.5	24.0			
S_{14}	Cycles, 6 Days,	700		695.8	22.2	598.4
S_{15}	Room Temperature	675	20.4			

TABLE 4.7. MODIFIED MARSHALL STABILITY AND FLOW OF MATERIALS TESTED AT 140°F (60°C)

Material	Uncorrected Stability	Flow	Average Uncorrected Stability	Average Flow	Average Corrected Stability
Instant Road Repair	1000.0	8.0			
	875.0	6.0	950.0	7.7	788.5
	975.0	9.0			
Traffix	40.0	---			
	30.0	4.8	25.5	5.1	21.9
	6.5	5.4			

Sylvax specimens fell apart when handled at this temperature.

INDIRECT TENSILE TEST

The Indirect Tensile Test was performed on the three repair materials in accordance with ASTM D 4123-82, Method of Indirect Tension Test for Resilient Modulus of Bituminous Mixtures.

Specimens were prepared as described previously. Tests were conducted on specimens allowed to stand at room temperature for four days and on specimens that were placed in a water bath for two days. Soaked Sylvax specimens fell apart in the water bath.

The results are recorded in Tables 4.8 and 4.9. The Sylvax specimens did not exhibit any recordable strength.

The results of the Indirect Tensile Test compared very favorably with the results obtained from the Modified Marshall Stability test. The relative material strengths and the effects of water on the materials were substantially identical. The results are displayed graphically in Fig 4.7.

BOND STRENGTH

The effectiveness of the bond that develops between a repair material and the surrounding pavement can be expressed in terms of the resistance to shearing forces that develop along the interface. The repair material, because it is less stiff (has a lower modulus of elasticity) than the surrounding pavement, which has become even stiffer with age and exposure to sunlight, will experience a greater vertical deformation under wheel loads and recover a greater portion of this deformation. This relative differential vertical motion is resisted by shear forces that develop along the interface of the two materials. An ineffective bond will not allow for the mobilization of sufficient resistance to this differential vertical motion, causing the repair material to "punch out".

The testing apparatus consists of three pieces fabricated of 303 gauge stainless steel. The base plate is a flat circular plate, 2 inches (5 cm) in

TABLE 4.8. INDIRECT TENSILE TEST, TRAFFIX

Specimen	Test Condition	Tensile Strength (lb.)	Average
T_1	4 Days,	41	
T_2	Room Temperature	44	43.0
T_3		44	
T_4	2 Days,	53	
T_5	Room Temperature	53	55.3
T_6	2 Days Water Bath	60	

TABLE 4.9. INDIRECT TENSILE TEST, INSTANT ROAD REPAIR

Specimen	Test Condition	Tensile Strength (lb.)	Average
R_1	4 Days,	126	
R_2	Room Temperature	132	
R_3		122	127.8
R_4		130	
R_5		129	
R_6	2 Days,	100	
R_7	Room Temperature,	88	87.0
R_8	2 Days Water Bath	73	

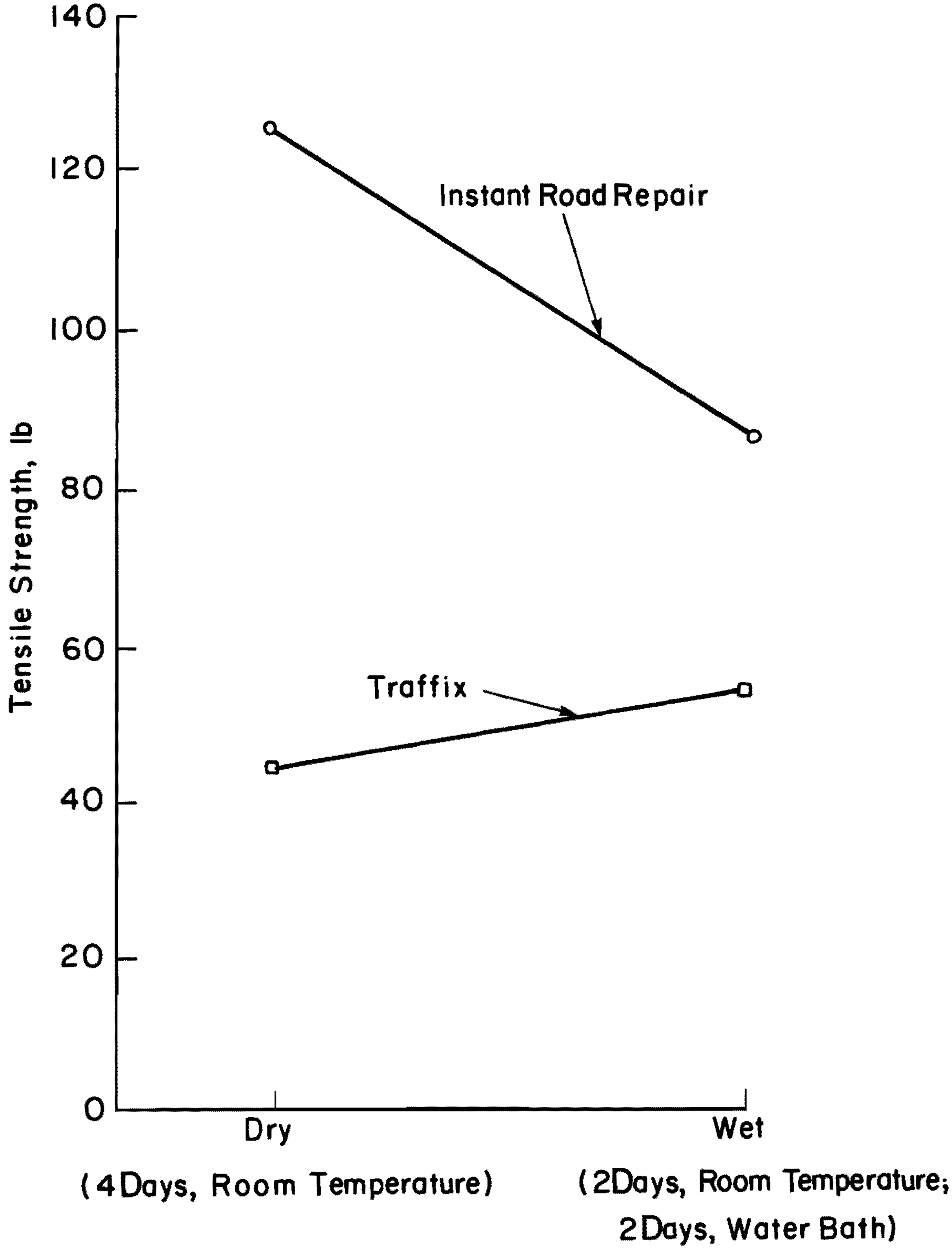


Fig 4.7. Effect of water on tensile strenghts, from indirect tensile test.

diameter, and 1/8 inch (0.32 cm) thick, into the center of which is welded a vertical rod 3/8 inch (0.95 cm) in diameter, and 1-1/2 inches (3.81 cm) long, with a threaded (male) end. The second piece is a solid cylinder, one inch high (2.5 cm) and 2 inches in diameter, through the center of which a 3/8 inch diameter hole has been drilled. The third piece is a rod 3.5 inches (8.8 cm) long and 3/8 inch in diameter, with one threaded (female) end and an end into which a circular eye has been welded. The photographs in Figs 4.8 and 4.9 show the assembled and disassembled apparatus.

Cylindrical specimens of hot-mix asphalt concrete approximately 4 inches (10 cm) in diameter and 2.5 inches (6.3 cm) high were drilled with a 2-inch rock drill, leaving a cavity 2 inches in diameter, and 1-1/8 inches (2.86 cm) deep in the center of the specimen. Figure 4.10 is a photograph of a specimen prepared in this manner.

Specimens were prepared by placing the base plate in the cavity and filling the cavity with the repair material to be tested. The plate prevented the repair material from adhering to the asphalt concrete at the bottom of the cavity; only the strength of the bond developed at the sides of the cavity will be measured. The repair material was added to a level such that just the top of the base plate's rod protruded. The solid cylinder was then placed over the top of the rod and a compaction drop hammer (as used in the preparation of Marshall Stability test specimens) is placed and centered on the cylinder. Five blows were administered. The cylinder was then removed and the third piece of the apparatus was attached to the protruding rod. Figure 4.11 shows a prepared specimen.

The specimen was tested by applying a tensile force through a cable attached to the eyelet. The load at failure is directly proportional to the resistant shear forces mobilized at the interface of the repair material and asphalt concrete. The effectiveness of the bond is indicated by the value of the load measured at failure.

The testing was performed on a Tinius-Olson Universal Testing machine, Electromatic IV, 120,000 pound capacity, with an applied load rate of 2 inches per minute. Six specimens of each material, under each test

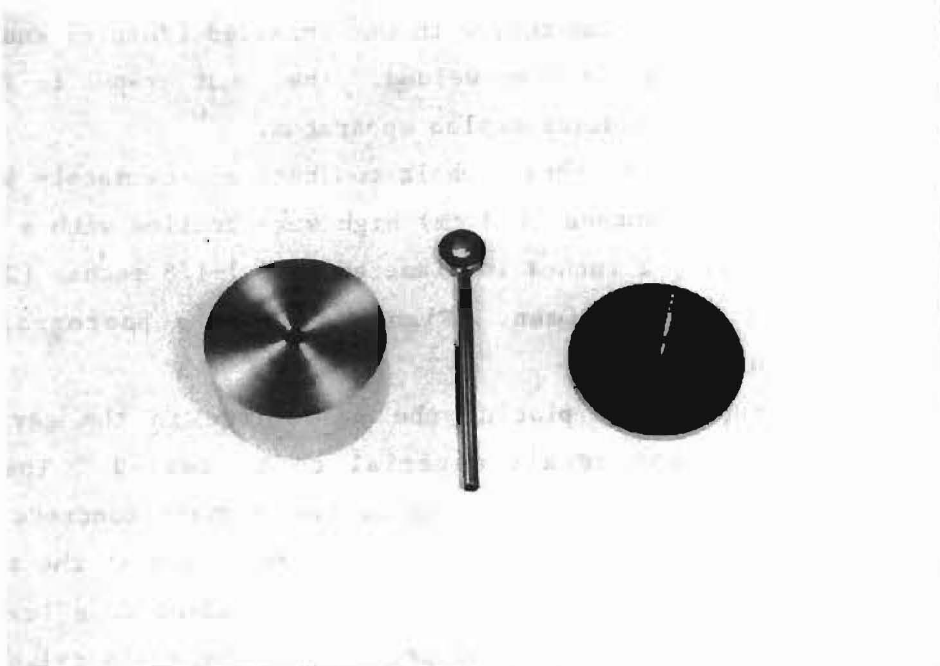


Fig 4.8. Disassembled bond strength test device.

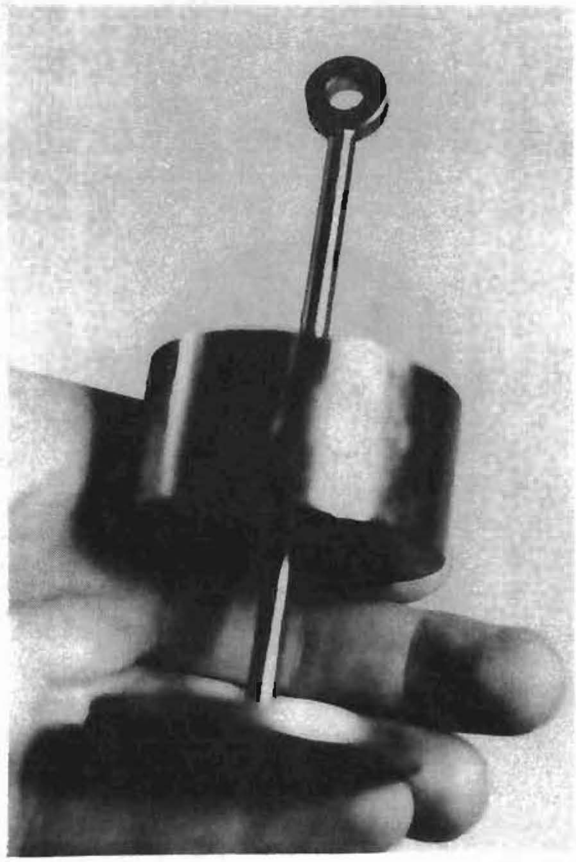


Fig 4.9. Assembled bond strength test device.

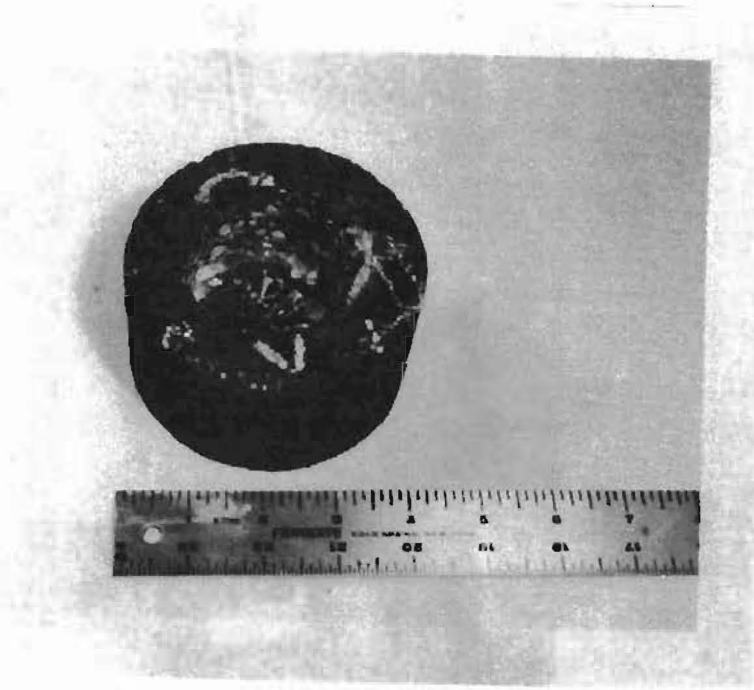


Fig 4.10. Specimen with cavity.

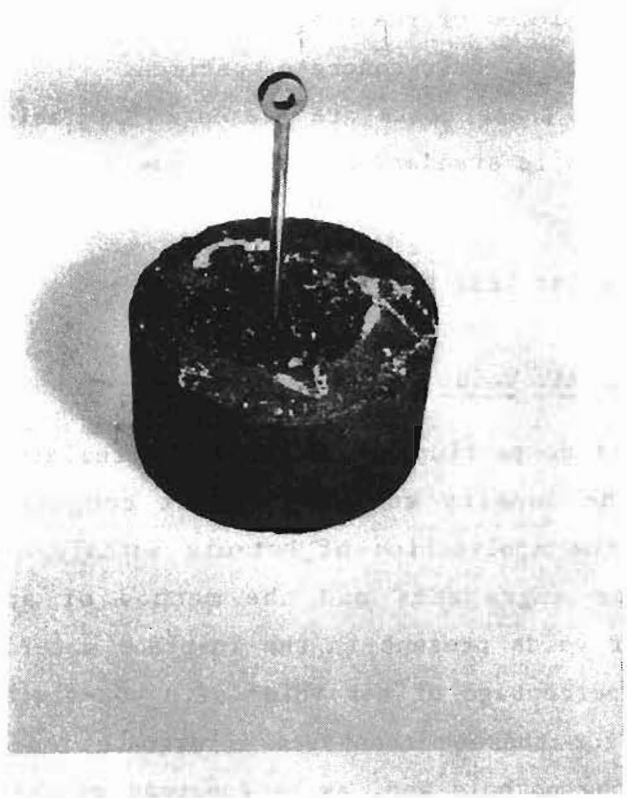


Fig 4.11. Specimen prepared for bond effectiveness testing.

condition, were tested to obtain a clearer indication of the variability associated with this test.

Specimens were tested in either a dry or a wet condition, the latter case being simulated by moistening the sides of the cavity before placing the repair material. Specimens were tested immediately after preparation. The same three asphalt concrete specimens were used in all testing. A wire brush was used to remove pieces of the repair material from the cavity and reexpose the aggregates of the asphalt concrete specimen.

The results of these tests are presented in Table 4.10. Additionally, the mean and the sample standard deviation have been calculated.

ANALYSES OF LABORATORY TEST RESULTS

Percentage of Air Voids

Placement and compaction of the repair materials in the field clearly indicate that the density achieved is not comparable to the densities associated with the application of hot-mix asphalt concrete. The uniform gradation of the aggregates and the method of application cause the percentage of air voids present in the in-place material to be considerably higher than the percentage of air voids of a hot-mix asphalt concrete. The values obtained for these percentages illustrate that the repair materials remain loose in the pothole and, as is apparent by the rate of effectiveness in field tests, perform optimally at far less than maximum density.

Strength

Instant Road Repair consistently yielded higher values of strength and stability under all test conditions than the other two repair materials. The SDHPT requirement for stability for bituminous materials is 750 pounds for use on moderate volume roads and 1,500 pounds for use on high volume roads. Due to the different manner in which the stability tests were conducted on the repair materials (the SDHPT criteria is based on tests conducted at

TABLE 4.10. BOND STRENGTH TEST

Material	Test Condition	Loads at Failure (lb)	Mean	S
Traffix	Dry	52, 62, 25, 86, 59, 40	54.0	20.76
Traffix	Wet	95, 55, 31, 63, 60, 69	62.2	20.75
Sylvax	Dry	89, 52, 50, 71, 52, 75	64.8	15.97
Sylvax	Wet	100, 78, 45, 71, 37, 77	68.0	23.26
Instant Road Repair	Dry	56, 29, 49, 61, 44, 32	45.2	12.80
Instant Road Repair	Wet	39, 45, 49, 52, 42, 25	42.0	9.55

140°F), direct comparisons of measured stabilities with these requirements are not applicable.

The materials become stronger with increased cure time at room temperature. The results indicate that Traffix increases in strength at a rate greater than the other two. The stability of Sylvax increases appreciably within the first few days of increased cure time but remains relatively unaffected by further increases in cure time.

The effect of water on the repair materials is clearly different for each of the three materials. The stability of Instant Road Repair decreased when specimens were exposed to water, Traffix actually gained strength, and Sylvax was unable to withstand immersion in water.

Exposure to the dry freeze-thaw conditions tested did not have any apparent detrimental effect on the stabilities of the three products. The general increase in strength with increased freeze-thaw cycling is probably due to the increased cure time accrued during the thaw portion of the cycle.

Results of Marshall flow measurements do not offer any discernible pattern or tendency that would allow for a categorization of product effectiveness based on this measurement.

Results of the Indirect Tensile Test closely support the results obtained from Marshall Stability measurements.

Bond Effectiveness

Considerable variation was associated with the results of the bond strength test. This was no doubt due to the small amounts of materials involved in the testing. In a small-scale test, such as the one reported here, material variability in the three products is very high and results are very much affected by the orientation or size of an aggregate particle at the interface between repair material and surrounding pavement. Certainly, if the test had been conducted on a larger scale, material variability would have been less prominent and test results might have been more consistent.

That is not to say that the results should be dismissed. Clearly, the bonding effectiveness of Instant Road Repair is on the average lower than that of the other two materials.

Water does not appear to have a significantly detrimental effect on the adhesive properties of the three materials. The values obtained under each test condition do not differ appreciably between wet and dry conditions.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Conventional methods used to repair potholes during inclement weather when hot-mix, hot-laid asphalt concrete is not available, have not proven to give more than temporary results. The costs of continually having to repair damaged pavements, not only in terms of manpower and materials but also in terms of user costs and the damage inflicted on vehicles, make the search for a longer term, more economical solution quite important.

Several pre-packaged, commercially manufactured products are currently available for use. Three of these products were selected for analysis of their potential for repair of potholes. Sylvax U.P.M., Traffix, and Instant Road Repair were evaluated in both the field and the laboratory, under various adverse conditions, to determine their effectiveness.

These three repair materials were emplaced in four diverse climatic regions of Texas and evaluated under actual weather and traffic conditions. The variety of temperature ranges and precipitation levels encountered throughout Texas required that the evaluations be conducted in locations that reflect this diversity.

The two most important characteristics of an effective pothole repair material were identified and formed the basis for the laboratory testing program. The strength of the repair materials themselves was evaluated in terms of the Marshall stability of each of them. Materials were tested under conditions that simulated the presence of water and severe freeze-thaw conditions.

A test was devised to evaluate the effectiveness of the bond that develops between the repair material and the surrounding existing pavement. This test, which relates the effectiveness of the bond to the magnitude of the shear forces that develop in resisting a tensile load, was also performed under simulated wet and dry conditions.

CONCLUSIONS

This investigation failed to significantly differentiate between the effectivenesses of the three materials selected for evaluation. No one material stood out clearly as the optimal solution to the problem of finding an all-weather pothole repair material.

The following conclusions can also be made.

Field Testing

The results of field testing in four distinct climatic regions of Texas indicate that all three products are effective. Incidence of repair material failures was low and none of the materials could be identified as unsuitable for use under the climatic and traffic conditions of the testing.

Laboratory Testing

Material Strength. Instant Road Repair was identified as clearly having more strength, under any and all test conditions, than the other two products. The tensile strength and Marshall Stability values for Instant Road Repair were several times higher than these values for the other two products.

The presence of water adversely affects the strengths of Instant Road Repair and Sylvax. The strength of Traffix is not affected adversely, and actually increases, when specimens are exposed to water.

Similarly, exposure to freezing and thawing conditions is not detrimental to the materials' strengths. The increase in strength exhibited by specimens subjected to increased freeze-thaw cycling is probably due to increased cure time and not directly attributable to exposure to prolonged periods of freezing temperature. Allowing six days between the end of freeze-thaw cycling and testing insured that the increased viscosity experienced by bituminous materials at lower temperatures does not influence the stability values measured.

The determination of material strength or stability by itself is certainly not the key to linking field and laboratory test results. Field performance is not reflected by the clear hierarchy of effectiveness suggested by Marshall Stability results. Based on these results, Instant Road Repair would far out-perform the other two products and Sylvax would prove to be ineffective when emplaced under wet conditions. Such, clearly, was not the case.

Bond Effectiveness. Sylvax and Traffix appear to have better adhesive properties than Instant Road Repair and tend to form stronger bonds with the existing pavement. Based on the variability associated with the test method used to determine bond effectiveness, this conclusion is perhaps tenuous. Handling these three products, however, tends to support this conclusion. Instant Road Repair has a far less "sticky" quality than the other two products; the bituminous binders used in Sylvax and Traffix adhere more readily to other objects than the binder used in Instant Road Repair.

The presence of water does not appear to detract from bond effectiveness. This does not suggest that a significant amount of standing water in a pothole does not adversely affect repair effectiveness. However, dampness in the bottom and sides of a pothole does not prevent an effective bond from forming between the repair material and the surrounding pavement.

Workability/Storage

All three materials can be applied in the same manner and all three are easy to use. The packaging is convenient for small-scale repairs; a few pails or a drum can be loaded into a truck and taken to an area requiring repair and the repair can be effected easily and rapidly. Utilization of the materials does not require specialized equipment.

Repairs conducted on a larger scale can make use of bulk quantities of materials (Traffix is not sold in bulk) which can be loaded into dump trucks and shoveled from the beds.

The workability of Instant Road Repair and Traffix decreased with decreasing temperatures. These two materials, especially Instant Road Repair, became quite rigid when temperatures dropped below 40°F (4°C) and were difficult to remove from their containers. Sylvax remained easily workable at temperatures experienced in field test situations.

Packaging of the products makes them convenient but storage of large quantities requires ample space. In regions subject to extreme cold, the storage area would have to be heated to maintain workability of the materials. Materials available in bulk quantities can be stored in stockpile but would still require some protection from direct exposure to cold.

Cost

The three products can be more easily differentiated between in terms of cost than in terms of effectiveness. Traffix is the most expensive of these products. Moreover, Traffix is not available in bulk quantity, and so, storage would present a problem.

Instant Road Repair is more moderately priced and is available in bulk. However, its sole distribution point is in Houston, remote from the regions in Texas that most experience the adverse weather conditions that justify the expense of these products. Transportation of bulk quantities to the northern parts of Texas would be inconvenient and costly.

Sylvax is by far the least expensive of the three products and is available in bulk quantities. A distributor is located in north Texas (in Weatherford, just west of Fort Worth) and the option of purchasing only the binder material, for local mixing, increases convenience.

RECOMMENDATIONS

Product Selection

Selecting the pothole repair material that best suits the requirement of the Texas State Department of Highways and Public Transportation requires reliance on the old bromide, "It is not important how it works, just that it does." In this case, the results of the field test establish the fact that each of the three products performs well, even if the laboratory testing program failed to establish criteria for evaluating product effectiveness.

Cost and availability of the product in bulk quantities proximate to where it is required make Sylvax the obvious choice as the most cost-effective product. If Sylvax is used, purchasing only the liquid binder, for mixing with local aggregates, should be considered. Local preparation of the mix should reduce shipping costs and possibly reduce storage requirements.

Further Testing

Further utilization of any of these products in any region in Texas should be documented for the purpose of collecting further data on service life, application methods, and traffic and climate conditions. The field tests did not constitute a large enough sample for a statistically complete picture. Not enough field tests were made to offer a statistically meaningful interpretation of the two incidents of failure that occurred. However, further accumulation of data could corroborate or refute assumptions made about the products' effectiveness in the field.

Further laboratory testing is also recommended. The repair materials, in place in the field, are subjected to a lateral confining pressure by the surrounding pavements. Strength tests in a mode that applies a confining pressure should be considered.

The bond effectiveness test that was devised should be refined by increasing the size of the specimens tested. If the resistant shear forces act over a larger area, material variances will have a minimized effect on the outcome. Determination of the relative strengths of the bonds that develop between the repair materials and the surrounding pavement should provide a very good indication of repair effectiveness.

Other materials should be incorporated into the testing program. Materials of known effectiveness (or non-effectiveness) should be tested to provide a basis for comparisons. Certainly the materials should be compared to cold-mix, cold-laid asphalt concrete, the material most used currently.

REFERENCES

1. Pothole Primer: A Public Administrator's Guide to Understanding and Managing the Pothole Problem, Special Report 81-21, United States Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire: U. S. Government Printing Office, September 1981.
2. "Standard Test Method of Indirect Tension Test for Resilient Modulus of Bituminous Mixtures," ASTM D4123-82, American Society for Testing and Materials, 1982.
3. "Standard Test Method for Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures," ASTM D2041-78, American Society for Testing and Materials, 1978.
4. "Standard Test Method for Bulk Specific Gravity of Compacted Bituminous Paving Mixtures Using Marshall Apparatus", ASTM D1559-82, American Society for Testing and Materials, 1982.

APPENDIX A
SURVEY INFORMATION

Fig A1.1. Questionnaire

RESEARCH STUDY 359
QUESTIONNAIRE ON WET WEATHER POTHOLE PATCHING

1. Please give us your opinion on the most important characteristics of materials to be used for wet weather pothole repair.

_____ Cost   _____ Performance

_____ Working Time   _____ Color

_____ Curing Time   _____ (Other) ____________________

_____ Ease of Mixing, placing and finishing   _____ (Other) ____________________

2. In your opinion, what are the most important mechanical properties of pothole repair materials in the order of importance.

_____ Strength   _____ Ductibility

_____ Bond to asphalt cement concrete   _____ Coefficient of thermal expansion

_____ Shrinkage   _____ (Other) ____________________

_____ Wear Resistance   _____ (Other) ____________________

3. In your opinion, what are the desirable chracteristics of a wet pothole patching material. Please circle or add your best answer.

(a) Curing Time (least time to opening to traffic) - Less than 15 minutes 15-30 minutes   30-60 minutes   Other ______________

(b) Strength - Same as existing pavement / Greater than existing pavement Other ____________________________

(c) Surface Texture - Smooth / exposed aggregate / immaterial

(d) Color - Black / grey / immaterial

(e) Minimum Service Life - Less than 30 days / 30-90 days / greater than 90 days

(f) Specialized Equipment - None / some / immaterial

(g) Forgiving Material - Difficult to use improperly / doesn't matter

(h) Other - ______________________________________

4. Please complete an evaluation form for each material used for repair of wet potholes in your district within the last 10 years. Where appropriate please refer to materials by brand name.

(Continued)

Fig A1.1. Questionnaire (cont.)

Name of Person Completing Questionnaire: Phone Number ______________

______________________________ District ______________

PLEASE RETURN THIS PAGE AND EVALUATION FORMS IN THE ENCLOSED ENVELOPE OR TO:

Alvin H. Meyer
Center for Transportation Research
ECJ6.102
University of Texas at Austin
Austin, Texas 78712

Fig A1.2. Material Evaluation Sheet

MATERIAL EVALUATION SHEET
(please use separate sheet for each material)

1. Name of material: ______________________________

2. Source of material: ______________________________

3. Period used in your District: from __________ to __________

4. Approximate amount of material used in District:

No. of: lbs / tons/ cubic yds per year: ______________________________

If used only once please estimate amount used: ______________________________

5. Evaluation of Material (Circle Number)

	Difficult				Easy
Mixing	1	2	3	4	5
Placing	1	2	3	4	5
Compaction	1	2	3	4	5
	Dislike				Like
Appeal to Workers	1	2	3	4	5
	Poor				Good
Bond to Existing Pavement	1	2	3	4	5
Durability	1	2	3	4	5
Appearance	1	2	3	4	5
Overall Performance	1	2	3	4	5
	None				Significant
Effect of Hot Temperature	1	2	3	4	5
Effect of Cold Temperature	1	2	3	4	5
Effect of Moisture	1	2	3	4	5
	Low				High
Cost	1	2	3	4	5

6. Is any specialized equipment required? YES NO
If yes, please describe briefly: ______________________________

(Continued)

Fig A1.2. Material Evaluation Sheet (cont.)

7. What size of repairs are made with this material?

   Area   0-2 ft^2 2-4 ft^2 4-9 ft^2 larger than 9 ft^2

8. Have you performed any laboratory tests on this material?   YES   NO
   (If yes, would you please provide a copy of test results.)

9. Comments: (If more space in needed please use back of sheet) ____________

   ____

TABLE A.1. SURVEY RESPONSES FOR TEXAS

SURVEY RESPONSES FOR TEXAS: TABLE 1

	CHARACTERISTICS	DISTRICTS 1	2	3	4	5	6	7	8	12	13	14	16	17	18	19	20	21	23	25	HU
	COST	5	4	5	3	5	2	5		3	4	3	2	3	5	5		5	3	4/5	5
CHARACTERISTICS	WORKING TIME	4	2	3	2	2	5	2/3		4	5	5	3	2	4	4		4	2	2	3/2
	CURING TIME	3	3	2	1	3	1	2/3		1	1	2	4		3	3		3	4	3	4/3
	EASE OF MIX, PLACE, FINISH	2	5	4	4	4	4	4		5	2	4	5	2	2	2		2	5	5/4	2/4
	PERFORMANCE	1	1	1	1	1	3	1	1	2	3	1	1	1	1	1	1	1	1	1	1
	COLOR	6	6	6	5	6	6	6		6	6	6	6		6			6	6	6	6
MECHANICAL PROPERTIES	STRENGTH	2	3	3	2	2	4	1	1	3	2	2	2	2	3	2		2	1	2	2
	BOND TO A.C.C.	1	1	1	1	1	1	5	2	1	1	1	1	1	1	1	1	1	3	1	1
	SHRINKAGE	4	4		4	4	2	4	6	2	3	5	4	3	5	6		4	5	4	3/6
	WEAR RESISTANCE	3	5	2	3	3	3	3	4	4	5	3	3	2	7	4		5	2	3	3/4
	DUCTILITY	5	2		5	5	5	2	3	5	4	4	5	6	4	3		3	4	6/5	4/6
	COEF. OF THERMAL EXP.	6	6		6	6	6	6	5	6	6	6	6		6	5		6	6	5/6	5
DESIRABLE	CURING TIME (MINUTES)	< 15	30/60	15/30	< 15	< 15	15/30	<15 15/30	< 15	< 15	15/30	15/30	15/30	< 15	< 15	< 15	< 15	< 15	30/60	< 15	<15 30/60
	STRENGTH (Relative to existing material)	-	-	-	-	-	-	-	>	-	-	-	-	-	-	-	-	-	-	-	-
	SURFACE TEXTURE	X	X	X	E	X	X	E/S		E	E/X	E	S	X	X	X	E	E	E	S	E
	COLOR	X	X	X	B	X	X	B/X	X	X	X	X	B	X	X	X	X	X	G	G	B
	MINIMUM SERVICE LIFE (DAYS)	> 90	> 90	30/90	> 90	30/90	> 90	> 90		> 90	30/90	> 90	30/90	30/90	30/90	> 90	> 90	> 90	> 90	> 90	> 90
	SPECIALIZED EQUIPMENT	N	N	N	S	N	N	N	N	N	N/S	N	N	N	N	N	N	N	N	N	N
	FORGIVING MATERIAL	dui	dui	x	x	x	dui	dui	dui	dui	dui	dui	dui	dui	dui	dui	dui	dui	x	dui	dui

TABLE A.2. CUMULATIVE SURVEY RESPONSES

Desirable Characteristics		Percentage of Total
	< 15	59.09
Curing time (minutes)	15 - 30	27.27
	30 - 60	13.64
Strength	=	95.00
(relative to existing)	>	5.00
	S	14.29
Surface texture	E	42.86
	X	42.86
	B	19.05
Color	G	9.52
	X	71.43
	<30	--
Minimum service life (days)	30 - 90	31.58
	>90	68.42
	N	86.36
Specialized equipment	S	9.09
	X	4.55
Forgiving	DUI	78.95
Material	X	21.05

APPENDIX B

FIELD TEST REPORTS

APPENDIX B.1. RAPID REPAIR OF WET ASPHALT (PRE-PACKAGED MATERIALS) AMARILLO, TEXAS, OCTOBER 25, 1983

1. Two repair materials were field tested in Amarillo at the intersection of Loop 335 and Highway 87/287 (see Fig B1.1). This section experiences heavy truck traffic. The materials tested were Sylvax U.P.M. and Instant Road Repair. A third material, Traffix, was to be tested, but was not available on site as arranged.
2. The site is shown in in Fig B1.2. The two materials were placed in exactly the same manner (as described below) except that each material was emplaced under dry and simulated wet conditions. For the latter, two potholes were partially filled with water, and compressed air was used to blow the excess, standing water out of the holes, leaving the sides and bottom of the holes still wet. The depth of each hole was 4 inches.
3. The potholes were prepared by digging a rectangular area around the damage surface with a 6-inch chisel. The holes were cleared of loose material with compressed air. The repair materials were emplaced in two lifts. Each lift was compacted by repeatedly hitting it with the back of a shovel. In addition, the second lift was compacted by running an unloaded 2-1/2 ton dump truck over the repaired area ten times.
4. The Sylvax U.P.M. repair material was very workable. It was emplaced with minimal effort. The surface of the repaired pothole was relatively soft; walking on the material after compaction left a distinct impression. The I.R.R. repair material proved to be relatively difficult to work. The I.R.R. was left overnight in a trailer and the temperature dropped to approximately 35°F. As a result, the I.R.R. would not come out of the pail until direct heat was applied by means of a butane torch. Further heat was required to make the material workable. The finished pothole was significantly harder than the Sylvax repaired pothole.

5. Efforts to core a sample of each emplaced material were unsuccessful. The samples broke apart inside the coring bit.
6. The maintenance supervisor of the SDHPT offices in Amarillo agreed to notify the CTR if there is any unusual wear of the materials or if the pothole needs to be re-repaired.

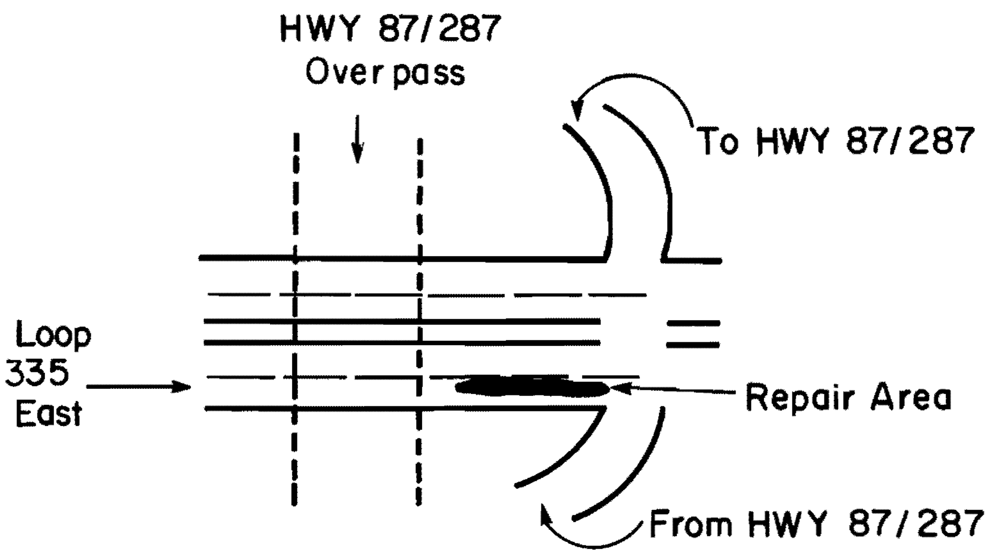
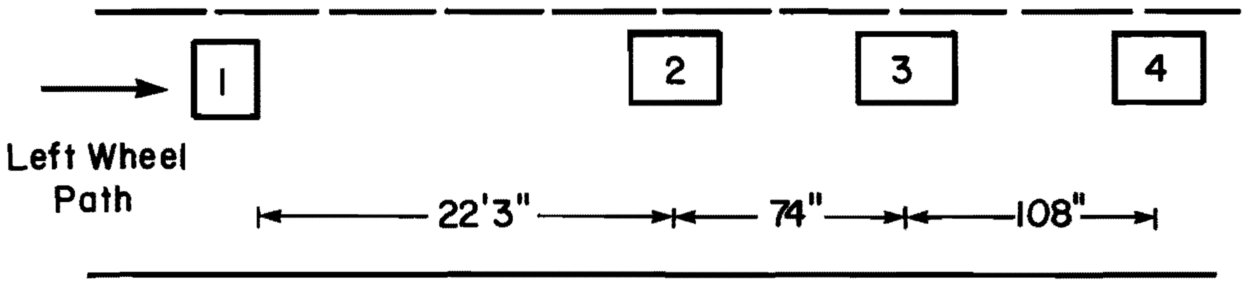


Fig B1.1. Repair Site -- Amarillo

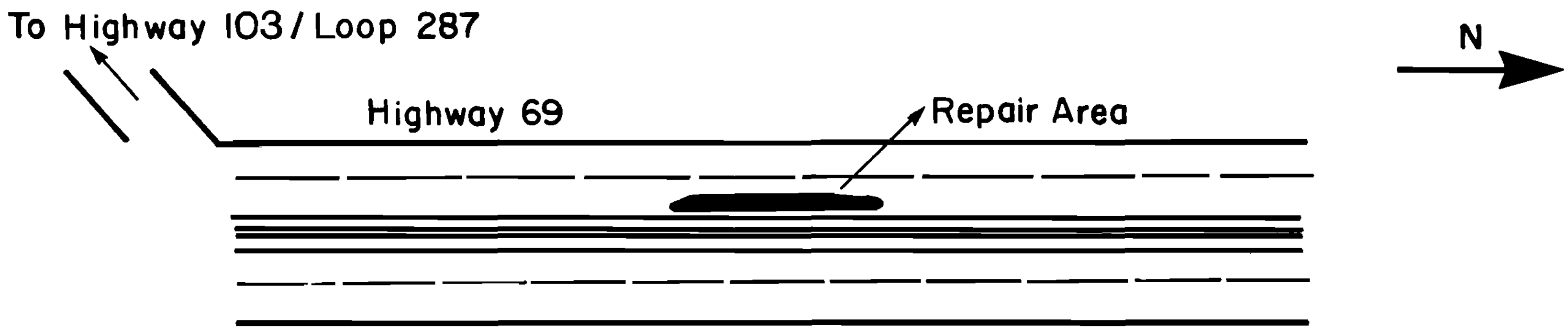


Pothole #	1	2	3	4
Dimensions	32" x 22"	22" x 32"	22" x 32"	22" x 32"
Distance from C/L	18"	18"	18"	18"
Material	Sylvax Dry	Sylvax Wet	IRR Dry	IRR Wet

Fig B1.2. Repair Dimensions, Amarillo.

APPENDIX B.2. RAPID REPAIR OF WET ASPHALT (PRE-PACKAGED MATERIALS) LUFKIN, TEXAS, DECEMBER 20, 1983

1. Three repair materials were field tested in Lufkin, Texas, on Highway 69 in the southbound, inside lane, just north of the Highway 103 and Loop 287 exit (mile post 12 1/2). See Fig B2.1. The highway has an 8500 ADT and experiences moderate to heavy truck traffic. The materials tested were Sylvax U.P.M., Traffix, and Instant Road Repair.
2. The site was as depicted in Fig B2.2. The materials were placed in exactly the same manner (as described below) except that each material was emplaced under dry and simulated wet conditions. For the latter, three potholes were partially filled with water and then swept with a broom to remove excess water, leaving the sides and bottoms of the holes still wet. The depth of each hole was 1-1/2 inches.
3. The potholes were prepared by digging a rectangular area around the damaged surface with a gasoline operated portable pavement breaker. The holes were broomed clean of loose material. The repair material was emplaced in one lift and partially compacted by repeatedly hitting it with the back of a shovel. Further compaction was obtained by running an unloaded 2-1/2 ton dump truck over the repaired area ten to fifteen times.
4. Previous difficulty in handling the materials after they had been exposed to low temperatures necessitated the storing of the materials in a heated warehouse overnight. As a result, all materials were emplaced quite easily and were very workable. The ambient temperature during emplacement was 40°F.
5. The maintenance supervisor of the SDHPT in Lufkin agreed to notify us if there is any unusual wear of the materials or if the repaired area requires further repair.



Fib B2.1. Repair site, Lufkin.

Note: A Seventh Pothole was Repaired to Utilize Excess Material.

Pothole #	1	2	3	4	5	6	7
Dimensions	41" x 23"	24" x 24 1/2"	23 1/4" x 23 1/4"	20" x 23"	22" x 18"	25" x 31"	16" x 13"
Distance from C/L	27"	25"	28 1/2"	27"	29"	29"	32 1/4"
Material	Sylvax Dry	Traffix Dry	IRR Dry	Sylvax Wet	Traffix Wet	IRR Wet	Sylvax Wet

Fig B2.2. Repair dimensions, Lufkin.

APPENDIX B.3. RAPID REPAIR OF WET ASPHALT (PRE-PACKAGED MATERIALS) SAN ANGELO, TEXAS, 6 JANUARY, 1984

1. Three repair materials were field tested in San Angelo, Texas, on Loop 360 in the eastbound, outside lane, 0.3 mile east of the Knickerbocker Avenue overpass. See Fig B3.1. The highway has a 6000 ADT and experiences moderate truck traffic. The materials tested were Sylvax U.P.M., Traffix, and Instant Road Repair.
2. The site was as depicted in Fig B3.2. The materials were placed in exactly the same manner (as described below) except that each material was emplaced under dry and simulated wet conditions. For the latter, three potholes were parially filled with water and then swept with a broom to remove excess water, leaving the sides and bottoms of the holes still wet. The depth of each hole was 1-1/2 inches.
3. The potholes were repaired by digging a rectangular area around the damaged surface with an axe and sledge hammer. The holes were broomed clean of loose material. The repair materials were emplaced in one lift and partially compacted with the back of a shovel. Further compaction was obtained by running an unloaded 2-1/2 ton dump truck over the repaired area ten to fifteen times.
4. As before, the repair materials were stored in a heated warehouse overnight to insure ease of workability. All three materials were emplaced easily and were quite workable. The ambient temperature during emplacement was 50°F.
5. The maintenance supervisor of the SDHPT in San Angelo agreed to notify us if there is any unusual wear of the material or if the repaired area requires further repair.

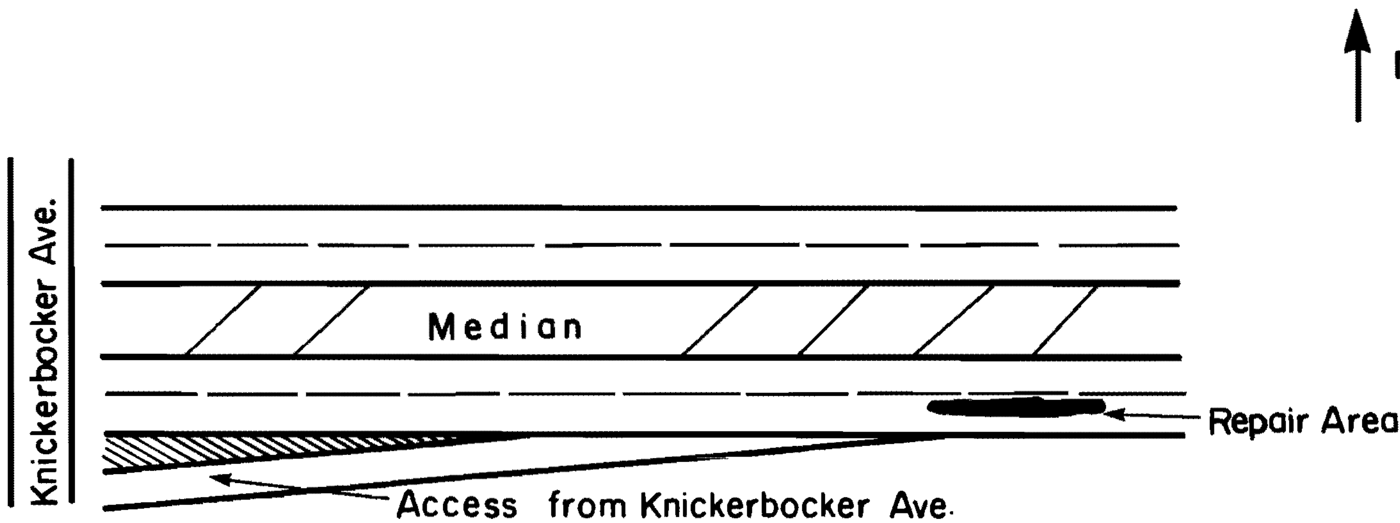
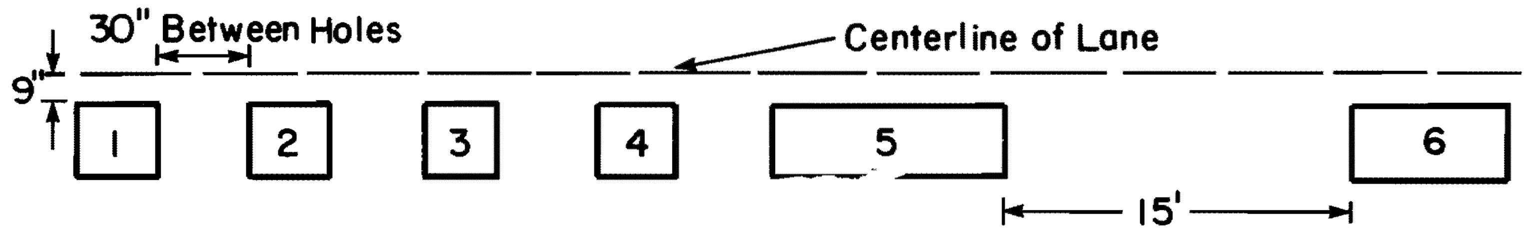


Fig B3.1. Repair site, San Angelo.



Pothole #	1	2	3	4	5	6
Dimensions	2' x 2'	2' x 2'	2' x 2'	2' x 2'	6' 2" x 2'	4' 2" x 2' 1"
Distance from C/L	9"	9"	9"	9"	9"	9"
Material	Sylvax Dry	Traffix Dry	IRR Dry	IRR Wet	Sylvax Wet	Traffix Wet

Fig B3.2. Repair dimensions, San Angelo.

APPENDIX B.4. RAPID REPAIR OF WET ASPHALT (PRE-PACKAGED MATERIALS) NEW BOSTON, TEXAS, FEBRUARY 17, 1984

1. Three repair materials were field tested in New Boston on Highway 98, 0.4 mile north of Interstate 30. (See Fig B4.1.) This section experiences light truck traffic and has an ADT of 560. The materials tested were Sylvax U.P.M., Instant Road Repair, and Traffix.
2. The site was as depicted in Fig B4.2. The materials were placed in exactly the same manner (described below), except that each material was emplaced under dry and simulated wet conditions. For the latter, three potholes were partially filled with water and then swept with a broom to remove excess water, leaving the sides and bottom of the holes still wet. The depth of each hole was 1-1/2 inches.
3. The potholes were prepared by "squaring off" the damaged surface into a rectangular area with a shovel. The holes were broomed clean of loose material. The repair materials were emplaced in one lift, and partially compacted by repeatedly striking the area with the back of a shovel. Further compaction was obtained by running an unloaded 2-1/2 ton dump truck over the repaired area with 15 times.
4. Materials had been stored overnight in a warehouse. The materials were very workable during emplacement and emplaced quite easily. The ambient temperature during emplacement was approximately 50°F.
5. The maintenance supervisor at the New Boston maintenance yard agreed to notify us if there is any unusual wear of the materials or if the repaired area requires further repair.

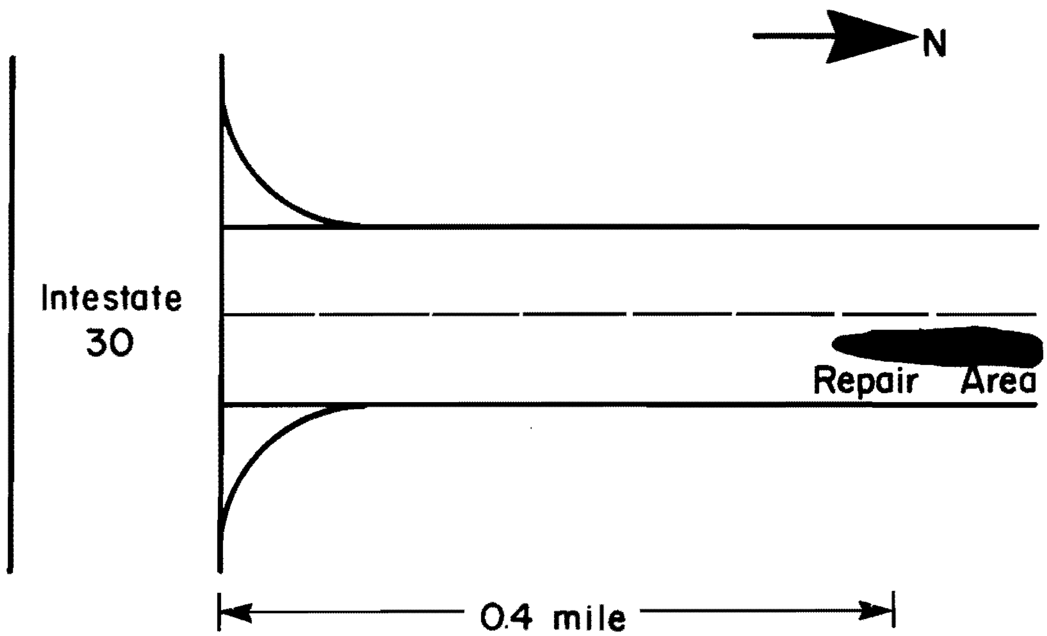
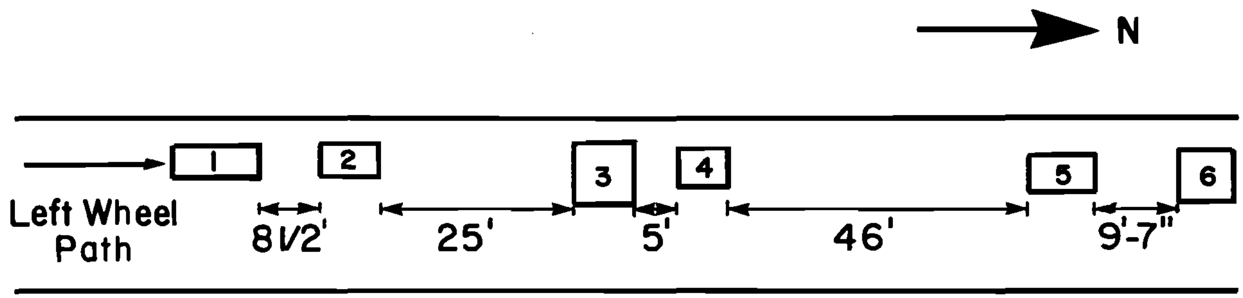


Fig B4.1. Repair site, New Boston.



Pothole #	1	2	3	4	5	6
Dimensions	2'6"x4'6"	2'3"x3'2"	5'6"x2'3"	2'x3'	3'8"x3'	4'x2'
Distance from C/L	9"	13"	1"	6"	14"	28"
Maerial	IRR Wet	IRR Dry	Traffix Dry	Sylvax Dry	Sylvax Wet	Traffix Wet

Fig B4.2. Repair dimensions, New Boston.

APPENDIX C

APPLICATION METHOD

Fig C.1. Prepare hole by forming rectangular area.

Fig C.2. Sweep area to be repaired clean of debris.

Fig C.3. Shovel repair material into area to be repaired directly from container.

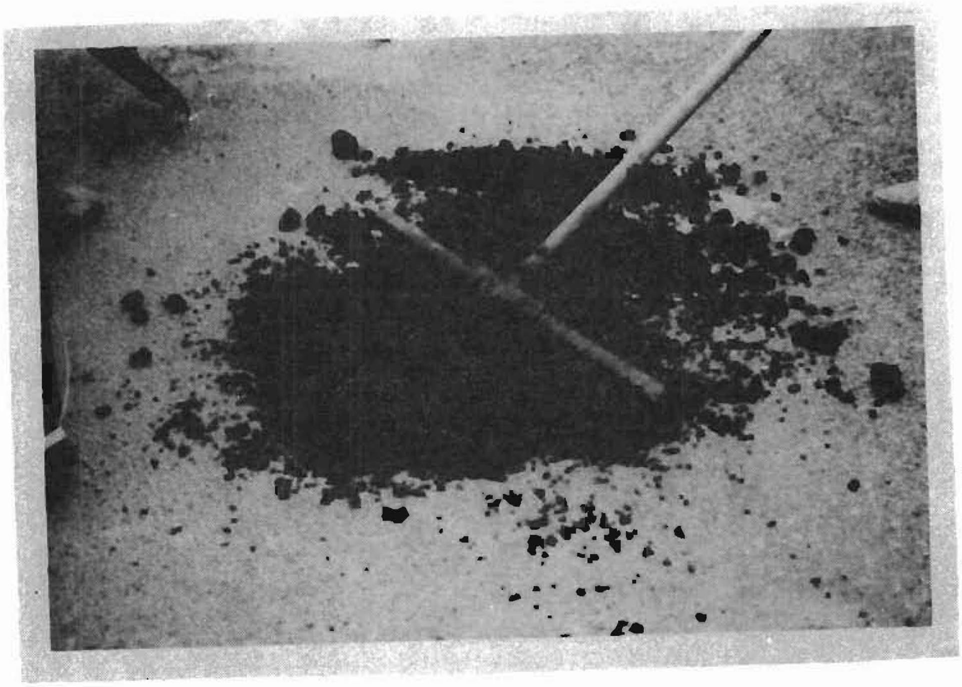


Fig C.4. Rake area to provide a smooth, even finish.

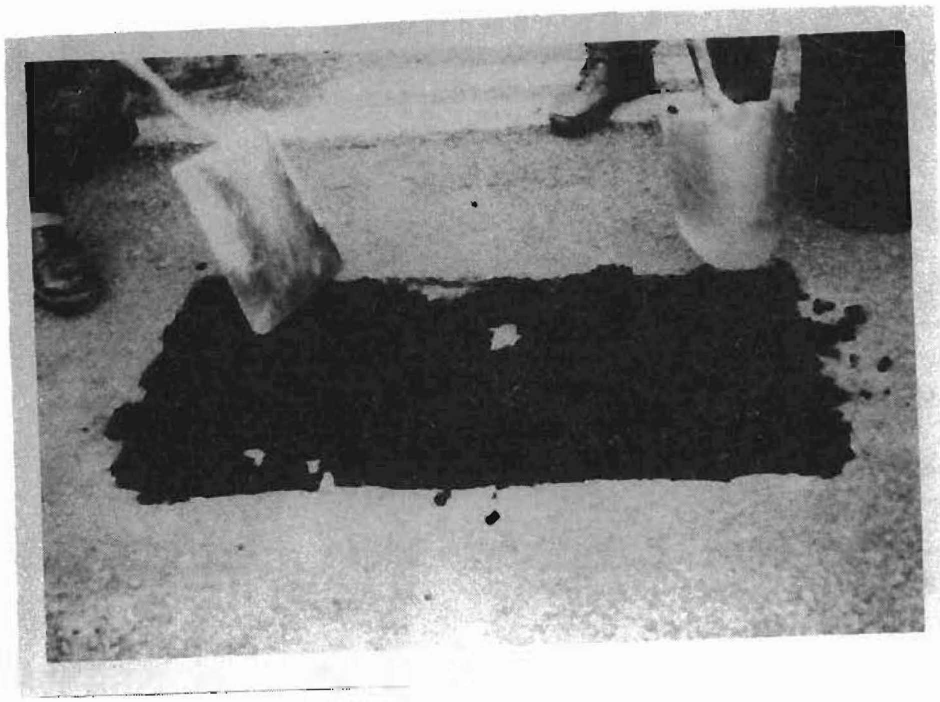


Fig C.5. Insure the repair material makes adequate contact with the sides of the area to be repaired.

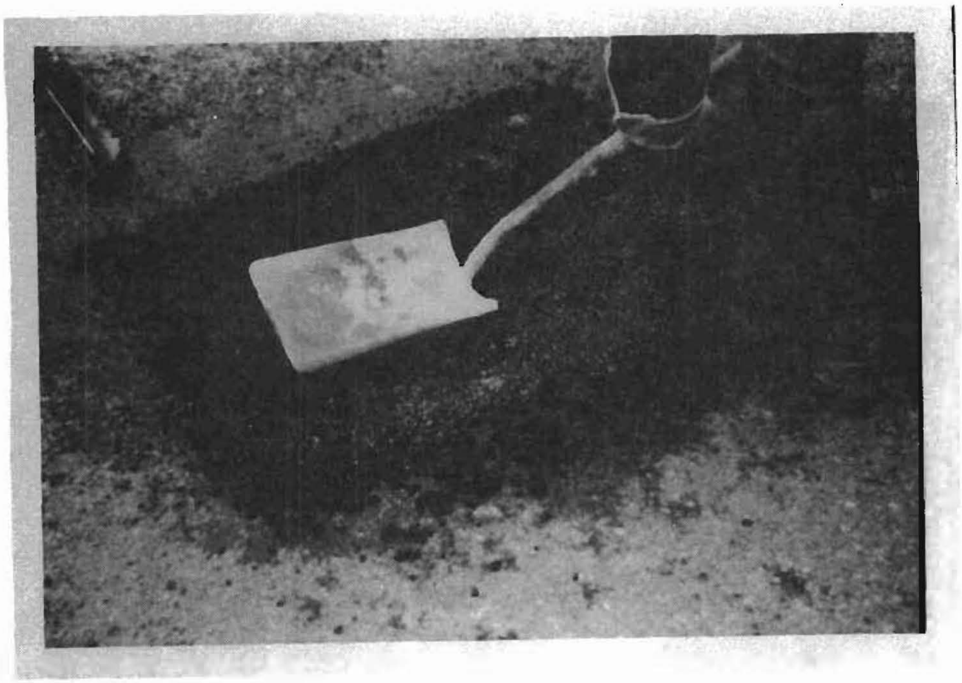


Fig C.6. Provide initial compaction by striking area with the back of a shovel.

Fig C.8. At cold temperatures, repair material is unworkable.

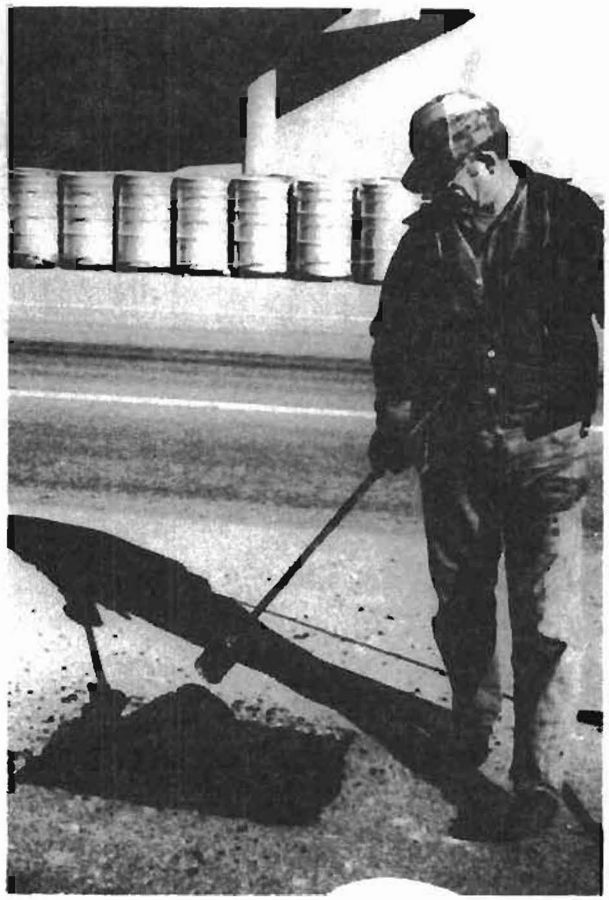


Fig C.9. Apply direct heat to "frozen" material to regain workability.

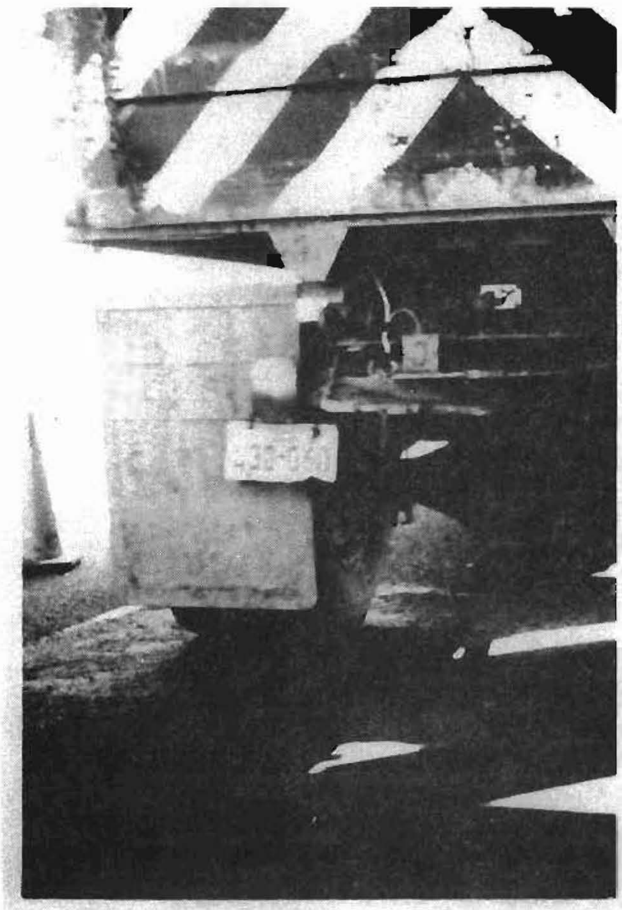


Fig C.7. Drive a heavy truck over the repaired area 10-15 times to complete compaction.