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16. Abstract

During periods of wet weather, particularly when it is also cold, asphalt pavements develop potholes which cannot be immediately repair with conventional asphalt materials. Materials are needed which can be successfully used to repair asphalt pavements in wet, or cold and wet, weather. The materials should be of reasonable cost and have at least a moderate life.

This report focuses first on fly ash as a potential material; and considers its compressive, flexural, and bonding properties. In addition, three commercially manufactured, pre-packaged pothole repair materials were evaluated in the field and in the laboratory under various adverse climatic conditions to determine their effectiveness.

A brief summary of the properties of all materials is given, followed by recommended procedures for batching, mixing, placing, and finishing the materials.

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# IMPLEMENTATION MANUAL FOR THE RAPID REPAIR OF WET ASPHALTIC CONCRETE

by

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Research Report Number 359-3F

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

October 1985

# PREFACE

This report is the culmination of a series which describes methods for repairing 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. In particular, appreciation is given to Richard Tyler, D-10 Planning and Research, whose suggestions and assistance in procurement of materials proved to be vital to the success of this project.

David Whitney, Dean Malkemus, Jim Anagnos, Pat Hardeman, Eugene Betts and James Stewart were instrumental in the laboratory and field investigations and their assistance is greatly appreciated. Special thanks are given to Michele Sewell, Ahlam Barakat and Jean Gehrke who prepared all the figures.

# ABSTRACT

During periods of wet weather, particularly when it is also cold, asphalt pavements develop potholes which cannot be immediately repaired with conventional asphalt materials. Materials are needed which can be successfully used to repair asphalt pavements in wet, or cold and wet, weather. The materials should be of reasonable cost and have at least a moderate life.

This report focuses first on fly ash as a potential material; and considers its compressive, flexural, and bonding properties. In addition, three commercially manufactured, pre-packaged pothole repair materials were evaluated in the field and in the laboratory under various adverse climatic conditions to determine their effectiveness.

A brief summary of the properties of all materials is given, followed by recommended procedures for batching, mixing, placing, and finishing the materials.

# SUMMARY

Conventional asphalt repair materials have been found to have difficulty making an adequate bond with wet asphalt, especially in cold weather. TSDHPT District 5 reports that Class C fly ash has been successfully used to repair potholes. The material hardens quickly and is said to be permanent. An additional characteristic which makes fly ash a desirable repair product is that it is very inexpensive compared with other materials now being tested. Several pre-packaged, commercially manufactured products are currently available. Three were selected for analysis of their potential for repair of potholes. Sylvax U.P.M., Traffix and Instant Road Repair were evaluated both in the field and the laboratory, under various adverse conditions, to determine their effectiveness.

The fly ash and the commercial products were examined in the laboratory and later evaluated in a series of field tests. This report contains the results of those tests along with the recommended procedures for making highway repairs.

# IMPLEMENTATION STATEMENT

This document presents an analysis of pothole repair materials in terms of their suitability for use under adverse weather conditions. Field and laboratory tests were conducted to make these evaluations. It is hoped that the results of this study will be used in the process to select a method or material that can be used to effect a long-term, economical solution to the problem of pothole repair.

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# CHAPTER 1
# INTRODUCTION

## 1.1 The Pothole Problem

Repair of potholes in wet weather is one of the most difficult tasks facing highway maintenance forces. Several factors have exacerbated the problem drastically. The phenomenal 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 the 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, water standing in drainage ditches, water seeping 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 damages to vehicles. Potholes in bad weather are especially hazardous, due to reduced visibility and the presence of water in the hole, which "hides" it from the driver. A literature review revealed one very promising repair material, fly ash, and an investigation of a solution involving fly ash, in a mix by itself or combined with other natural materials (sand, gravel) or synthetic materials (polypropylene fibers), was initiated.

The review 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.

# CHAPTER 2
# MATERIALS

## 2.1 Background

During periods of wet and cold weather special materials for making rapid repairs in asphalt must be used. The material implemented in this report include class C fly ash and three commercially available products.

## 2.2 Fly Ash

Ash is the residue that is formed as a consequence of the imperfect combustion of matter. When ground coal is burnt, there are three types of residues: fly ash, bottom ash, and vapors.

Fly ash is the finest part of the residue and it is usually collected by air filters or by pollution control equipment. Bottom ash is composed of heavier and coarser particles than fly ash, which remain on the burning surface. The vapors that are expelled into the atmosphere as a result of the combustion of coal are merely the volatilized portion of the various minerals contained in it.

ASTM classifies fly ashes according to their coal source: class F is for ashes of bituminous coal, and class C is for ashes of sub-bituminous and lignite coals. Texas fly ashes are mostly class C, which has been less researched, since sub-bituminous and lignite coals have not been mined as extensively as the bituminous ones. This research deals mainly with fly ash from Texas.

The Environmental Protection Agency (EPA), aware of the problems that the projected 1,500 million metric tons of fly ash production in the United States for the year 2,000 will cause, has mandated the use of waste materials, such as fly ash, in government sponsored jobs. Due to the federal government's inducements, plus the availability of fly ash, many ingenious ways of using it are being reported.

### 2.3 Commercial Asphalt Materials

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 is a summary of the survey results. These three materials were evaluated on a scale of 1 to 5, with a rating of 1 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.

#### 2.3.1 Descriptions

The descriptions of the materials 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 $-15^{o}F$ ($-26^{o}C$). 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."

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 $20^{o}F$ to $140^{o}F$ ($-7^{o}$ to $60^{o}C$) 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 ... "

All the manufacturers claim that their repair materials are easily applied and that the repaired area can be opened to traffic immediately after the repair is made.

### 2.3.2 Costs

Quantities of these three materials were purchased for the purposes of beginning testing. Due to the small quantities required, the products were purchased in 5-gallon pails. Larger scale use of these materials would require purchases of larger unit quantities for ease of storage/stockpile and reduce unit costs. Table 2.1 presents price and quantity information, current as of February 14, 1985.

# TABLE 2.1 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 | $69.00/ton | .035 |
| | Weatherford, Texas | | |

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

# CHAPTER 3
# RESEARCH RESULTS - LAB

## 3.1 Background

This chapter contains the results of the formal lab research, i.e., that part of the investigations in which the material origins are known. The testing procedures followed the guidelines of ASTM except where noted otherwise.

All of the fly ash initially tested came from three plants in Texas located near the cities of San Antonio, Amarillo, and Cason. After different kinds of fly ash were examined, this portion of the research centered around finding the optimum ratios of fly ash, sand, coarse aggregate and water. Finally, different additives to fly ash were investigated to see if fly ash could be further improved as a road repair material.

In regard to the commercial repair materials, two principal characteristics of a repair material were selected as representative of how well the material performs. First, the material should be "strong" in its own right. It should be able to withstand expected traffic loads. Also, the repair and this pavement should 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, that does not form a strong bond with the original pavement is that much more susceptible to failure. Table 3.1 presents a summary of the characteristics of a repair material that are considered the most important by the SDHPT districts.

The next step in the formulation process was to identify currently accepted test methods, perhaps in modified form, to "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; Hveen Stability, Marshall Stability, and the Indirect Tensile Test are a few methods that could be selected. The results obtained in the determination of material strength are detailed at the end of this chapter.

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.

TABLE 3.1 MOST IMPORTANT CHARACTERISTICS OF MATERIALS TO 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.

## 3.2 Fly Ash

### 3.2.1 Flexural Strength

Figures 3.1 through 3.3 show the results of flexural tests performed on the different types of fly ash at 40°F, 72°F, and 100°F.

It can be concluded that the catalyst effect of high temperature on the hydration of the fly ash precludes the formation of a strong chemical bond.

### 3.2.2 Compression Strength

Figure 3.4 shows the compressive stresses of different kinds of fly ash when mixed in various proportions with sand. Welch No. 2 and Welch No. 3 refer to different shipments of fly ash from the Welch power plant. As can be seen from this figure there seems to be reasonable consistency in the quality of fly ash coming form this plant. This is important because the research indicated that fly ash obtained from the Welch plant has the best possibility of being an adequate road repair material. Perhaps more importantly, Fig. 3.4 indicates that a fly ash-to-sand ratio of 1:1 or 2:1 works significantly better than a ratio of 1:0 or 1:2 no matter what kind of fly ash is used. This possibility will be examined more extensively in the test which follow. Note that water having a pH of 6.0 was added for all tests in Fig. 3.4.

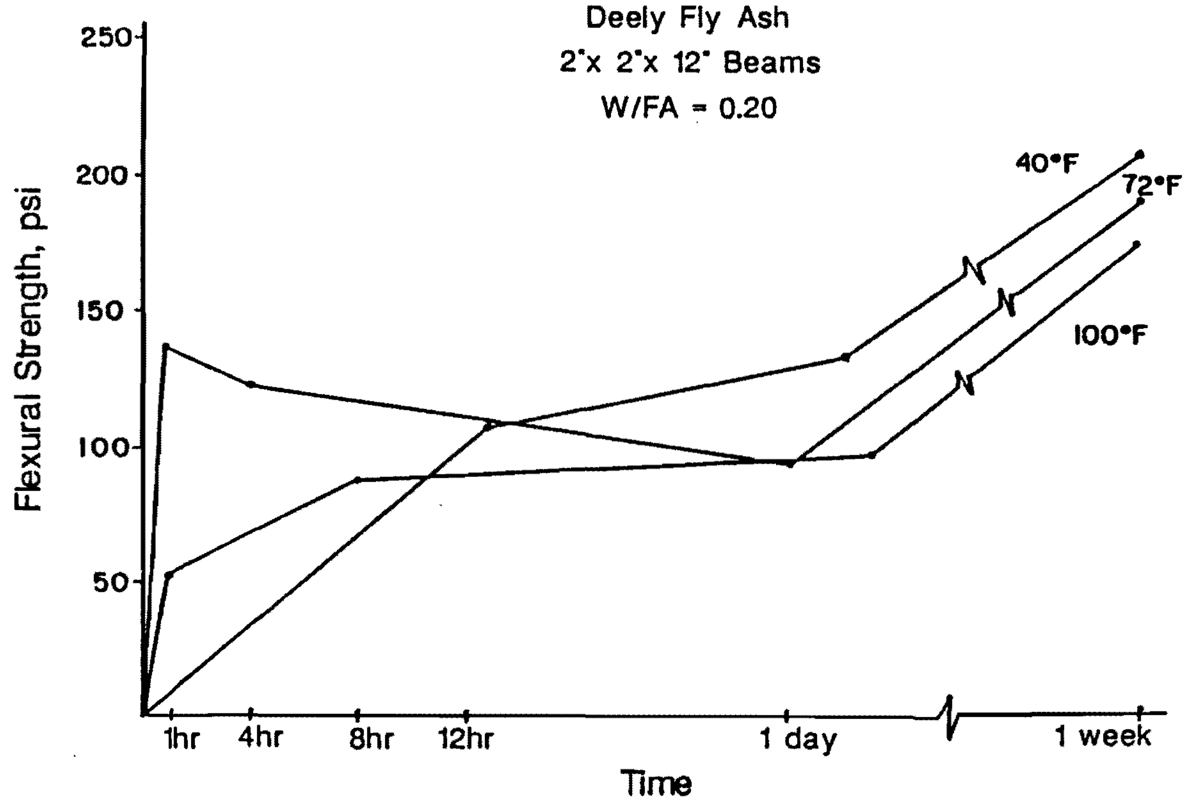

Fig. 3.1 Comparison of the of Deely Fly Ash at Different Temperatures

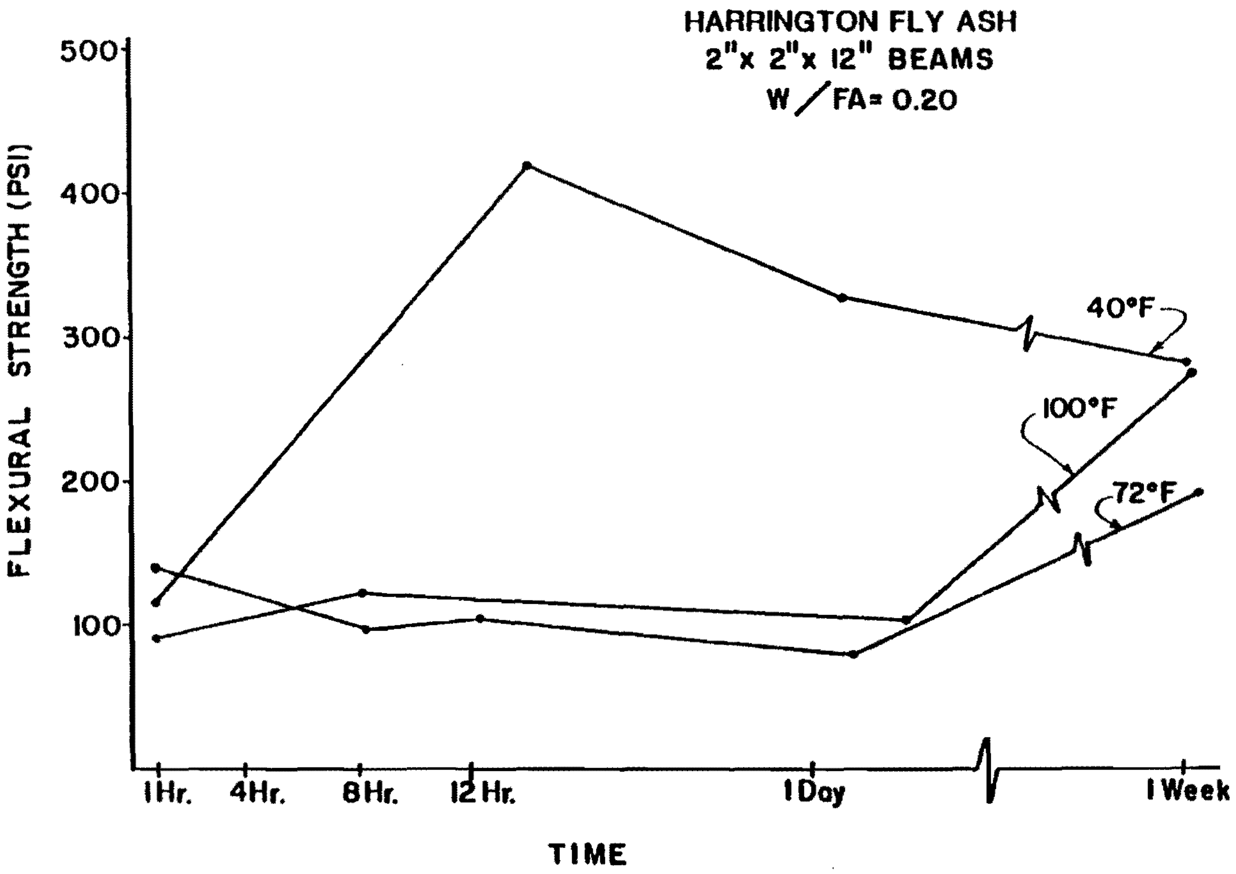

Fig. 3.2 Comparison of the Flexural Strength of Harrington Fly Ash at Different Temperatures

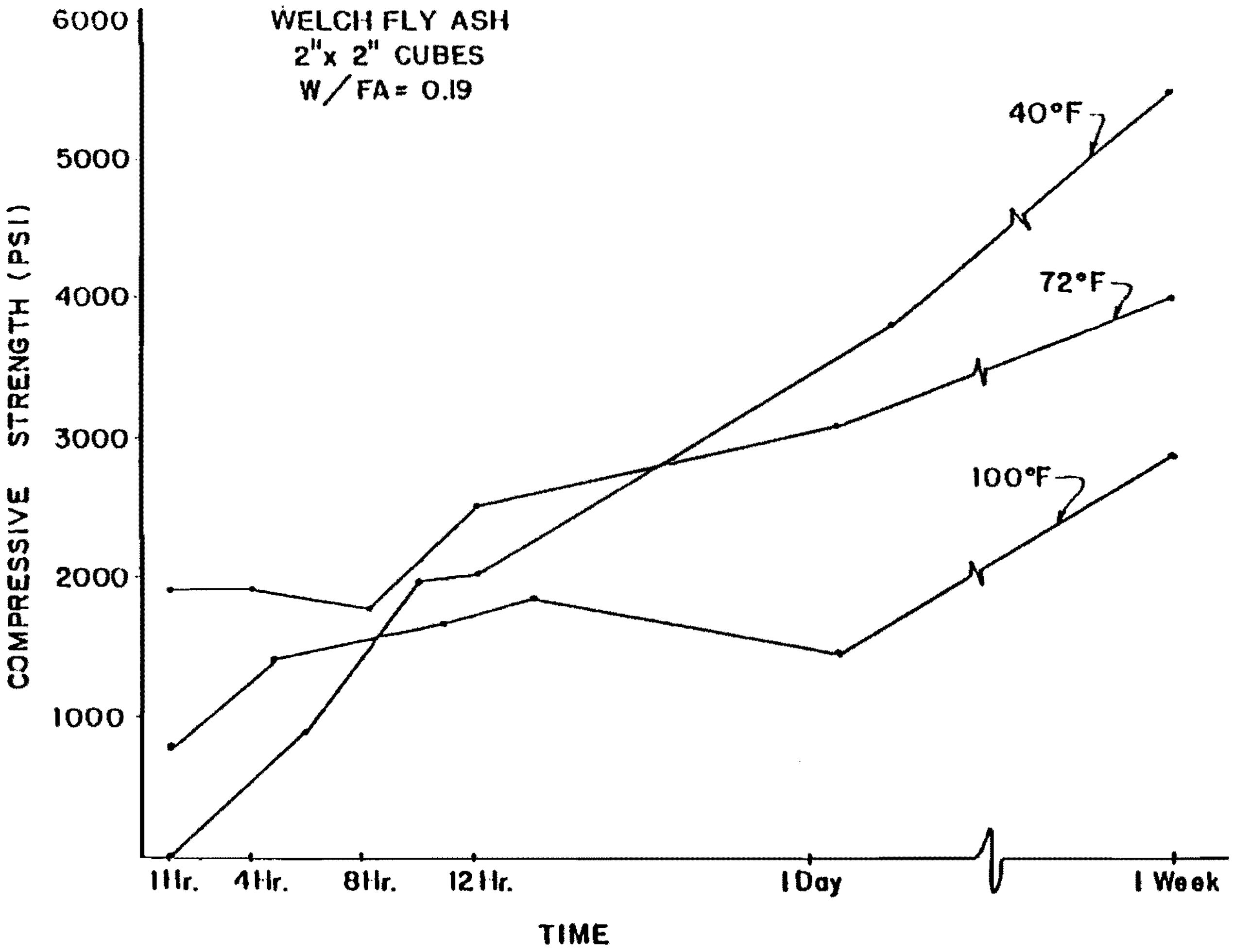

Fig. 3.3 Comparison of the Flexural Strength of Welch Fly Ash at Different Temperatures

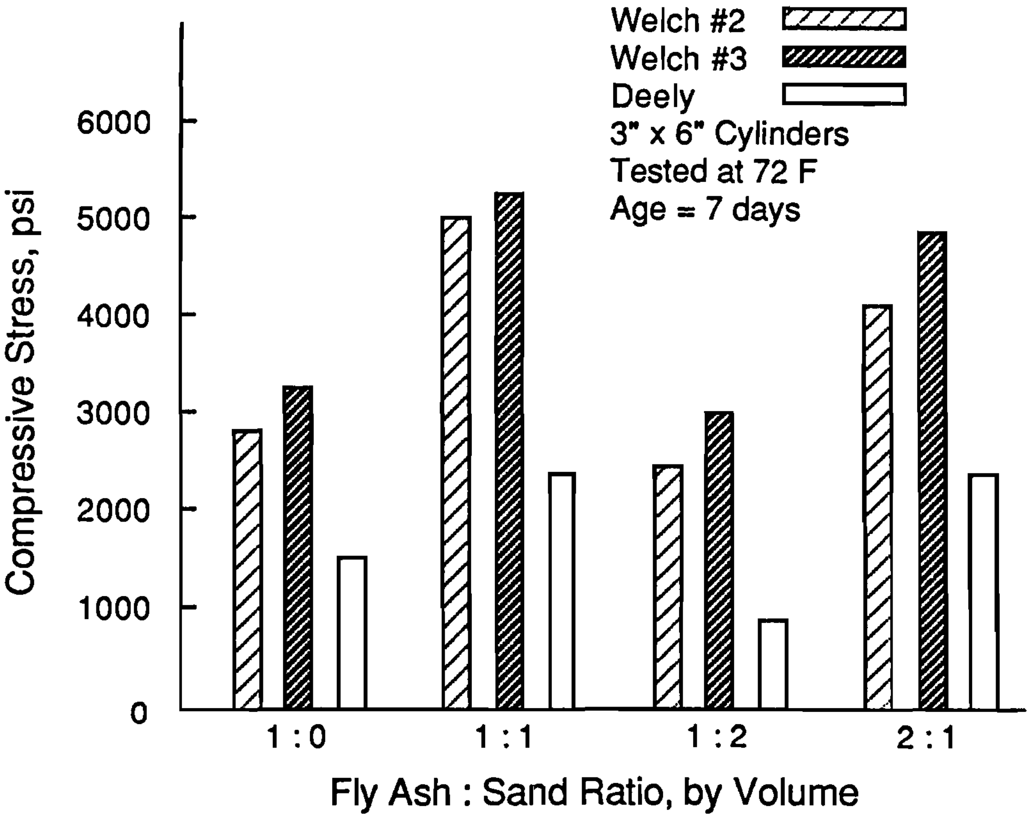

Fig. 3.4 Ulimate Compressive Stresses for various Fly Ash: Sand Ratios.

### 3.2.3 Sensitivity to Water Content

Figure 3.5 shows this relationship for Deely fly ash mixed with different amounts of sand. In general it can be seen that those mixes with less water tend to be stronger no matter how much sand is used. The only exception is the initial value on the 1:1 curve which resulted when so little water was added that the material could not be properly placed within the molds. Another feature shown by this graph is that even though the 2:1 and 1:1 ratios yield much higher strengths, they also tend to be much more sensitive to any excess water which is added. Since it can be anticipated that exact measurements will not be made by maintenance workers who would use fly ash in the field, it is quite likely that some excess water will be added on a regular basis. In considering Fig. 3.5 it should be noted that those points located on the far right of each of the three curves represent extremely wet mixes and normally would not be encountered.

### 3.2.4 Underwater Curing

Because this report is specifically aimed at repairing wet asphalt with fly ash the question arises as to whether fly ash will cure properly if it is submerged under water. This kind of situation could occur if a road repair was made in a section of highway with poor drainage just before a thunderstorm. Although no graphs are shown, various tests indicate that fly ash cures as well under water as it does out of water. Whether standing water has the ability to decompose fly ash which has already cured was not examined in this study and would be an interesting area for further research.

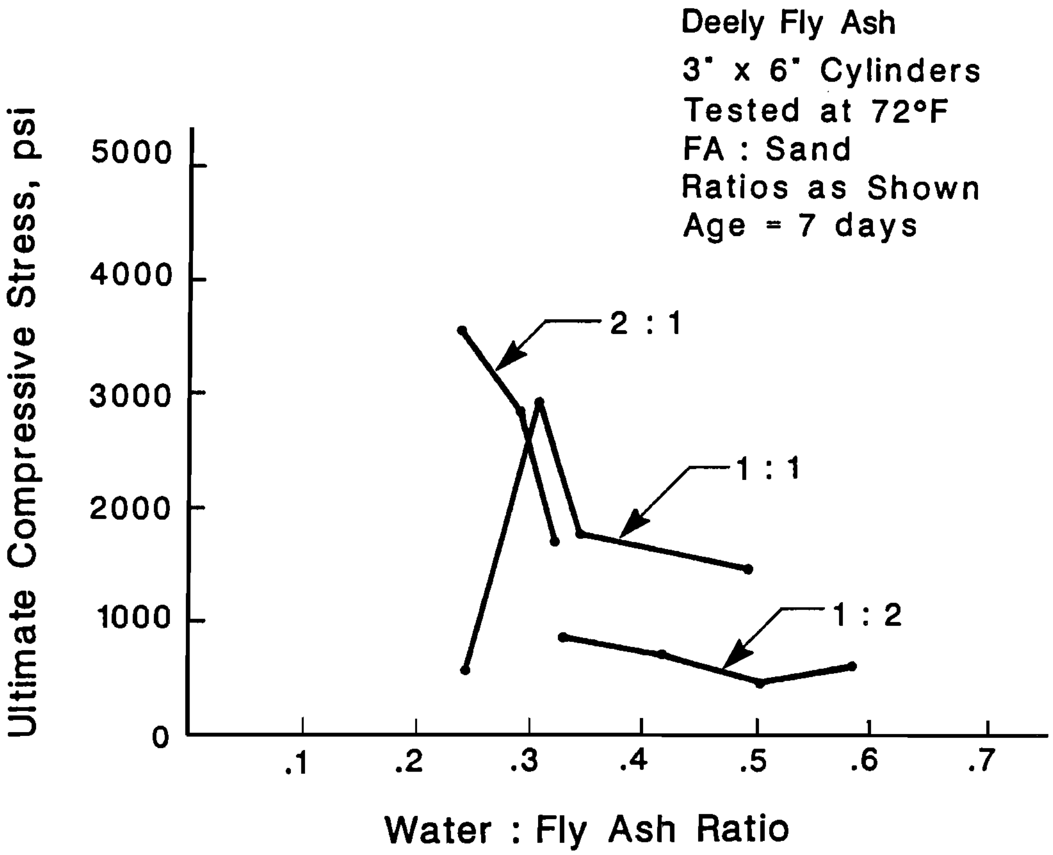

Fig. 3.5 Optimal Water Content for various
FA: Sand Ratios

### 3.2.5 Shear Strength at the Interface

Shear tests were conducted on the different types of mortar examined thus far. As can be seen by the large variations shown in Fig. 3.6 between the high and low values the test appears to be somewhat crude. Only by making hundreds of runs and refining the procedure would it be possible to make absolute conclusions.

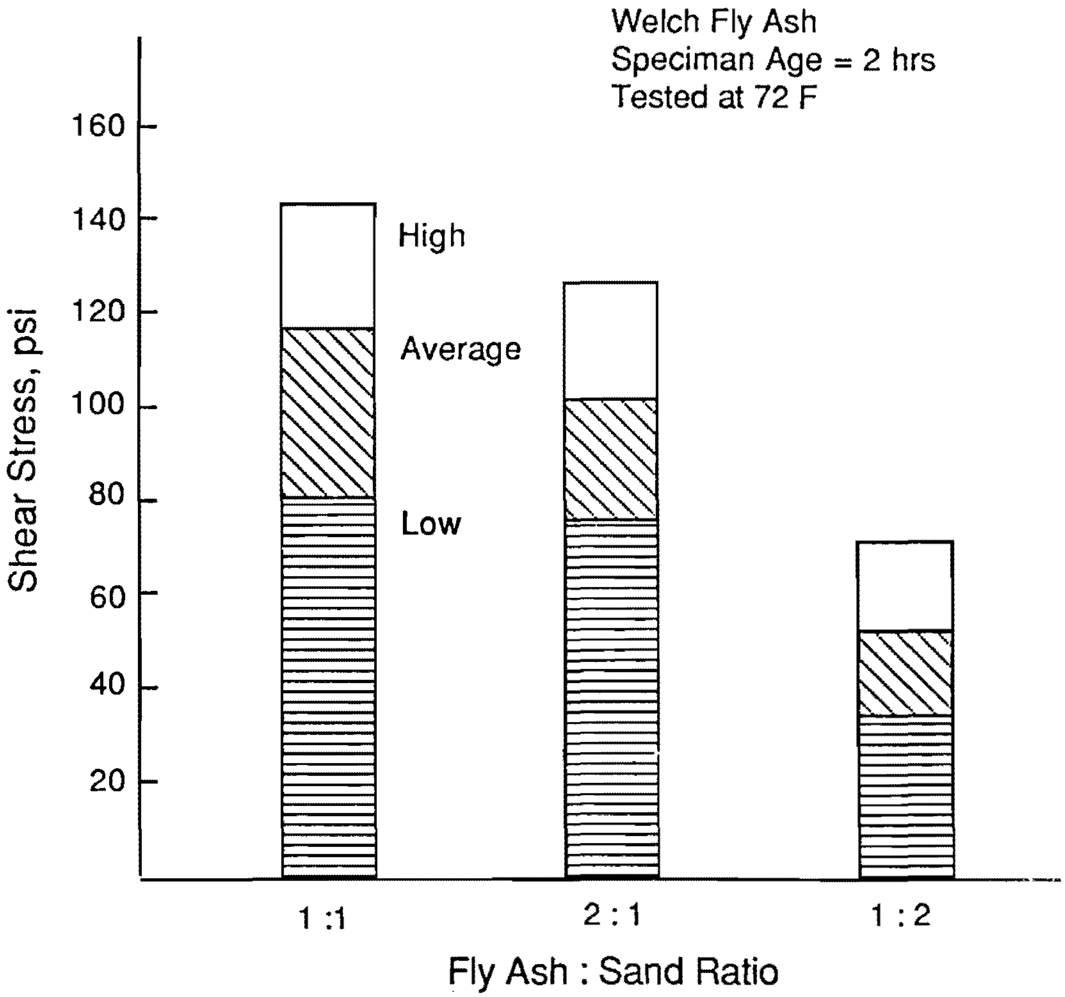

Fig. 3.6 Shear Strength at the Interface between Fly Ash and Asphalt Concrete

Nevertheless, the bar graph does show the tremendous bond that takes place between fly ash and asphalt. Part of the reason for this bond may be the fact that fly ash was captured out of the air and hence is extremely fine. When mixed with water these particles are capable of penetrating microscopic cavities in the walls of the asphalt. The shear bond at the interface appears to be substantially larger for the 1:1 and 2:1 ratios. This evidence supports the use of these fly-ash-to-sand ratios for small road repairs in which the fly-ash-to-asphalt bond may be very important. The fact that fly ash is a strong rigid material coupled with the fact that mechanical interlocking almost certainly takes place help make the bond at the interface stronger than the bond between the asphalt and itself. Indeed, for each of the mortars used, failure sometimes took place in the asphalt rather than at the asphalt-to-fly-ash interface.

### 3.2.6 Polypropylene Fibers

The effect of polypropylene fibers in regard to shrinkage was examined and it was discovered that fibers do not greatly reduce the shrinkage of fly ash mortar. In this section the effect of fibers on compression, flexure and load-deflection will also be examined. In particular, the change of behavior after failure has taken place will be discussed. Fibers were added in the prescribed concentration of 1.6 lb/cu. yd. (0.951 g/liter). Unlike the other materials discussed thus far, fibers must be measured by weight rather than by volume because they are subject to settlement.

Polypropylene fibers have almost no effect on the ultimate compressive stress of fly ash concrete. After many tests incorporating different ratios of fly ash, sand and coarse aggregate, only a slight increase in compression strength was found to occur with the use of fibers. The most important effect of fibers, however, is seen after failure has taken place. Figure 3.7 shows the sudden disintegration of a fly ash cylinder without fibers compared to that of an identical cylinder which contained fibers. This important difference implies that a road repair containing fibers will probably have a longer lifespan after cracking occurs than one without fibers. This gives road repair crews an extended period of time to replace the cracked repair without jeopardizing the safety of highway traffic.

Figure 3.8 shows the results of the load-deflection test in which numerous beams were made with and without fibers. Except for this difference the beams were identical and were tested under identical conditions. As can be seen by the graph the ultimate flexural strength for both sets of beams is the same. Comparing these results with those of shrinkage and compression it can be said in general that fibers do very little to enhance the characteristics of fly ash specimens before failure occurs. Fig. 3.8 appears to indicate a definite advantage after failure if fibers have been used. The beam containing fibers was capable of deflecting over 10 times more while sustaining almost five times the load after failure as the beam without fibers. As with compression, the importance of this advantage is that it will most likely result in a longer repair life. This becomes even more important in light of the fact that flexure is probably one of the major failure mechanisms of fly ash concrete in asphalt road repair.

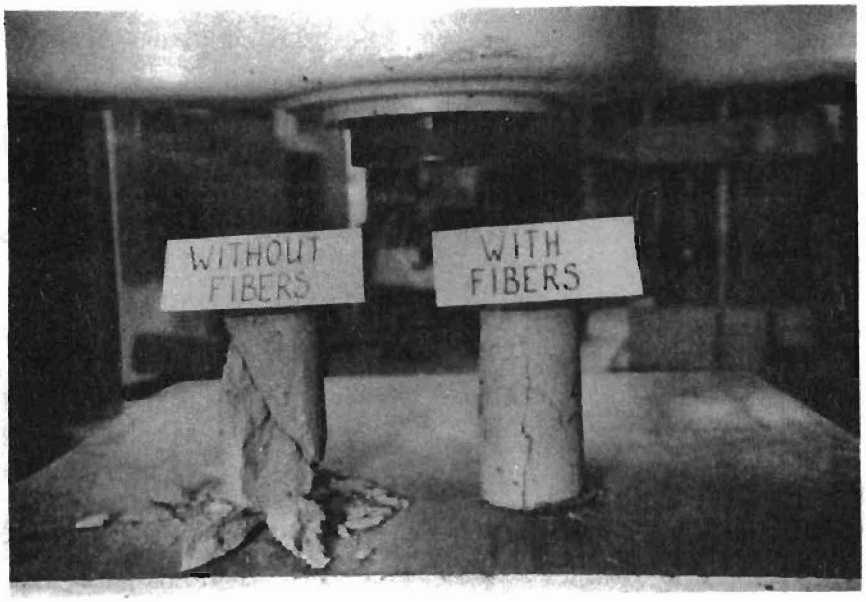

Fig. 3.7 The effect of polypropylene fibers is most significant after failure has taken place

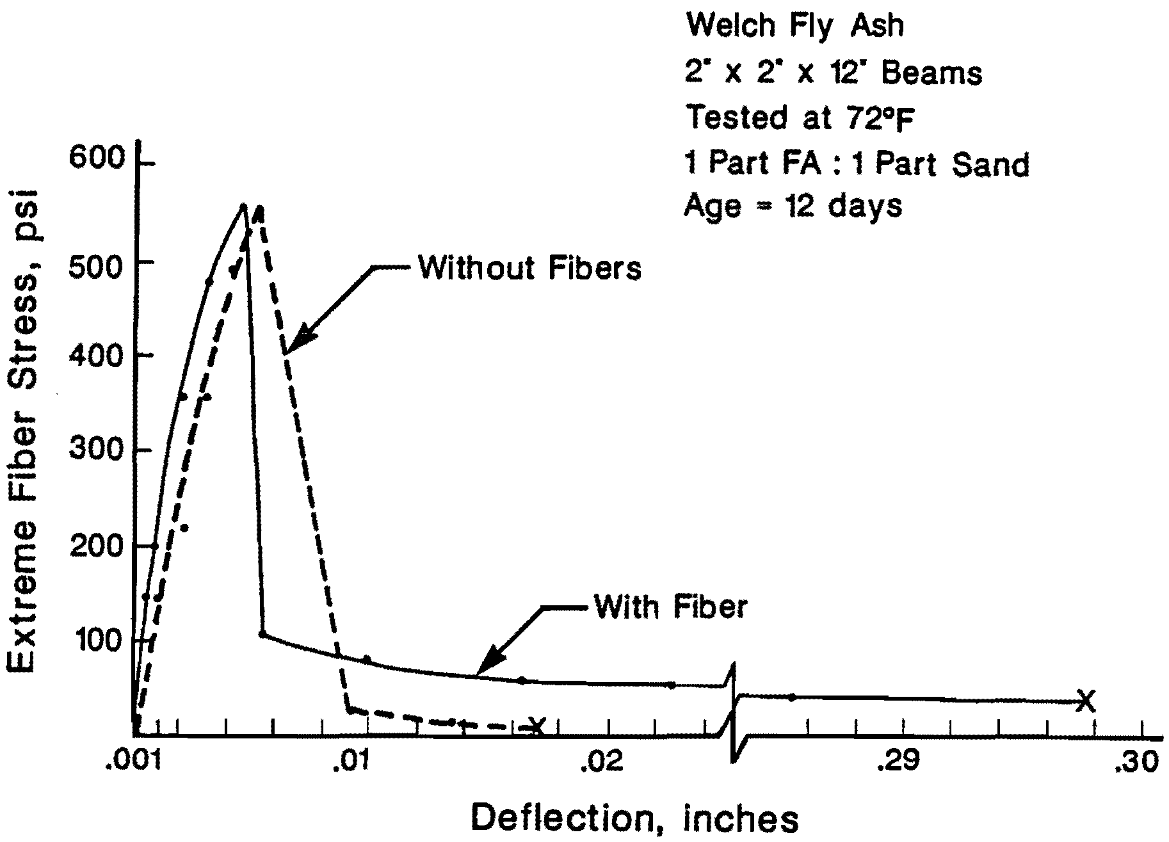

Fig. 3.8 Load-Deflection Test incorporating the use of Polypropylene Fibers

### 3.2.7 Iron Oxide Coloring Agent

Normally, fly ash has a distinctive brown color when it is mixed with sand and aggregate. Figure 3.9 shows the relative colors of fly ash mortar (1 part fly ash: 1 part sand: no aggregate) when mixed with 0.0 percent, 0.2 percent, and 1.0 percent iron oxide by weight. These can be compared with the asphalt concrete cylinder on the far right. Since the brown color of fly ash eventually blends with the color of asphalt (the rate depends on the amount of traffic) adding 1.0 percent iron oxide by weight should be more than sufficient to remove the distinctive brown color. It should be noted that almost no color change occurs in the dry fly ash until immediately after water is added. Furthermore, since almost all other ratios in this report are given in terms of volume, 1 percent by weight converts to about 2 percent by volume when both iron oxide and fly ash mortar are loosely packed. This is based on the approximate dry specific weights of the materials:

fly ash only - 84.7 pcf (1.36 g/ml);
1 part fly ash: 1 part sand - 99.2 pcf (1.59 g/ml);
and iron oxide - 47.2 pcf (.756 g./ml).

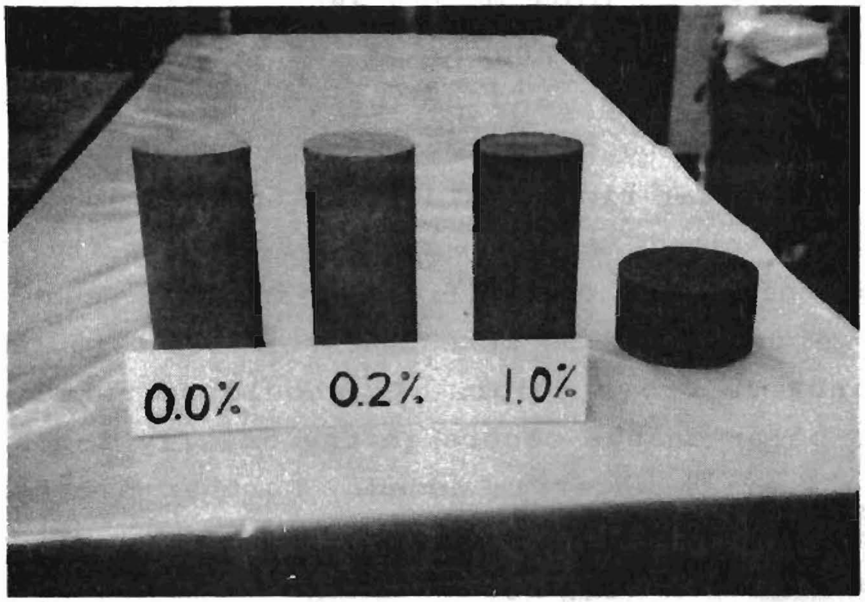

Fig. 3.9 Fly ash mixed with various ratios (by weight) of iron oxide compared to the cylinder of asphalt concrete on the right

### 3.2.8 Compression Tests

Throughout the remaining research, 3/4-in. (19.05-mm) coarse aggregate was used exclusively except where specifically stated otherwise.

Figure 3.10 shows the results of compression tests involving different ratios of fly ash, sand, and coarse aggregate. Each figure represents a specific ratio of fly ash to sand. Moving horizontally from left to right along the graph one sees the effect of increasing the proportion of coarse aggregate in each mix.

One of the first obvious conclusions that can be made from observing all three figures together is that using a mortar of one part fly ash to two parts sand will results in a very weak final product regardless of the kind of fly ash used or the amount of aggregate added. This is important because the natural tendency would be to mix the fly ash initially in the same manner as portland cement, roughly one part fly ash, two parts sand, and three parts aggregate; this procedure was used extensively in the Louisiana studies (5). As can be seen by the data point in the lower right hand corner of the graph, such a combination results in a very weak material.

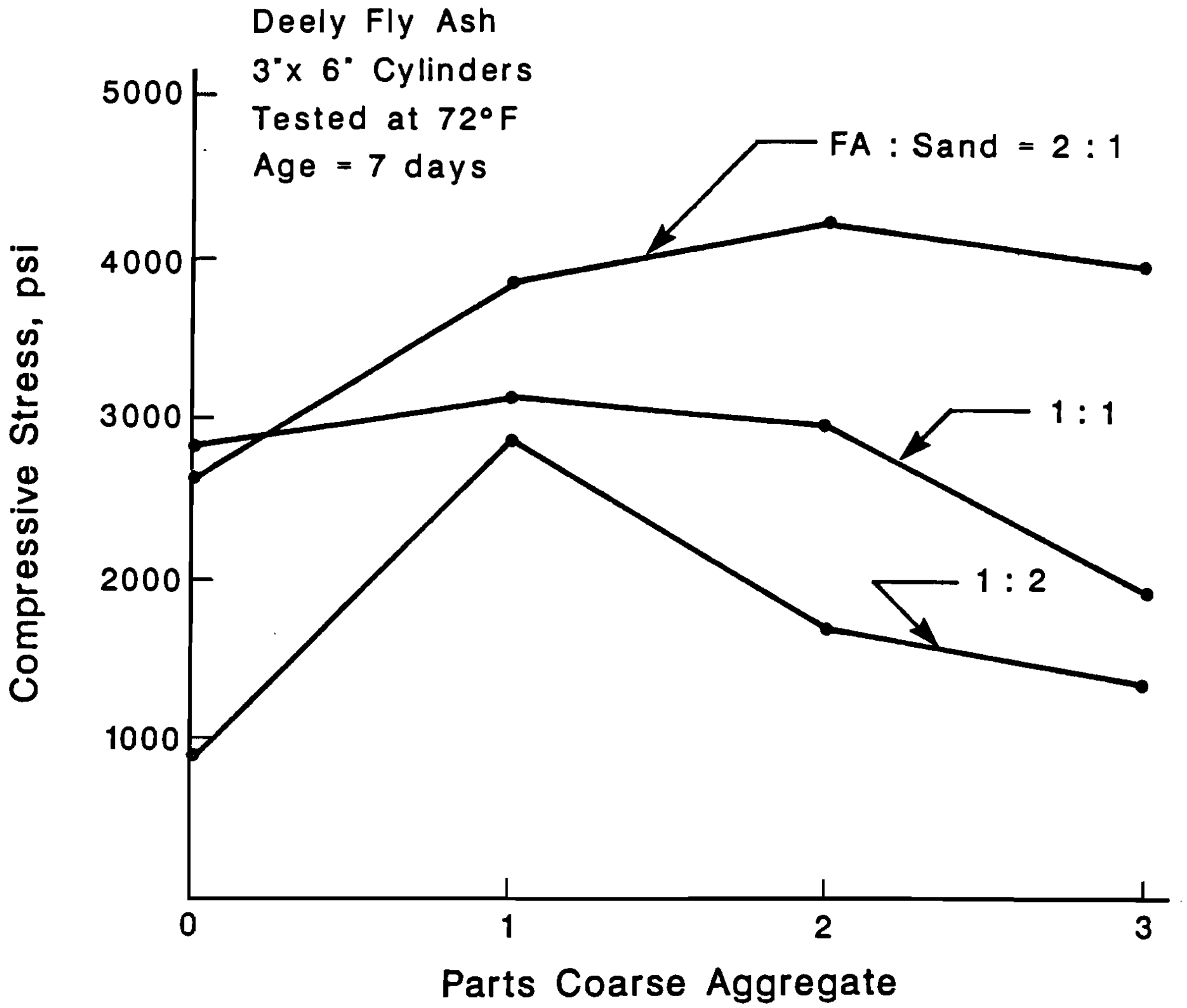

Fig. 3.10 Compression strength of Deely Fly Ash when different mortars are mixed with aggregate according to Table 5.1

A second generalization that might be made from these figures is that the mortar consisting of two parts fly ash and one part sand does not seem very sensitive to the amount of coarse aggregate which is added. In other words, when this mortar is used there can be a large amount of aggregate added with only a modest reduction in strength. This is significant because it has already been mentioned that using a fly ash which contains some aggregate may be advantageous. If aggregate is desired, then these tests indicate that the proportions of two parts fly ash and one part sand result in one of the strongest mixtures possible.

### 3.2.9 Optimal Water-to-Fly Ash Ratio

It is understood that road repair crews do not have the facilities or the time (particularly in wet weather) to make careful measurements of water content in the field. For this reason it is important to ascertain the effects on the fly ash if too much or too little water is added instead of the optimum amount. Figure 3.11 shows the different fly ash mortars considered thus far in which two parts of aggregate are used. It is important to note that the low water-to-fly-ash ratios produce a very dry mix and the high values produce a very wet mix. It would be unusual for a repair crew to mix in an amount of water outside of the ranges which are shown. One of the most obvious conclusions form this graph is the tremendous sensitivity exhibited by some of the mixtures. It appears that adding a small amount of excess water has the potential of reducing the ultimate strength by over 1000 psi (over 25% of the original strength) in some cases. This leads to the question of whether or not fly ash really needs to have the consistency and workability of "typical" wet concrete. Since there may not be a need for fly ash mixes to be placed between narrow openings between rebars or flow into small voids, perhaps drier mixes could be used. Certainly one of the advantages of this is that the fly ash would harden more rapidly. The main disadvantage is that if too little water is added mixing may be incomplete when the hardening takes place and a dramatic loss in strength will occur. Another important feature shown in Fig. 3.11 is that when the stronger mixtures are used there is a good chance that they have adequate reserve strength even if a great amount of excess water is used. In other words, if the 2:1:2 ratio is selected and too much water is added, the chances are good that the resulting f'c of 4000 psi will have adequate strength. In fact, this graph shows clearly that the mortar containing two parts fly ash to one part sand is almost twice as strong even in its wet conditions as the mortar containing one part fly ash to two parts sand in its dry condition.

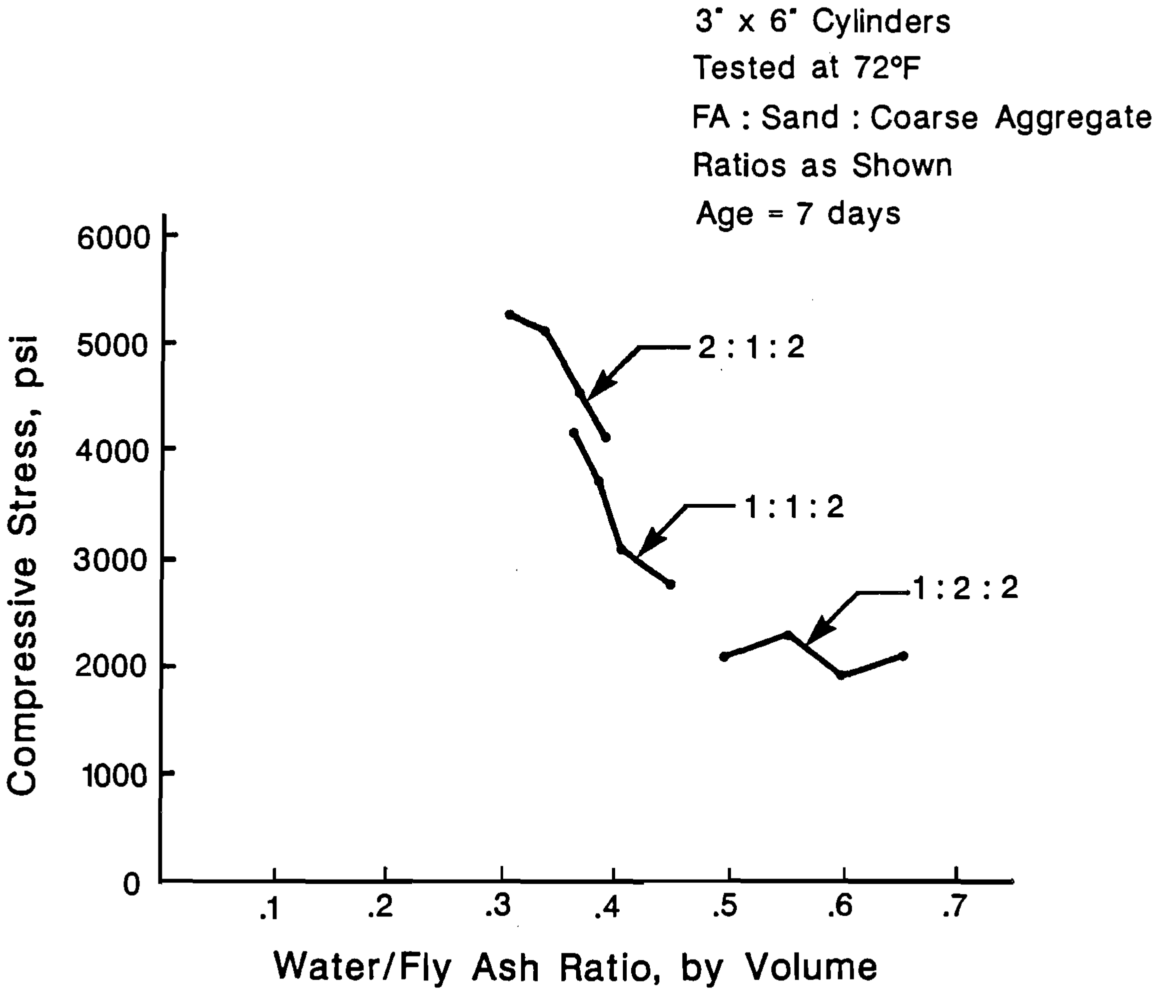

Fig. 3.11 The Optimal Water - to - Fly Ash Ratio for different ingredient ratios of Welch Fly Ash

### 3.2.10 Increase of Strength with Time

One of the most important aspects of fly ash in this research study is the fact that it has the ability to harden very rapidly. Figures 3.12 and 3.13 show the rapid rate at which the fly ash mix acquires strength. Figure 3.12 shows that within 15 minutes there is easily enough strength to support the weight of a car or truck. Figure 3.13 shows that within 24 hours over 50 percent of the ultimate 28-day strength has already been achieved. Although this rate may be slowed somewhat during cooler temperatures, the trade-off is that higher ultimate strengths will ultimately be achieved. Exploring various methods of controlling this rate of hardening may be helpful in view of the fact that new problems, such as incomplete mixing and the inability to clean equipment thoroughly, are generated by rapidly setting materials.

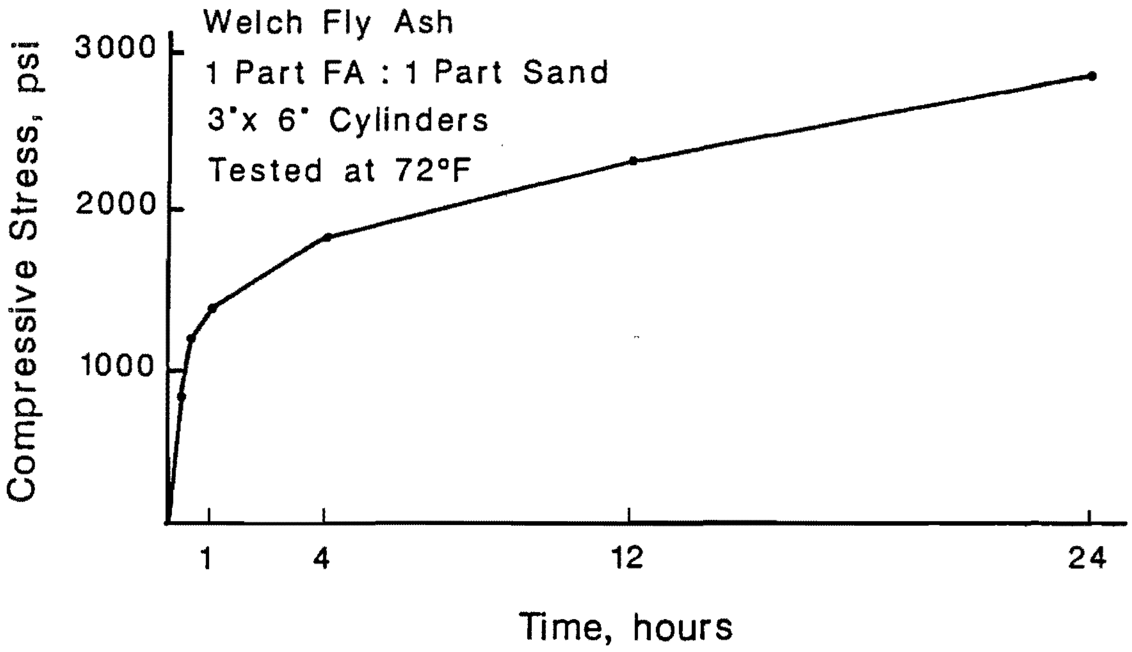

Fig. 3.12 Strength with Time Curve for Fly Ash Mortar (24 hours)

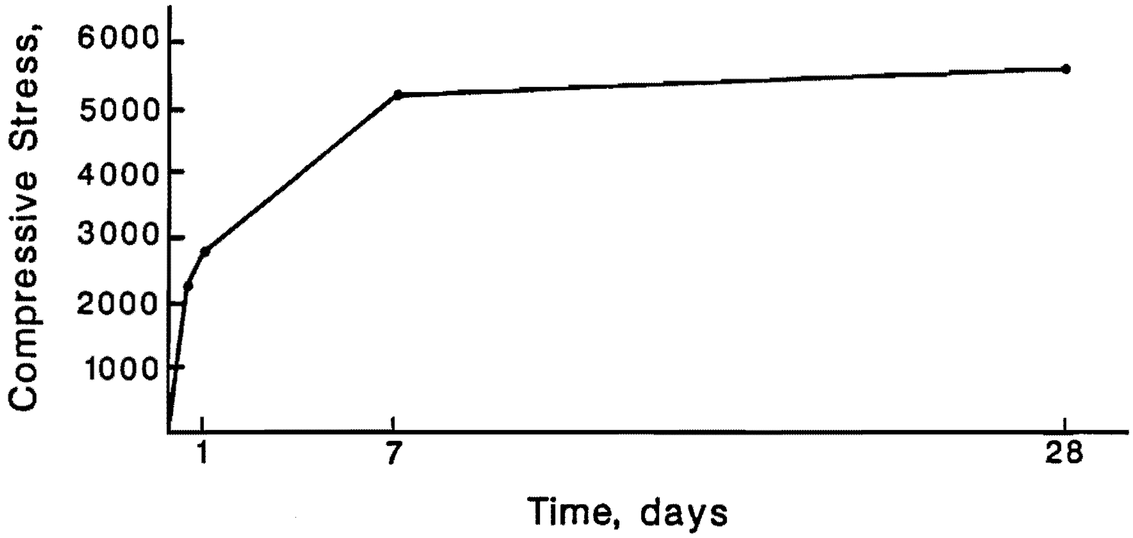

Fig. 3.13. Strength with Time Curve
for Fly Ash Mortar (28 days)

## 3.3 Commercial Asphalt Materials

### 3.3.1 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 hierarchy of relative strengths was the same for both methods -- and it was decided to continue the testing using one method only.

The Indirect Tensile Test and the 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 procedure most clearly 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 having soaked in water, after having undergone freeze-thaw cycling, and after having "cured" at room temperature. Time intervals between preparation and testing were varied in order to determine strength gain or loss with time.

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. (Is it a suitable material for wet repair.)

The response of materials to cold temperatures was 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 cooled as a result of the air temperature ($0^{\circ}F$). It was not practical to place the specimens in a freezing medium, such as water, due to the deterioration of the Sylvax specimens 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 3.2. to 3.4.

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

## TABLE 3.2 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 3.3 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 3.4 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 | | | |

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 3.5.

TABLE 3.5 MARSHALL STABILITY AND FLOW OF MATERIALS TESTED AT 140°F (60°)

| 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.

### 3.3.2 Analysis of Laboratory Test Results

#### 3.3.2.1 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.

#### 3.3.2.2 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 high volume roads. Due to the different manner in which the stability tests were conducted on the repair materials (the SDHPT criteria changes are based on tests conducted at 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 result indicate the 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 freeze-thaw conditions 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.

### 3.3.2.3 Bond Effectiveness

There was considerable variation associated with the results of the bond strength test (Table 3.7). This was no doubt due to the small amounts of materials involved in the testing. Since only a relatively few number of tests were conducted, 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, had the test 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

Table 3.7 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 |

Road Repair is significantly 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 4

# RECOMMENDATIONS FOR USE OF MATERIALS

## 4.1 Fly Ash

The following recommendations are made based on the laboratory and field studies:

1) Although all 3 types of fly ash examined in this report behaved satisfactorily (Deely, Harrington, and Welch) the fly ash obtained from the Welch plant in Cason, Texas, gave the best results.
2) Do not use fly ash when air temperatures exceed 80°F.
3) Add polypropylene fibers in the proportions of 1.6 lb/cu. yd (.000951 g/cc) to control cracking.
4) Add iron oxide as a coloring agent in the proportions of one percent by weight or two percent by volume.
5) If at all possible, premix all of the dry ingredients before reaching the repair site, using a ratio of one part fly ash: one part sand: one part course aggregate (by volume). Include polypropylene fibers and iron oxide in the premix if they are to be used.
6) Fill or drain the pothole so that the water level is approximately one-fifth of the total volume.
7) Add the fly ash premix directly into the pothole and begin stirring rapidly with a hand tool.
8) Continue stirring and adding more fly ash until the mixture has a fairly stiff consistency.
9) Trowel the surface of the repair.

10) Open the repair to traffic as soon as it has hardened, usually within 15 minutes.
11) Fly ash should be regarded as a temporary repair lasting from one to three years.

## 4.2 Commercial Asphalt Materials

Selecting the pothole repair material that best suits the requirements of the Texas State Department of Highways and Public Transportation requires reliance on the old saying, "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 for 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.

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 in 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$^{\circ}$F (4$^{\circ}$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.

## 4.3 Cost

Fly ash in general is very inexpensive when compared with other repair materials. A major portion of the cost is for shipping. For this reason, it is recommended that the fly ash obtained from the Welch plant be used.

The three commercial 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 storage would present a problem.

Instant Road Repair is more moderately priced and is available in bulk. However, its sole distribution point is located 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.

# CHAPTER 5
# HIGHWAY REPAIR PROCEDURE

## 5.1 Fly Ash

For tests which involved different fly ash/sand/coarse aggregate ratios, water was added so that the workability of each mix was approximately the same. Keeping workability consistent for all the different mixes became important because too much water greatly reduced strength whereas too little resulted in an unworkable mix. Because fly ash is a rapidly setting material, conventional methods of determining slump cannot be used unless the time at which the slump was taken is identified. For this reason the workability of each batch was categorized subjectively by observation. A letter scale was used to record the workability: "A" indicates a very watery consistency, "B" indicates optimal workability, and "C" indicates a material too stiff to be considered mortar. Determining the workability by more objective means could be useful in future studies; however, this method proved to be satisfactory for this initial study.

Table 5.1 shows the ratio of ingredients used to produce mixes having the optimum workability. Throughout all the lab and field testing, except where indicated this table was used to determine how much distilled water to add to each mix. Once the total volume of the road repair is estimated, the ratios in this table are enough to determine how much of each ingredient should be added. A method was developed using Table 5.1 to make this procedure as simple as possible. Two different examples

## TABLE 5.1 RATIO OF INGREDIENTS DATA

| FA : S : CA, by Volume | W : TV, by Volume | W : FA, by Volume | S : TV, by Volume | Workability @ 30 Seconds |
|---|---|---|---|---|
| 1 : 1 : 0 | .18 | .31 | .55 | B− |
| 1 : 1 : 1 | .15 | .38 | .40 | B+ |
| 1 : 1 : 2 | .13 | .39 | .33 | B+ |
| 1 : 1 : 3 | .11 | .40 | .28 | B |
| 2 : 1 : 0 | .20 | .27 | .37 | B |
| 2 : 1 : 1 | .17 | .30 | .28 | B |
| 2 : 1 : 2 | .16 | .33 | .24 | B+ |
| 2 : 1 : 3 | .15 | .36 | .21 | B |
| 1 : 2 : 0 | .17 | .43 | .80 | B− |
| 1 : 2 : 1 | .16 | .48 | .67 | B |
| 1 : 2 : 2 | .15 | .56 | .53 | B+ |
| 1 : 2 : 3 | .13 | .56 | .47 | B |
| 1 : 0 : 0 | .20 | .20 | .00 | B− |

Key

FA – Fly Ash
CA – Course Aggregate
S – Sand
W – Water
TV – Total Volume

Workability Index

A – Watery
B – Optimum
C – Stiff

are given illustrating field calculations: (1) when the dry materials are premixed in the lab and (2) when they are mixed in he field. The ratios given in Table 4.1 are based upon all materials being loosely compacted.

### 5.1.1 Sample Calculations When Using Premixed Dry Materials

Typical road repairs come in random shapes and often it is difficult to estimate the volume of material required to fill them. The method which consistently gave the best results was the following:

1) Estimate the area of the hole at the road surface.
2) Estimate the area at the base of the hole.
3) Average the two areas and multiply by the depth.

Thus, for a 9-in. (22.9 cm) deep hole with an area at the road surface of 500 square inches (3226 sq. cm.) and an area at the base of 300 square inches (1935 sq. cm.) the estimated total volume would be:

9 (500 + 300)/2 = 3600 cu. in. (13.4 gal.)

To fill the hole with a mix containing two parts fly ash, one part sand, and two parts aggregate (2:1:2) the premixed dry ingredients using these ratios would be brought out and 3600 cu. in. removed. This should be sufficient since the volume of dry ingredients changes only a small amount once water is added. Next, the volume of water is calculated by referring to the second column in the row containing the 2:1:2 ratio of Table 4.1. Since the total volume is 3600 cu. in. the amount of water needed in our example is:

Water Volume - .16 x 3600 = 576 cubic inches (2.1 gal.)

### 5.1.2 Sample Calculations When Dry Materials are not Premixed

Assume that a road repair the same size as in the previous example needs to be filled with the same ratio of ingredients except that none of the materials has been mixed prior to arriving at the test site. Using the first, third, and fourth columns of Table 4.1, the amount of each ingredient may be calculated as follows:

Sand Volume = (0.24) (3600) = 864 cu. in. (3.2 gal.)
FA, Aggregate Volume = (2) (864) = 1728 cu. in. (6.4 gal.)
Water volume = (0.33) (1728) = 570 cu. in. (2.1 gal.)

In any case, because fly ash will harden in about four minutes, the dry ingredients ought to be mixed together (including fibers and iron oxide if desired) before the water is added.

### 5.1.3 Mixing Procedures

#### 5.1.3.1 Mixing Directly in the Pothole

Several methods of handmixing were used in an effort to determine a fast and simple method for placing this material. Because Welch fly ash hardens so rapidly it was decided that hand mixing ought to be seriously considered so that the potential of hardening in mixing machines could be eliminated. By far, the method that seemed to be the most efficient was that of mixing the fly ash right in the pothole itself. Figures 5.1 to 5.8 show the complete procedure by which the majority of the road repairs were made. The method was found to be simple, efficient, and most important, fast. Different hand tools were tried but the one shown in this series of photographs seemed to work particularly well. The fact that the blade is smaller than that of a hoe and also at a slight angle gave it more versatility and better mixing characteristics than most other tools. It is called a "Swoe," a trademark of the manufacturer, True Temper, Allegheny International Hardware Group, Shiremanstown, Pa. Some of the advantages of this method are that no expensive equipment needs to be transported or maintained. Working with an electric generator in wet weather conditions is not recommended. Cleaning of tools after the repair is completed is very simple and because of the rapid setting characteristic of fly ash this is an important feature. If it appears that the fly ash is beginning to harden before the water has been thoroughly mixed the material can be quickly smoothed out and troweled. Mixing directly in the pothole eliminates the danger of having the material harden in a mixer. One of the disadvantages of this method is that it is difficult to prevent either fly ash or water from splashing out of the hole and so for research purposes the exact quantities of either material could only be approximated. Also, there may be times when it will be difficult to mix the materials thoroughly. This could be due to an exceptionally jagged surface on the interior of the hole or to high temperatures which initiate more rapid curing or simply to a repair requiring a large volume of material. For large potholes, better mixing may be obtained by making several small batches in sequence as

Fig. 5.1 The loose material is first swept from the base of the pothole

Fig. 5.2 Measurements are taken in order to estimate the volume of material needed

Fig. 5.3 The sides of the hole are moistened to simulate wet weather conditions

Fig. 5.4 A measured amount of water is poured in the hole

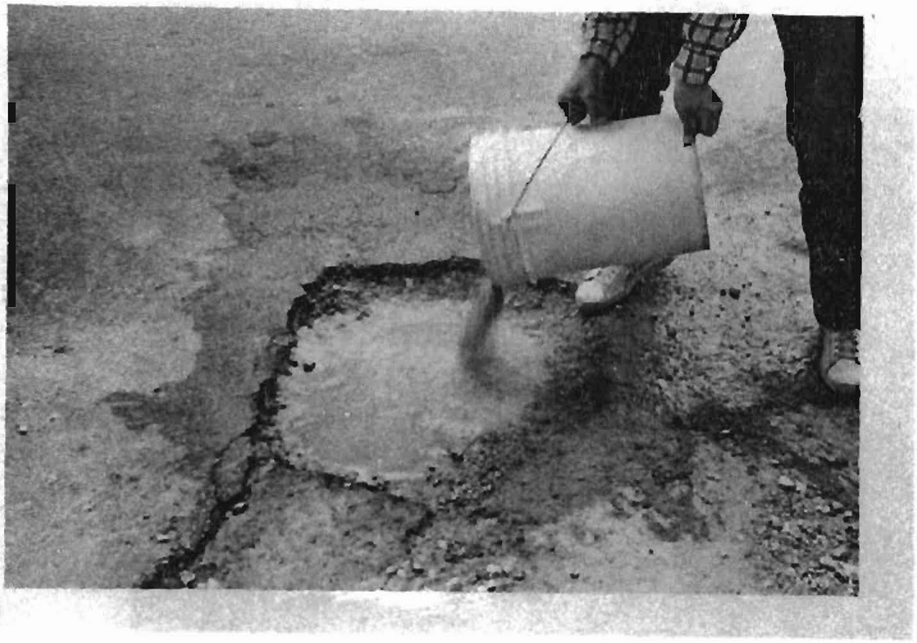

Fig. 5.5 A corresponding amount of premixed dry material is then added

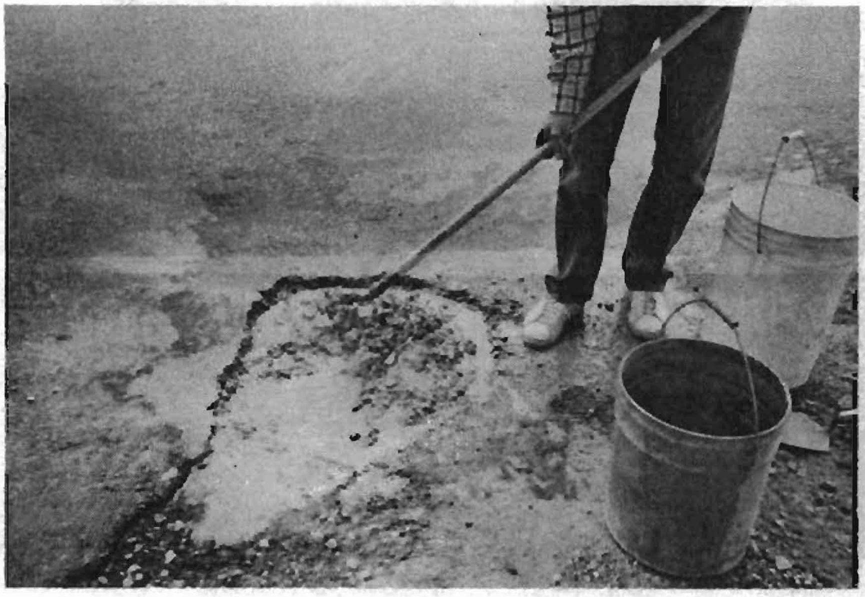

Fig. 5.6 The materials are thoroughly mixed with a hand tool

Fig. 5.7 The surface is troweled to a smooth finish

Fig. 5.8 The material is hard before the water has even evaporated from the surrounding road surface

opposed to one very large batch. Although it will be discussed later, the cold joint between a new batch and a freshly hardened batch does not appear to be a problem

### 5.1.3.2. Mixing in a Wheelbarrow

Because mixing materials in a wheelbarrow with a hoe is a fairly common practice very little needs to be said. This method has most of the advantages of the previous method and it may be that it is especially helpful ofr larger road repairs. Again it should be stressed that this material is not portland cement and that mixing must be done as quickly as possible once the water comes in contact with the fly ash.

### 5.1.3.3 Mixing in a Bucket

To alleviate the problem of splashing, several potholes were filled by first mixing the material in a five-gal. bucket. The procedure was simply to pour in the correct amount of water first (this is important), add the fly ash mix and stir with the "swoe" hand tool. This method worked extremely well because there was no mess, the bucket was easy to clean, and there could be certainty that the materials were mixed in proper proportions. The main limitation of this procedure is that it obviously could not be used for large repairs. Even so, many of the repairs which must be filled during wet weather will be small in size and well within the range of this procedure. Since normally the bucket is filled to more than two-thirds capacity a somewhat larger container may be desirable.

#### 5.1.3.4 Machine Mixing

For very large road repairs there may be no alternative other than using conventional machines to mix the material. A sufficiently large crew should be available to place the material and to clean the machine immediately after the mixing is complete or the material will begin hardening very rapidly inside. Because the rate at which fly ash hardens is sensitive to temperature, special precautions may be necessary in hot weather. At the expense of decreasing strength, extra water should be added to provide more time for thorough mixing to take place. Extra water may be required whenever machine mixing is used but it is especially important when the temperature is above 75°F. In any case, the first step in any mixing operation should be to put the correct amount of water into the machine before any dry material is added. This is especially important for fly ash because if the dry material is added before the water, the sticky nature of fly ash will prevent mixing from taking place.

## 5.2. Commercial Asphalt Materials

Manufacturers' recommendations for application are quite similar and should be followed as much as is practical. Specific hole preparation methods and methods of placement are detailed in the following photographs (Fig. 5.9 - 5.17), but the general method of placement is quite simple.

The procedure first involves "squaring off" the damaged area into a rectangular hole. If possible, the sides should be cut so that they are vertical. If this is not possible use of these commercial materials still will generally give better results than conventional materials.

Fig. 5.9 Prepare hole by forming rectangular area.

Fig. 5.10 Sweep area to be repaired clean of debris.

Fig. 5.11 Shovel repair material into area to be repaired directly from container.

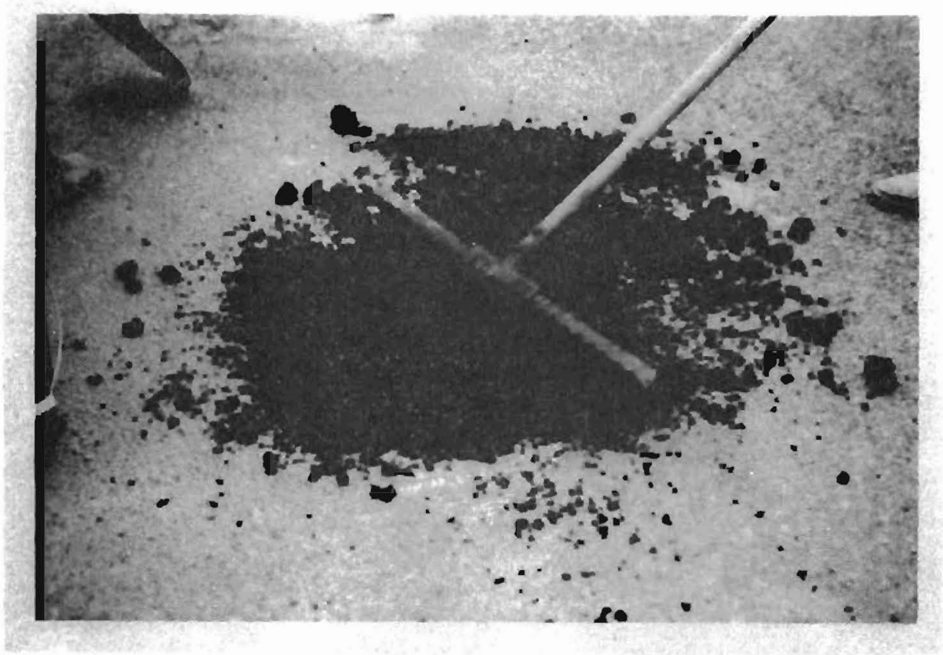

Fig. 5.12  Rake area to provide a smooth, even finish.

Fig. 5.13 Insure the repair material makes adequate contact with the sides of the area to be repaired.

Fig. 5.14 Provide initial compaction by striking area with the back of a shovel.

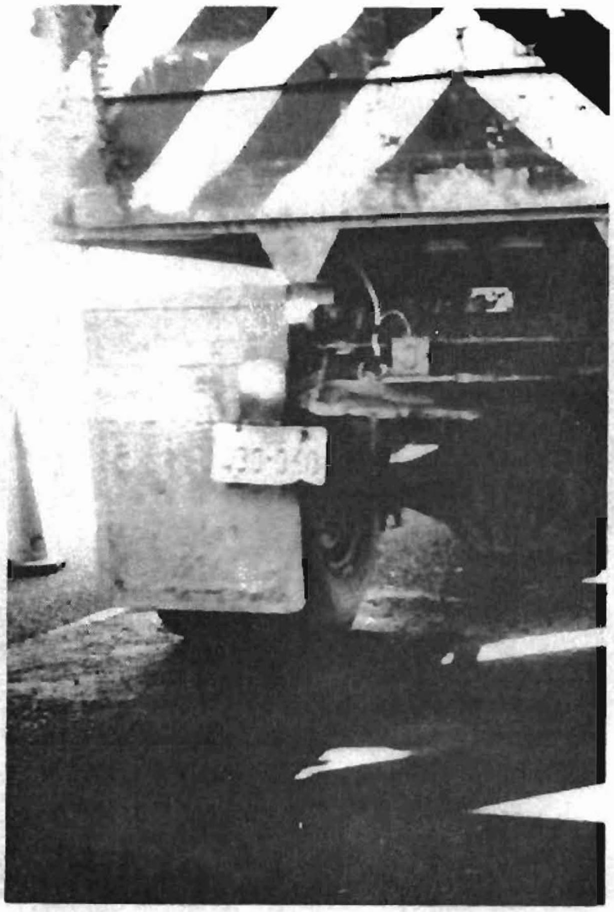

Fig. 5.15 Passage of a heavy truck 10-15 times complete compaction requirement.

Fig. 5.16 At cold temperatures, repair material is unworkable.

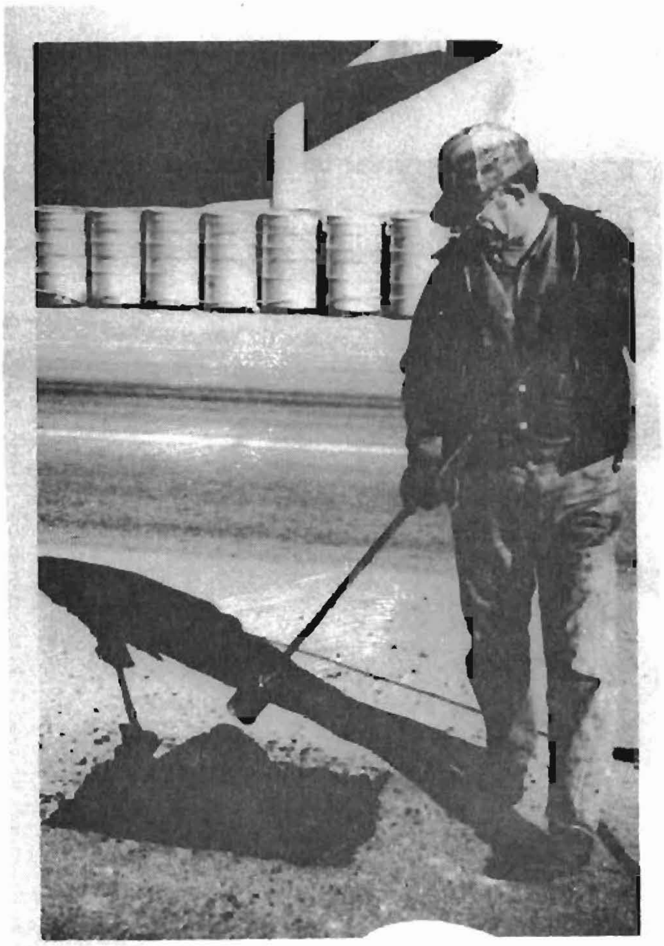

Fig. 5.17 Apply direct heat to "frozen" material to regain workability.

Excess standing water should be broomed out of the hole along with any loose debris. Finally, the material should be placed in one or more lifts. Striking the repaired area with the back of a shovel initially provides sufficient compaction to allow for the passage of a truck. A 2-1/2 ton dump truck (unloaded) is then driven over the repaired area 10 to 15 times before the area is opened to traffic.

Enough material should be 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 causes the material to compact to the extent that, after 10 to 15 passes, the level of the repaired area is essentially at grade with the original pavement.