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16. Abstract

The primary objective of this study is to identify cold-laid paving materials which could provide viable alternatives to Limestone Rock Asphalt (LRA) currently produced by Vulcan Materials Company at its quarry near Uvalde, Texas. The requirements were that the materials be suitable for stockpiling application in winter-wet weather, not require specialized equipment for handling, and be cost-effective. To meet the objective of the study, performance requirements for successful cold, wet-weather pothole and surface patching materials were established, using surveys of maintenance programs in Texas and other states.

The study also involved the field testing and performance evaluation of a number of cold, wet-weather maintenance materials. A total of 13 different maintenance mixture designs were evaluated in seven districts. Both pothole and surface patching (blade-on) maintenance operations were incorporated into these trials. The performance of these materials was evaluated over a nine month period. All participating districts were visited at least twice during this period, and discussions relative to the handling and performance of these mixtures were held with the district maintenance personnel.

A laboratory test program was performed to characterize the materials utilized in the field trials. It was found that most current mix designs for hot mix-cold laid, maintenance materials were inadequate except at temperatures above 60°F. Stockpile hardening often required that mixtures be softened with additives and reworked before they could be placed. To offset these deficiencies, a new mix design was generated using criteria gleaned from literature and field surveys.

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# ALTERNATE MATERIALS

# FOR

# LIMESTONE ROCK ASPHALT

by

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Final Report

Research Study No. 2-18-91-1176

Prepared for

Texas Department of Transportation
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Texas Transportation Institute
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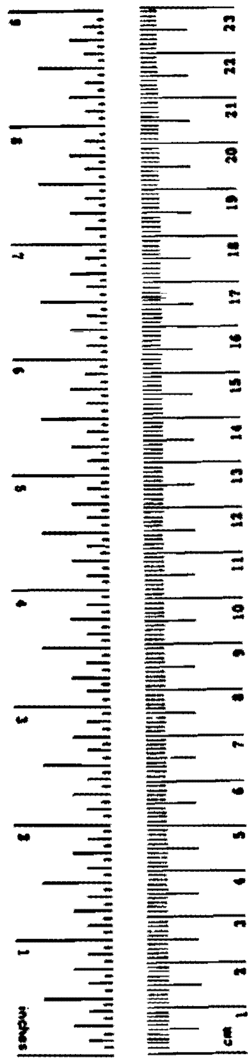
# METRIC (SI*) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

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

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

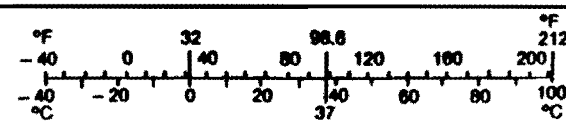
| | **TEMPERATURE (exact)** | | | |
|---|---|---|---|---|
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |



## APPROXIMATE CONVERSIONS TO SI UNITS

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

| | **TEMPERATURE (exact)** | | | |
|---|---|---|---|---|
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |




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

* SI is the symbol for the International System of Measurements

## IMPLEMENTATION STATEMENT

Field, laboratory, and library investigations were conducted in an attempt to find suitable alternatives for limestone rock asphalt (LRA) maintenance mixtures so LRA would not have to be purchased on a proprietary basis. As written, Texas DOT Specification Item 330 allows no product other than LRA which is available only from a single source near Uvalde, Texas. In order to permit competitive bidding, it appears that LRA must be allowed to compete with other specification items, either existing or forthcoming. Specifications (toward this end) are suggested and recommendations are given herein.

A new LRA material was developed by Vulcan, as a result of this study, which provides a cost-competitive alternative for Unique Paving Material (UPM). Field performance of these materials was essentially equivalent. Minor handling problems associated with the new LRA are presently being addressed by the supplier.

Paving material are normally purchased on a weight basis but applied on a volume basis. Materials of significantly different weight per unit volume often provide equivalent performance. It may be advantageous to the state to specify that purchases be made on a volume basis rather than weight.

Research is needed with the specific objective of developing a laboratory test method to quantify cold-weather workability of maintenance mixtures both in the stockpile and for application.

## DISCLAIMER

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# INTRODUCTION

## BACKGROUND

This project was necessitated by the declaration of Limestone Rock Asphalt (LRA) DOT Standard Specification Item 330, as a sole source procurement item. This action also limited the availability of LRA as a low-cost, cold mix-cold laid material for cold weather maintenance activities. The unique characteristics of LRA are derived from its existence in an almost ."ready-to-use" condition in naturally created deposits located almost exclusively in Texas. Attempts to use other existing (DOT) specification items to offset the inability to purchase LRA have, for the most part, been unsuccessful due, in part, to poor stockpile longevity, high cost and/or inadequate performance. The need to resolve this problem, either by identifying suitable alternative mix designs or by means of recommended changes in DOT procurement policies, was the objective of this research effort.

## LIMESTONE ROCK ASPHALT

Limestone Rock Asphalt (LRA) is a relatively hard, porous stone impregnated with natural bitumen comparable in grade to that of Mexican or Trinidad asphalt. This material is found in very large deposits in the southwest corner of Uvalde County, Texas, and extending into Kinney County. The material is marketed by Vulcan Materials Company of Birmingham, Alabama, and its subsidiaries. LRA is quarried with the aid of explosives, which create tremendous piles of rubble, including very large boulders. These boulders are passed through a series of primary and secondary crushers and screened to standard gradation specifications for asphaltic mixtures.

After crushing, the limestone rock asphalt aggregate is blended with varying amounts of flux oil, water, neat asphalt and additives to produce a series of cold mix-cold laid (CM/CL) paving materials for highways, streets, parking lots, etc. Since the aggregate contains natural bitumen, the amount of additional asphaltic binder required to produce a quality paving mixture is significantly reduced.

The rock asphalt deposits mined in Uvalde County, Texas, reside in a late, cretaceous formation known as Anacacho Limestone. According to geologists, 65 to 70 million years ago, the development of this limestone was closely tied to volcanic activity of that period. Volcanic eruptions on the floor of shallow marine seas which covered south Texas at that time created small volcanic islands. These outcroppings served as nuclei for carbonate development (1).

In shallow, warm water, these coalesced carbonate beaches and reefs formed on the flanks of closely spaced volcanic mounds. Thick, laterally extensive accumulations of carbonate sediments composed mainly of broken particles of shells and plates and spines of various marine organisms, particularly of sea urchins, mollusks, and small foraminifera, were later exposed to fresh water environments due to lowering of sea level.

Out of the marine environment, the carbonate sediments evolved into hard, fossiliferous limestone. The diagenetic processes which changed the sediment into solid rock also created less dense layers which resulted in thick sequences of porous, permeable rock as well as "tight" non-porous strata.

The limestone was then buried beneath other formations. The porous and permeable Anacacho Limestone subsequently acted as a trap for migrating hydrocarbons causing the limestone to act as a giant hydrocarbon reservoir. Through millions of years of erosion of the overlying formations, the Anacacho was exposed to this migration. In contact with the surface, the hydrocarbons devolatilized and produced the asphalt we find today. This naturally produced resource of bitumen impregnated stone possesses properties typical of high-grade asphaltic paving mixtures.

In LRA, the asphalt is integrally bound into the aggregate, and the natural binder content varies between 3 and 10 percent (2).

LRA commonly exhibits 4-cycle Magnesium Sulfate test loss values of between 5 and 15 percent (3). These excellent soundness numbers are attributable to the size, type, and cementation of the fossil shell particles in the lean rock asphalt. The lean rock asphalt is composed of very small fossil shells which are cemented together by coarsely crystalline calcium carbonate. This type of cementation is relatively non-porous, which leaves the magnesium sulfate solution very little opportunity for disruptive duty.

Excellent polish numbers (38 to 41) are also related to the hard fossiliferous-broken shell composition of the limestone. Coarsely crystalline calcite cement crystals, and shell fragments act to generate excellent friction on pavement surfaces.

LRA has been used as a highway paving material in the United States since the latter part of the 19th century. It was shipped from Texas by water to New York City, Philadelphia and other northeastern states to compete against other natural bitumen materials imported from Trinidad. It was first used in San Antonio, Texas, in the 1890s as a hot mixed street and road surfacing material. LRA was pulverized, heated to about 300°F without any additives, placed and compacted to achieve the required density (3).

By 1928, the first LRA cold mix-cold laid (CM/CL) material had been developed. This material could be prepared at the quarry and shipped long distances to the job site ready to place (4). In contrast, conventional hot mix materials must be prepared in central hot mix plants usually located near the job site.

It is estimated that approximately 65 percent of the total LRA production in Texas is utilized by the Texas Department of Transportation (DOT) primarily for pothole repair, patching, level-up and blade-on maintenance operations (5) in addition to construction. At the present time, CM/CL mixtures utilizing flux oils, cover stone for surface treatments, and seal coats are the primary LRA products used by the State. Specifications (6) covering these uses include:

1) Item 302, Type E (Aggregate for Surface Treatments, Class B).
2) Item 304, Type PE (Aggregate for Surface Treatments, Precoated - Class B).
3) Item 330, and Item 332 (Cold Mix Limestone Rock Asphalt Pavement, Class A and Class B).

From the above discussion, it is apparent that LRA has become one of the more frequently utilized maintenance materials in the State, and thus its performance on highway pavements is of particular interest to the Texas DOT. For this reason, the State has undertaken several studies to investigate the properties of LRA mixtures and to evaluate their performance on the roadway. Some of these investigations include:

1) Use of rock asphalt coarse aggregate in HMAC (3).
2) Skid resistance of LRA pavements (2,3,7).
3) Properties of rock asphalt screenings (8).
4) The effect of flux oil type and content, white rock content, bitumen content of aggregate and gradation on mixture performance (9,10,11,12).

Three additional investigations performed by TTI for White's Mines of San Antonio in 1982 represent some of the more recent investigations of LRA paving mixtures (13,14,15). These studies evaluated the structural integrity and curing characteristics of various sections of the highway in five districts in which LRA paving mixtures were used in surface courses (13). The investigation was extended to assess the effect of flux oils and aggregate gradation on properties of cold mix LRA paving mixtures (14,15). These studies formed the groundwork for upgrading mix design rationale and extended the use of cold mix LRA mixtures to pothole repair, blade-on patching, and other maintenance operations.

Over the years, the LRA material has been furnished by White's Mines and Uvalde Rock Asphalt Co. A few years ago, White's Mines acquired Uvalde Rock Asphalt Co. More recently, White's Mines was purchased by Vulcan Materials of Birmingham, Alabama. Although the basic price of these materials has remained relatively unchanged during this transition, problems associated with its recent designation as a sole-source procurement item has created the need for alternate products to provide competition for LRA.

## ALTERNATIVE MAINTENANCE MIXTURES

Current alternatives to the use of LRA include DOT Specification Item 350, which is a hot mix-cold laid specification, UPM (Unique Patching Material) Special Specification ????, and IRR (Instant Road Repair) Special Specification 3563. Another hot mix-cold lay mixture, Special Specification Item 3475, was developed by D-9 but was not recommended for use on this project (16).

Problems associated with the use of hot mix-cold laid mixtures for cold, wet weather maintenance include:

a) Tendency to set up in the stockpile during cold weather periods.
b) Lower temperatures required to prepare these mixtures in order to minimize loss of volatiles often preclude the use of drum mixers which have in turn, limited some bidding responses.
c) HM-CL mixtures placed in colder regions of the State have experienced overnight degradation and subsequent loss of mix even when tack coating was employed.
d) HM-CL mixtures tend to be susceptible to stripping, requiring aggregates to be surface treated prior to use.

The stockpile hardening problem has been offset in some districts by preparing these mixtures "on the ground" in small quantities for immediate use or for short duration stockpiling. In the early stage of this study only District 19 (Atlanta) had reported satisfactory results both in performance and stockpiling of Item 350 mixtures. Item 350 material produced for District 19 was included in the field testing segment of this project.

UPM (Unique Patching Material) is a proprietary bituminous material composed of cutback asphalt, additives and aggregate. It is marketed by SYLVAX Corporation of New York as a "high performance cold mix". Although significantly higher in cost than Item 350 or LRA, it has the distinct advantage of being capable of successfully repairing water-filled potholes using the basic "dump and run" procedure. Midway during this project this material also became a "sole source" procurement item.

Instant Road Repair (IRR) is another proprietary bituminous material marketed by Safety Lights Company of Houston, Texas. This material is considerably more expensive than UPM and has found limited use around the State. This material is not normally stockpiled, but delivered in 5-gallon buckets. Some districts consider this factor as an advantage while others felt it to be bothersome.

One district reported good results using an Item 350 Type FF mixture with an emulsified asphalt binder. Others who had never used this material predicted poor performance with emulsified asphalt binder in cold weather applications in their districts. Two of these districts agreed to field test this specification on their roads.

## PROJECT OBJECTIVES

The overall purpose of this study is to ameliorate the problem of purchasing LRA on a proprietary basis. At the same time the field trials incorporated into this study provided an opportunity to compare the performance of a number of materials and mix designs under different climatic conditions and placement procedures inherent to several of the northern-most districts of Texas.

The project was designed to gain a more complete understanding of cold, wet weather maintenance problems in Texas and to alleviate the restrictions associated with purchasing limestone rock asphalt on a proprietary basis. The reasons underlying the desirable performance characteristics of LRA as a cold, wet weather pavement maintenance material was to be identified along with other material systems which could serve as cost-effective alternatives. The primary objectives of the study are three-fold:

1) Identify paving materials which could provide a viable alternative to LRA,
2) Broaden materials selection options for cold/wet weather maintenance, and
3) Provide rationale and/or recommend changes in Department policies, regulations and specifications to permit purchase of limestone rock asphalt when certain requirements are met.

## SCOPE OF STUDY

The methodology for achieving these objectives were carried out in the four tasks described below.

### Task 1 Literature Review

A comprehensive literature review of activities associated with cold/wet weather maintenance materials either currently in use or under development was performed. The survey revealed that a number of states and agencies have conducted research in this area (17,18). As a result of this task, mixture designs designated for field evaluation were identified. This activity was also extended to solicit comments from district maintenance personnel by means of questionnaires as to the specific cold/wet weather maintenance materials and procedures they currently utilize and their respective performance characteristics.

### Task 2 Technical Advisory Panel

An advisory panel was organized and convened periodically during the study period. This panel was composed of representatives of TTI, the Center for Transportation in Research, D-4, D-9, D-18, and the State Purchasing General Sources Commission (SPGSC). The mission of this advisory panel was to provide guidance regarding procurement policy, regulations, or material specification changes which could help alleviate the purchasing problem. The panel also offered suggestions for new or existing materials that could provide viable alternatives to limestone rock asphalt (Task 3). The panel was also instrumental in the selection of the materials and specific districts to participate in the field test (Task 4) and subsequent evaluation of results.

### Task 3 Identify Alternative Materials for LRA

This task was designed to establish suitable alternative materials to limestone rock asphalt for cold weather maintenance. Initially, this work involved interfacing with personnel in most of the State's northern districts primarily responsible for pavement maintenance to determine their experience relative to the utilization of LRA. Personnel from districts that did not use much LRA were also interviewed to determine the types of materials they used as substitutes. Detailed information regarding both the favorable aspects and shortcomings of other patching materials were also solicited. This was accomplished by direct visits to the district offices, specially convened conferences, and by questionnaires.

### Task 4 Field Trials

This element of the study involved the evaluation of a number of cold/wet weather maintenance materials by means of a series of field trials.

A total of 13 different maintenance mixture designs were evaluated in seven districts. Both potholes and surface patching (blade-on) maintenance operations were incorporated into these trials. The performance of these materials was evaluated over a nine month period. All of the participating districts were visited at least twice during this period and discussions were held with each maintenance engineer and his foremen regarding the performance of each material.

A laboratory test program was developed to test and correlate these results with the effectiveness of the materials utilized in the field trials.

# TECHNICAL BACKGROUND

## LITERATURE REVIEW AND FIELD SURVEYS

A review of the literature revealed several related studies which had been conducted in New Jersey, Indiana, New York, Colorado, Connecticut, Delaware, Pennsylvania and New Mexico. These studies identified mix designs and rationale for conducting pothole and blade-on repairs made under cold, wet weather conditions using cold-mix, stock-piled patching mixtures. A brief summary of the results of these studies is elaborated by-state, below. This review also identified some of the more important mix design criteria involved in achieving good performance under cold, wet weather conditions.

### Projects in Other States

**New Jersey** The New Jersey Department of Transportation conducted a study to identify patching materials for rapid, durable, and economical winter patching of portland cement concrete (PCC) and asphalt cement concrete (ACC) pavements (18). In addition to hot-mix asphalt, three types of cold-mix patching mixtures were evaluated. The State's standard winter mix (RR) was used as the control. The methods employed to place and compact the bituminous materials ranged from simply dumping the mix into the pothole and tamping the patch with the back of a shovel to reheating the material in a portable pugmill (McConnaughay HTD-10) followed by compaction with a small vibratory roller. It was found that the standard cold-mix patching material (RR) performed better than the other patching mixtures tested. The other two cold-mix patching mixtures studied (a proprietary patching material and an asbestos-modified RR mix) proved unsuitable because of their short patch life and high cost. In addition, the asbestos-modified RR mix presented a potential health hazard. It should be noted that the conventional hot-mix asphalt outperformed their standard RR mix, but hot-mix is not readily available during the winter months.

Another investigation conducted by the New Jersey DOT utilized the McConnaughay HTD-10 mixer to produce hot-mix patching material (19). As a part of the study, New Jersey's standard cold-weather patching material (designation RR) was evaluated with four different patching procedures. The RR mix, which is no longer in use, consisted of a one-to-one blend of stone and sand and an MC-800 binder. In technique No. 1, the mix was compacted by tamping with the back of a shovel. Hole preparation was not required. Technique No.2 called for the use of tacking material and compaction of the mix with a hand tamper. Again, trimming the edges was not required, but lose debris was removed with a broom. Technique No.2 was used as the control. Technique No. 3 included trimming edges and cleaning the hole before filling it with RR mix preheated (at the job site) in the McConnaughay unit. In this case, the material placed in the hole was compacted with a vibratory roller. Technique No.4 was the same as Technique No.2 except that the vibratory roller was used for compaction.

It was found that RR mix used with Technique No.2 and Technique No.4 had similar patch life; whereas, patches repaired with Technique No.3 (reheated and rolled) lasted 75 percent longer. In high traffic volume locations, the average number of replacements (per winter season) for patches repaired with Techniques 2,3 and 4 was 2.9, 1.7, and 3.0, respectively. However, patching operations with Technique No.3 incurred a higher cost per ton than operations using the other three techniques.

Indiana In 1980, the State of Indiana completed an extensive pothole repair study (20). The study compared the performance of heated and unheated, stockpiled patching mixtures. A total of 324 potholes were repaired, and several patching techniques were investigated. As was the case in New Jersey, the cold mix was heated and transported in hot boxes.

The Indiana study concluded that heating the stockpiled cold mix resulted in improved durability compared with using unheated cold mix, and the best durability was obtained when cold mix was heated to 200°F (93°C) in a Porta-Patcher. This conclusion was verified in a study sponsored by the Federal Highway Administration, in which it was also found that heated stockpiled mixes performed comparatively well (21). Another finding in the Indiana study was that tacking and sealing were detrimental because they contributed to patch failures such as rutting, shoving and bleeding resulting from poor application control and excessive use of tack material.

New York The studies discussed above dealt mainly with conventional bituminous patching materials. Other investigations have focused on new materials for patch repair. One such investigation was conducted in New York State under the FHWA HPR program (22). The New York study was based on the premise that its cold-mix patching material commonly used in winter is, at best, only a temporary solution. Problems cited include: it does not produce a good bond with the surrounding pavement, it tends to ravel, and it cannot withstand more than a few freeze-thaw cycles.

Repairs made with the standard New York cold mix and a proprietary product were evaluated for two winters. The New York DOT cold-mix, stockpiled patching mixture is relatively coarse graded, and the binder may be an emulsion or a cutback. The type and content of the binder in the cold-mix used in the study were not provided in the report.

Five potholes were repaired with the State's cold-mix versus 44 repairs made with the proprietary mix. All of the patches made with the State specification mix failed within four weeks, but only two of the 44 repairs made with the proprietary mix failed. The failed repairs were at sites where vehicle tires exerted lateral forces, resulting in the shoving of the mix. The study recommended that the proprietary mix not be used in locations of frequent vehicle acceleration and deceleration. Another conclusion of this research was that the high cost of the proprietary mix may be offset by longer patch life and reduced necessity for repatching.

Colorado A study conducted by Swanson et al. (23) in Colorado, between December 1979 and July 1980, focused on the field testing of a variety of materials and techniques for repairing bituminous concrete. The investigation included Colorado's standard hot mix (with AC-10), a standard cold mix (with MC-800), and a cold mix containing polypropylene fibers and an anti-stripping agent.

In one repair technique, a rubberized emulsion was used to tack the sides and the bottom of a pothole. Layers of aggregate were then placed in the hole. Each layer was covered with the emulsion. The patch was covered with masonry sand and compacted.

In some cases, a slightly different technique was used. The pothole was first tacked with the rubberized emulsion. The aggregate and emulsion (thinned to two parts emulsion and one part water) were then mixed inside the hole. More of this mix was added to fill the pothole. The patch was covered with a layer of sand and compacted by truck or roller.

The following patching procedure was adopted when foamed asphalt was employed. In this case, MC-70 was used to tack the hole. The hole was then filled with a foamed asphalt mix. Compaction was accomplished using a truck or a roller. Finally, MC-70 was poured on the patch and blotted with fine aggregate.

Several potholes were repaired with a hot mix produced by mixing SULFLEX and aggregate in an improvised drum mixer. The SULFLEX binder and the aggregates were preheated to 250°F (121°C) and 310°F (154°C), respectively. The patches were compacted with a roller. The other six patching mixtures (a proprietary cold mix, a conventional hot mix with AC-10, a standard cold mix with MC-800, a cold mix with MC-800 and polypropylene fibers, a cold mix with MC-800 and an anti-stripping agent, and a cold mix with MC-70) were employed, separately, to fill several potholes.

By July 1980, seven months after the study began, all the asphalt patching materials (with the exception of the SULFLEX and the hot mix) had failed and were replaced with standard hot mix. Common failures were raveling and dishing. In July, the SULFLEX patches also began to strip. The use of SULFLEX mixtures in portable mixers without proper temperature control may give off toxic fumes. When SULFLEX is heated (24) above 310°F (154°C) toxic gases ($SO_2$ and $H_2S$) are released.

Connecticut In 1980, the Connecticut Department of Transportation conducted an FHWA sponsored study to develop and evaluate a number of commercial and nonproprietary patching mixes (25). During the month of January, bituminous patching material was placed in 35 test holes, 18 in. (0.46m) by 18 in. (0.46m) by 3 in. (76mm) deep. These test holes were cut out in an asphalt concrete pavement at a location with an average daily traffic (ADT) of 25,700 vehicles per day.

In the study, the aggregate gradation, binder type, and the use of anti-stripping agents were varied in an effort to produce an optimum bituminous patching mixture. The researchers selected five aggregate gradations and four emulsions. Three anti-stripping agents were also incorporated.

The total distribution of failures observed in the bituminous patches was based on aggregate gradation and binder type. Failure was defined as mechanical breakup, development of depressions, flushing, and freezeouts. The report concluded that: (1) when a bituminous patch failure takes place, it generally occurs early in the life of the patch, especially in the presence of rain and (2) aggregate gradation plays a major role in the performance of bituminous patching mixtures.

Delaware In May, 1984, the Delaware Department of Transportation completed the field evaluation of two cold-mix, stockpiled asphalt patching materials, one modified with the addition of a polypropylene fiber and the other made with a latex-modified emulsion (26). Patches were placed during the winter season. The performance of these materials was compared with the known performance of Delaware's standard cold mix and with a proprietary cold mix. The objective of the study was to assess cost-effectiveness, mixability, workability, durability, and stockpile weathering. However, the stockpiled proprietary cold mix experienced stripping problems, and the performance of the standard mix was unusually poor. In light of these problems, a fair comparison was not possible. Therefore, the evaluation was based on visual observations. Results of this study showed the following:

1. All four patching materials demonstrated satisfactory plant mixability,
2. At temperatures below 40°F (4°C), the latex-modified mix exhibited poor workability while the other three mixtures, hot or cold, exhibited satisfactory workability, and
3. The heated, fiber-modified, cold mix yielded the best performance.

Pennsylvania A series of comprehensive pothole repair studies was undertaken in Pennsylvania. In the first series, mixture design requirements were evaluated, and a new specification, PennDOT 485, for cold-mix, stockpiled patching mixtures was established. Subsequently, PennDOT adopted a specification for fiber-modified mixtures, PennDOT 481, and these mixtures are now used routinely in the State (17).

As part of the Pennsylvania studies, the standard for repairing potholes was reviewed, and a guide for repairing potholes was developed. This procedure is referred to as the "do-it-right" or standard method and includes provisions for cutting out deteriorated material, using a plant-mixed, cold, stockpiled patching mixture, and compacting the filled hole by mechanical means (27).

The effectiveness of a standard procedure used in conjunction with a well-designed and controlled cold-mix, stockpiled patching mixture was verified in another Pennsylvania study. As part of this study, more than 1,000 repairs were performed on both asphalt concrete and portland cement concrete pavements. Two patching materials were investigated: PennDOT ID-2 and PennDOT 485. ID-2 is a dense graded, hot-mix asphalt concrete normally used for wearing courses in Pennsylvania; whereas, PennDOT 485 is a stockpiled cold mix.

The repairs were monitored for rutting, shoving, dishing, raveling, and cracking. After two winters, more than 70 percent of the repairs were rated good to excellent. There was no significant difference in the survival rate of the repairs made with either the cold or hot mixes.

## PROPERTIES OF BITUMINOUS PATCHING MATERIALS

Extreme climatic conditions, including excessive rainfall and freeze-thaw cycles have been the bane of highways and streets in recent years. Coupled with an increase in severity of vehicular loadings, an increase in pothole repair and resurfacing operations has been created throughout the state of Texas. Bituminous materials have consistently proven to be the most versatile of all highway maintenance materials because of their comparatively low cost, good stability, quality and ease of application. They have the ability to deal with virtually all types of highway repair problems. A National Cooperative Highway Program (NCHRP) study (28) has identified some of the common causes of failures of bituminous patching materials along with the related mixture property which contributes to their failures are summarized in Table 1.

Table 1. Causes of Failure in Bituminous Patching Materials.

| Problem* | Related Mixture Property |
|---|---|
| Shoving | Stability |
| Lack of adhesion to sides and bottom of hole | Stickiness, binder content |
| Binder stripping from aggregate | Resistance to moisture |
| Raveling | Durability, resistance to moisture |
| Slick surfaces | Aggregate texture, shape, gradation, binder content |
| Bleeding/flushing | Binder content |
| Mix difficult to handle and | Workability shovel |
| Stockpile hardening | Aging and loss of volatiles |

* This listing does not include failures produced by improper construction practices.

Some of the more significant mixture properties that are critical for bituminous patching materials are discussed below:

Stability Stability is a measure of the compacted bituminous patching material's ability to resist vertical and horizontal displacement due to imposed traffic loads. This property is related to most characteristics of the materials used in producing patching materials. Shoving due to low stability will occur if too soft a binder or excessive binder is used in the mixture. Graded aggregates enhance mix stability when they have rough surface texture and are angular. Very high stability mixtures often exhibit poor workability and compactability.

Resistance to Moisture Bituminous patching mixtures in wet potholes are especially susceptible to water action when they contain high air voids due to under compaction during construction. Cold-mixed bituminous patching mixtures may also strip due to poor coating of the aggregate particles during mixing.

Resistance to stripping is affected by the as-mixed condition of both binder and aggregate. For instance, for hot-mixed-cold laid mixes, asphalt cement must be hot, and the aggregate both hot and dry to obtain satisfactory coating. Emulsions, on the other hand, may be used successfully when water is present on the surface of compatible aggregates. Proper placement and compaction provides added assurance for resistance to water-induced degradation.

Durability Durability is the measure of a material's resistance to deterioration and disintegration due to the combination of traffic and weathering forces. This phenomenon is related to the oxidative hardening of the binder. Deterioration may first occur with the loss of fine aggregate particles from the surface. This is usually referred to as "raveling". Other forms of distress, such as cracking, can occur over a period of time but are not too common in patching mixtures.

Durability of patching mixtures is closely related to the quantity and type of binder. For instance, surface raveling may result in a mix with binder content below optimum. The binder viscosity can also significantly influence durability; soft binders with soft residues are often considered more desirable. Fine graded and/or highly absorptive aggregate will often accelerate the apparent rate of binder hardening. Compacted mixtures that contain permeable air voids above five percent tend to harden faster than dense mixtures.

Skid Resistance Bituminous patching mixtures should provide acceptable skid resistance particularly when patches are large. Low skid resistance occurs when the surface of a pavement produced with excess binder is wet or covered with water. Slipperiness can also develop in mixtures containing aggregates with low polished resistance.

Nonpolishing aggregates that retain their microtexture during service should be employed where high levels of skid resistance are needed. This means good, high polish value, coarse and fine aggregate should be used and the bitumen content closely controlled to prevent excess binder.

**Workability** All-weather workability is of prime concern in cold/wet weather maintenance operations. Pothole repair or patching material should be soft and pliable for easy handling (shoveling, raking, shaping and compacting). Temperature has a pronounced effect on workability because it controls stiffness and age hardening of the bituminous binder and influences the evaporation of volatiles. Improvements can be made by using low viscosity binders, as provided by some emulsions and cutbacks and by covering the stockpile. In general, the mixture should be "alive" and workable after several months in the stockpile.

It is postulated that highly absorptive aggregates will adversely affect workability. Asphalt technologists claim that some aggregates selectively absorb asphalt such that the soft more mobile components are absorbed into the aggregate leaving the harder, more viscous material to act as the binder between the aggregate surfaces. It may be possible to offset these effects and thus enhance workability by using softer asphalts with highly absorptive aggregates. Research should be performed to evaluate this procedure.

# MATERIALS

## MATERIAL SELECTION

On the basis of detailed discussions with a number of district maintenance engineering personnel, and the Technical Advisory Panel, 13 test materials were selected for implementation in seven of the State's northernmost districts. Some of the decision criteria which influenced the selection of these materials include:

- Various climatic conditions among the districts.
- Historical preference and experience with different mix designs.
- Evaluate new materials heretofore not comparatively evaluated in the field.
- Involve a variety of native aggregate systems.
- The need to broaden the range of maintenance materials available to the districts.
- Compare mixtures which perform well in one district under the climatic conditions of another district.

## MATERIAL CHARACTERISTICS

The test materials proposed for field evaluation by the advisory panel and district maintenance personnel were:

1. UPM - Type I (Special Specification Item ????).
2. Instant Road Repair (Special Specification Item 3563).
3. New LRA (no state approved specification).
4. Item 330 - Type "CC" (330-009).
5. Item 330 - Type "D" (330-009).
6. Item 330 - Type "AA" Modified (330-007).
7. TTI design (100 percent crushed stone).
8. Item 350 - Type "DD" Atlanta Design (350-040).
9. Item 350 - Type "DD" Atlanta Design & Materials.
10. Item 350 - Type "FF" Brownwood Design (350-038).
11. Item 350 - Type "FF" Brownwood Design & Materials.
12. Item 350 - Host District Design.
13. Local Vendor Design (if available).

The test matrix of materials to be tested by the districts is presented in Appendix 1.

A concise description of the materials studied is below.

## UPM

Unique Paving Mixture (UPM) is primarily a crushed stone-cutback asphaltic concrete with asphalt additives. The binder can be either an MC-250 or MC-800. These binders comply with the requirements of Item 300, "Asphalts, Oils and Emulsions", or meet the requirements of a special cutback material.

The mineral aggregate used is as specified for Item 350, "Hot Mix-Cold Laid Asphaltic Concrete". A breakdown of the composition of this product by weight is listed below:

| Item | Percent of Total |
|---|---|
| Aggregate | 94.5 |
| Asphalt Cement | 3.9 |
| Fuel Oil | 1.5 |
| UPM Additives (proprietary) | 0.17 |

It is used primarily in wet potholes. The State Purchasing and General Services Commission (SPGSC) contends that only one manufacturer (Sylvax Corporation, New York) produces the special cutback material used in this product and has therefore declared the material to be a proprietary item (sole source). This is of special interest to the SPGSC, because the cost of the special cutback material is very significant compared to the total cost of the product.

## Instant Road Repair (IRR)

This specification covers the properties of a rapid-curing asphaltic concrete mixture for the repair of pavement joints and patching small pavement areas. It is composed primarily of crushed stone, rapid curing cutback asphalt and additives. The asphalt content, exclusive of volatiles ranges between 4.0 and 6.5 percent by weight. The IRR aggregate gradation specification is shown below:

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 95 to 100 |
| Passing 1/4" | 75 to 100 |
| Passing 1/4 ", retained on No.10 | 40 to 75 |
| Passing No.10, retained on No.40 | 8 to 30 |
| Passing No.40, retained on No.80 | 3 to 15 |
| Passing No.80, retained on No.200 | 2 to 10 |
| Passing No. 200 | 0 to 6 |

The material is packaged in either air-tight containers or plastic lined bags.

New LRA

At the outset of this program, most district maintenance engineers preferred to use UPM for pothole repair and LRA for blade-on application or patching operations. This was due to the ability of the former product to be utilized successfully in water-filled potholes. During the course of this study Vulcan Materials Company made available for field testing a new LRA mixture designed to perform in wet potholes as well as UPM. There is currently no state specification for the new LRA product. However, Vulcan has advised TTI that the aggregate used was a blend of 50 percent crushed LRA and 50 percent trap rock. The bituminous material was a liquid asphalt with additives including aromatic oils and petroleum distillates. The new LRA was introduced, not as an alternate to Item 330, but as as a cold/wet weather pothole patching material. In-as-much as UPM has also been designated as a proprietary item, it has been suggested that the new LRA design be considered as a competitive alternative to UPM if its field performance proved to be satisfactory.

Item 330 - Type " CC " (330 - 009)

This item is a cold mix-cold laid material made up of natural LRA, uniform and well graded, with an average bitumen content of 5 to 9 percent by weight of naturally-impregnated asphalt. The remaining bituminous material is composed of flux oil (MS-1 or RC-250). The paving mixture consists of a uniform mixture of crushed LRA, flux oil and water if needed. The gradation specification is as follows:

| Sieve Information | Percent by Weight |
|---|---|
| Retained on 1/2" sieve | 0 |
| Retained on 3/8" sieve | 0 - 2 |
| Retained on No.4 sieve | 35 - 50 |
| Passing No.10 sieve | 35 - 50 |

**Item 330 - Type "D" (330-009)**

The composition of this material is similar to Item 330 Type "CC" described above with the exception that the aggregate gradation is as follows:

| Sieve Information | Percent by Weight |
|---|---|
| Retained on 3/8" sieve | 0 |
| Retained on 1/4" sieve | 0 to 2 |
| Retained on No.4 sieve | 5 to 15 |
| Retained on No.10 sieve | 35 to 50 |

**Item 330 - Type "AA" Modified (330-007)**

This mixture is coarser than Type "CC". This gradation has been modified from Type "A" (coarse graded base course) by the following:

| Sieve Information | Percent by Weight |
|---|---|
| Retained on 1½" sieve | 0 |
| Retained on 1¼" sieve | 0 - 10 |
| Retained on 7/8" sieve | 0 - 25 |
| Retained on 3/8" sieve | 15 - 45 |
| Retained on No. 4 sieve | 25 - 60 |
| Passing No. 10 sieve | 20 - 55 |

## TTI Design

In order to establish a suitable candidate as a cost-competitive alternative paving maintenance material for LRA, a special mixture was designed, prepared, and tested in the laboratory and in the field.

The material, was designated as the "TTI Design". It conforms basically with the current Item 350 specification with the following exceptions:

1. Requires 100 percent crushed stone,
2. Requires a maximum nominal particle size of 3/8 inch,
3. Limits material passing the #200 sieve to a range of 0-4 percent,
4. Requires a minimum voids in the mineral aggregate (VMA) of 15 percent for a specimen prepared by the standard Texas CMCL compaction method (standard gyratory compaction at 100°F).

The requirement of 100 percent crushed stone provides the stability needed to resist plastic deformation in maintenance applications. Workability will be provided by limiting the maximum particle size, the minus #200 aggregate, and the minimum VMA. Specifically, limiting the minus #200 material will yield a low viscosity mastic to minimize setting in the stockpile and thus enhance workability. Limiting the VMA will provide for thicker asphalt films which will improve workability as well as resistance to damage by moisture and oxidative aging. It is felt that LRA can be prepared to meet this specification.

## Item 350 - Type " DD " Atlanta Design (350-040)

This is a hot mixed-cold laid asphaltic concrete Type "DD" which meets the requirement of DOT 1982 Specification Item 350 and special provision 350-040. The grade of asphalt used is MC-800. The coarse aggregate has a polish value not less than 32. Coarse aggregates are comprised of a blend of non-polishing with polishing aggregates, to achieve an acceptable combined polish value. In this case, percent by volume of the non-polishing aggregate retained on the No. 10 sieve should comprise at least 20 percent of the total aggregate. In addition, the blended coarse aggregates shall contain non-polishing aggregates of at least 50 percent by volume of the material retained on the No. 10 sieve.

Item 350 - Type " DD " Atlanta Design & Materials (350-040)

This is the same item as described above with the sole exception, that AES-300 was used in place of MC-800. During the early stages of the program, District 19 advised TTI that they did not use LRA because of prohibitive shipping costs, and its standard cold weather maintenance material was Item 350. Visits to the District's stockpiles showed very good long-term workability. Arrangements were made to ship Item 350 material prepared in District 19 to at least two other districts (Districts 3 and 5) for field testing under different climatic conditions.

Item 350 - Type "FF" Brownwood Design (350-038)

This is a hot mixed-cold laid asphaltic concrete Type "FF" in accordance with DOT Item 350 of the 1982 standard specifications and special provision 350-038. The asphalt used is MC-800.

Item 350 - Type "FF" Brownwood Design & Materials (350-038)

This item is the same as the Brownwood design mentioned above with the sole exception of AES-300 which is used in place of MC-800. Abilene (District 8) indicated that they had some success using a Type FF, an emulsified mixture obtained out of Brownwood, Texas, as a maintenance material. Some of the northern districts did not feel that emulsified mixture could be used in the colder climate. It was decided to ship this Item 350 Type FF material prepared in Brownwood, Texas, to both Lubbock (District 5) and Wichita Falls (District 3) for field testing.

Item 350 - Host District Design

Each district was invited to submit a design to be included in the field demonstration study.

Local Vendor Design

The vendors of each district were asked to submit a design of their own. This was done to provide local vendors with an opportunity to offer their "best" material for inclusion in the field experiments. However, no vendor participated or proposed any design to this effect.

# FIELD TRIALS

## SELECTION OF PARTICIPATING DISTRICTS

The following seven districts were selected for the study (Figure 1):

| | |
|---|---|
| District - 2 | Fort Worth |
| District - 3 | Wichita Falls |
| District - 4 | Amarillo |
| District - 5 | Lubbock |
| District - 7 | San Angelo |
| District - 8 | Abilene |
| District - 11 | Lufkin |

## PROCUREMENT OF MATERIALS

The 13 mix designs discussed above were incorporated into the field test program using the test matrix depicted in Appendix 1. Two types of maintenance operations were to be performed: 1) pothole repair and 2) blade-on patching. The test materials mutually agreed upon by TTI, the seven participating district engineering personnel, and the Technical Advisory Panel were designated for procurement during Fall 1989. Test materials were to be made available to the districts before January 15, 1990. Some materials were received as early as November, 1989, however, due to some procurement and delivery delays all districts did not receive the materials within the specified time. Two of the districts even reported receiving the materials as late as March 1990.

The intent of the field trials was to evaluate the long term performance of each repair, with respect to the material's ease of handling, susceptibility to raveling, bleeding, shoving, and its ability to maintain stockpile workability. It was specified in the test plan that all repairs were to be performed primarily, when daytime temperatures were at or below 40°F. Unfortunately, during the unusual winter of 1990-91, these temperatures were observed only during the latter half of December. At that time, most districts had not received their materials. This resulted in field trials being initiated during the first quarter of 1990, when daytime temperatures generally ranged between 50°F and 70°F. In some cases, the placement was held up awaiting a new wave of cold weather which

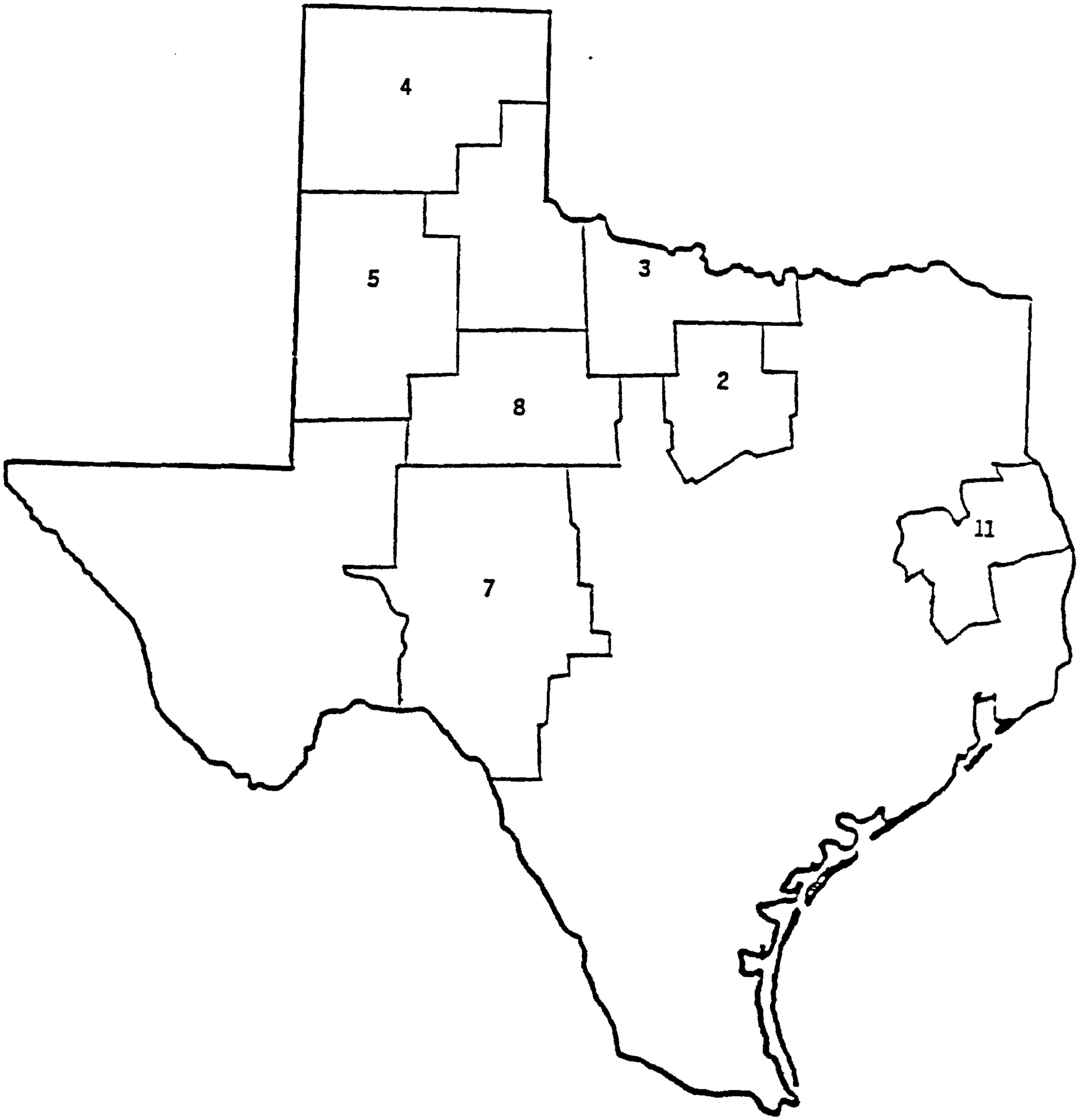


Figure 1. Location of Districts for Field Tests.

did not develop. This caused some materials to be placed at temperatures at least 20°F above that desired for cold weather evaluation. Furthermore, some potholes had to be filled with water by maintenance crews in order to simulate wet weather conditions.

## TEST CRITERIA

In order to uniformly assess the performance of each material, some basic criteria for performing the tests were recommended, as follows:

1. A minimum of six test sites were required for each material,
2. Test sites were to be on roadways with ADT greater than 1000,
3. Pothole dimensions were to be at least 12 inches in length and 2 inches deep,
4. Placement in potholes required both wet and dry condition,
5. Only naturally occurring potholes were utilized, and
6. Blade on areas were to have a minimum length 50 feet.

The methodology for placement of materials was left to the respective district maintenance engineers. It was apparent that standard repair methods would be made in placing and compacting the materials. Most of the repairs were performed using the "dump and run" procedure. In others, the pothole was trimmed, squared and swept clean before filling and compaction.

## DATA SHEETS

At the time of placement, various measurements and subjective evaluations were made on the mixtures and recorded by the maintenance foremen using special construction documentation forms devised for the project. Copies of typical Maintenance Data Sheets are included in Appendix 2 to this report. Selected illustrations of some typical field operations are shown in Appendix 3.

# LABORATORY TEST PROGRAM

## DESCRIPTION OF PROGRAM

The field investigation indicated the character and performance of the materials as evaluated by the respective district engineering personnel. Subsequent to the field evaluation, a laboratory investigation was conducted to assess the effectiveness of the candidate materials.

Samples of the field tested materials described above were forwarded to TTI from the districts. As indicated earlier, the TTI design performed well in all districts that used the material, with the exception of Lubbock, where the material had set in the stockpile and could not readily be removed. In view of this situation, samples of this material were tested and compared with the TTI design used successfully in Wichita Falls. Moreover, a "TTI Design" mixture using crushed limestone (obtained from Brownwood,Texas) and AES-300 was prepared in the laboratory and analyzed.

An asphalt concrete mixture design was performed for the mixture containing 100 percent crushed stone and a maximum nominal particle size of 3/8 inch. An aggregate gradation was selected based on gradations typically used in the field. The gradation was designed to meet Texas DOT Item 340, Type D specifications (29). The optimum asphalt content (5.8 percent) was used in preparing all mixes (Table 2).

All materials were heated in a 140°F (60°C) and low humidity environment for a period of 18 hours, to ensure curing was completed under uniform conditions. The 2-inch high and 4-inch diameter cylindrical specimens were then compacted at 100°F using the Texas gyratory shear compactor (30).

## DESCRIPTION OF TESTS

Several tests were used to characterize the mixtures: indirect tension, Hveem and Marshall stability, extraction and recovery of binder and aggregate gradation. Temperature susceptibility of the materials was evaluated by determining the resilient modulus at a range of temperatures. Moisture susceptibility was also estimated (Figure 2).

Hveem stability tests were performed in accordance with Texas DOT test method Tex-208-F (30) which is a modification of ASTM D 1560.

Table 2. Design Data for TTI Mix Containing 100% Crushed Stone.

| Mix No. | Asphalt Content, percent | Density, percent | VMA, percent | Hveem Stability, lbs | Unit Weight, pcf |
|---|---|---|---|---|---|
| 1 | 4.0 | 91.4 | 15.8 | 50.4 | 147.3 |
| 2 | 5.0 | 94.1 | 14.2 | 51.5 | 150.8 |
| 3 | 6.0 | 95.5 | 13.8 | 39.3 | 151.2 |
| 4 | 7.0 | 97.1 | 13.3 | 16.3 | 152.5 |
| 5 | 8.0 | 97.2 | 14.1 | 14.6 | 152.2 |

Optimum Asphalt Content - 5.8%

Marshall stability tests were performed in accordance with ASTM D 1559 method.

Resilient moduli (ASTM D 4123-82) of the specimens were determined at various temperatures using the diametral test equipment. Temperatures included -13°F, 33°F, 68°F, 77°F, and 104°F.

Indirect tension tests (31) were conducted at 77°F and 2 inches/minute on the samples. The 2-inch high and 4-inch diameter cylindrical specimens were loaded diametrally at a constant rate of deformation until the peak load was obtained.

Indirect tension tests were performed on a second set of specimens after exposure to moisture in accordance with test method Tex-531-C, "Prediction of Moisture-Induced Damage to Bituminous Paving Mixtures using Molded Specimens".

Binder content was measured through extraction from the bituminous mixtures, in accordance with ASTM D 2172 Test Method "A". Viscosity tests at 140°F and standard penetration tests at 77°F were then performed on the recovered bitumen in accordance with ASTM D 2171-85 and ASTM D 5-86, respectively.

Gradation of aggregates obtained after the extraction of bitumen was analyzed. The particle size distribution of fine and coarse aggregates for each material was determined in accordance with ASTM C 136-84a.

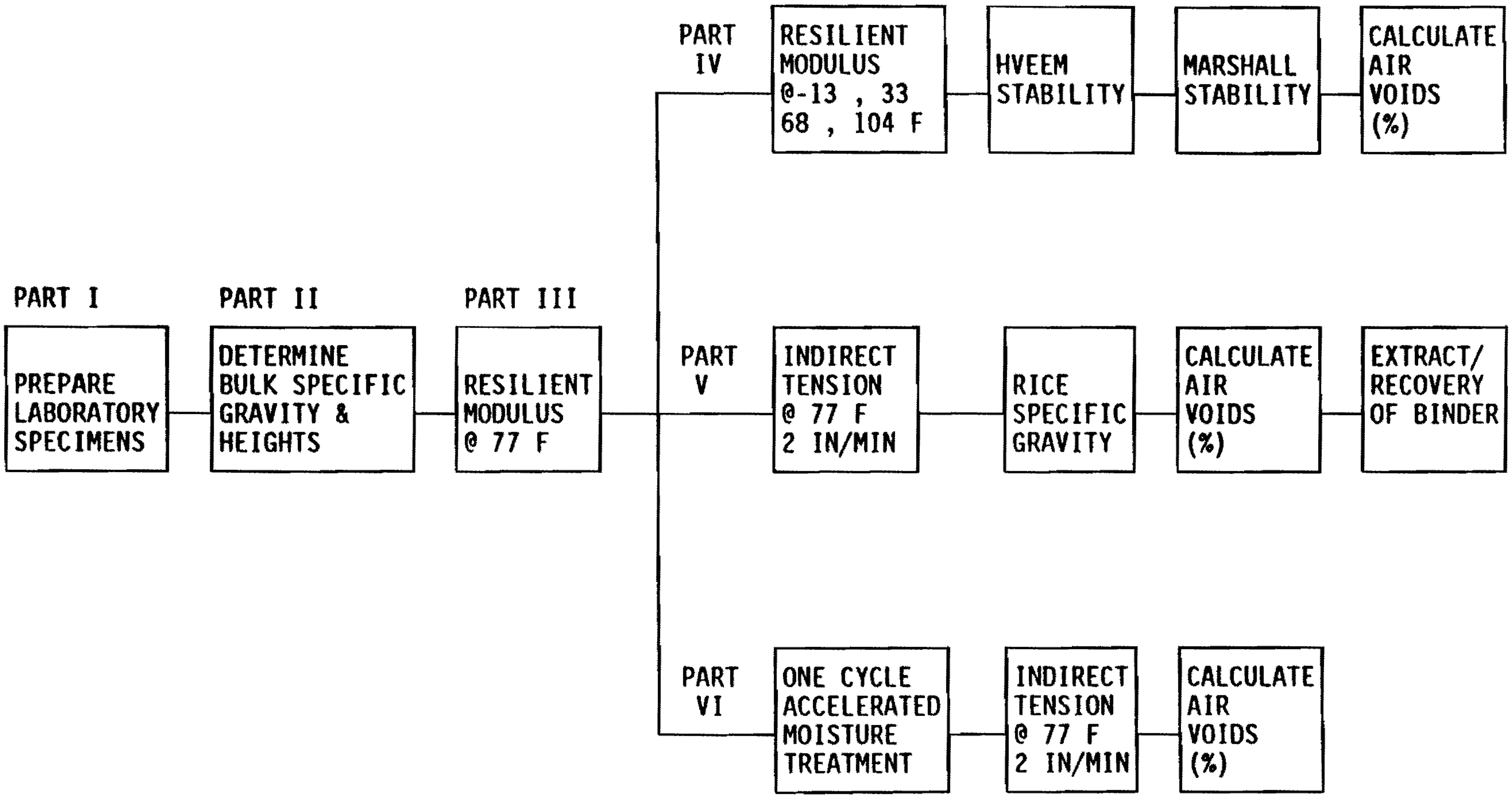


Figure 2. Laboratory Test Program.

## DISCUSSION OF RESULTS

### FIELD TEST PROGRAM

This section describes the field test results along with comments of the district maintenance engineers and their foremen on the performance of each material. The repairs were carried out under temperatures ranging from 45°F to 60°F. Visits were made to each district during the Spring and Fall of 1990, by TTI to evaluate the performance of each material and to discuss with the maintenance engineers and their foremen their assessment of the performance of these materials. A summary of these comments by district and material is given below:

District - 2 Fort Worth

UPM - (Spec ????)

- Used for wet potholes.
- It is the main pothole patching material in winter/wet weather.
- Although traffic can be allowed on the road immediately upon placement, UPM requires three to six weeks to completely set up in the field.
- No pothole preparation required, "Dump and run" procedure is the primary pothole repair method.
- Both winter and summer mixes are used.
- Used on high volume roads.
- Slight crust developed after 15 months in the stockpile.

Instant Road Repair (Spec. 3563)

- Used for wet potholes.
- Available in five gallon buckets, no stockpiling required.
- Shoving problems experienced.
- Performance generally similar to UPM.
- Very expensive.

New LRA (No Specification)

- Used for potholes only.
- Performed well in both wet and dry potholes.
- Performance similar to UPM, although slightly stickier.
- Good stockpile life, with slight crusting on the surface.
- Cost could be the deciding factor, in the choice between UPM and New LRA.

Item 330 - Type "CC"

- Used for both potholes and blade-on applications.
- Generally prefer using it for blade-on applications.
- Spreads, blades and finishes very well.
- Did not perform as well in wet potholes.
- Stockpile workability very good (lasts for over a year).
- About half the district's maintenance personnel prefer this material.

Item 330 - Type "D"

- Used for blade-on applications only.
- Performed well in overlay, blade-on and patching etc.
- Gives good surface finish.
- Excellent stockpile workability.

Item 330 - Type "AA"

- Used for potholes only (greater than 3" depth).
- Also serves as a good base material.
- Does not perform well in wet potholes.
- Compacts well, when material is fresh.
- Top size needs to be raked out for smooth finish.
- Does not maintain the same workability in the stockpile as Type-CC.

TTI Design

- District 2 did not receive this material.

Item 350 - Type "DD" Atlanta Design

- Used for both potholes and blade-on applications.
- Does not always perform well in potholes due to a tendency to shove.
- Material worked well during blade-on applications, however; some overlays started to break-up after five to six months.
- Stockpile life limited to one season (Less than six months).

Item 350 - Type "FF" Brownwood Design

- Used for potholes and blade-on applications.
- Did not perform well in potholes due to a tendency to shove.
- Material worked well for blade-on applications.
- Begins to set up in stockpile after 60 days.

Item 350 - Host District Design

- District did not test any new locally produced material.

**District - 3 Wichita Falls**

UPM - (Spec ????)

- Used for potholes only.
- Worked well in both wet and dry holes greater than 2" deep.
- Stockpile material began to crust after one year.
- It is the district's sole winter patching material.
- "Dump and run" is the normal procedure used.
- Gives excellent overall performance.

Instant Road Repair (Spec. 3563)

- Used for potholes only.
- Stiffer than UPM.
- Works well in both wet and dry potholes.
- Cold weather advantage because it can be stored indoors in buckets.
- Gives excellent overall performance in potholes.

New LRA

- Used for potholes only.
- Gave excellent performance in both wet and dry holes.
- Appeared to have less tendency to freeze-up in cold weather than UPM.
- Did not have time to test for stockpile workability, as all the material was utilized immediately.

Item 330 - Type "CC"

- Used for potholes and blade-on applications.
- Excellent workability even at 35°F.
- Does not work in wet holes.
- Easy to apply and potholes can be compacted with truck tires.
- Minor raveling was noticed after three months.

Item 330 - Type "D"

- Used for blade-on application only.
- Performed well in patching process.
- Provides good surface finish.
- Excellent stockpile workability.

Item 330 - Type "AA"

- Used for potholes only greater than three inches deep.
- Good stockpile workability.
- Compacts well.
- Too coarse for shallow holes.
- Tendency to roll out.
- Difficult to finish.

TTI Design

- Used for both potholes and blade-on applications.
- Material was in the stockpile for only two weeks.
- Used in potholes with ranging from ½" to 4" deep.
- Material easy to work with.

- Used in ½" deep hole; over brick surface tacked with RC-250. After two days in-place, it rained - TTI mix remained in the hole; however, an adjoining patch (3'x 5'), containing HMAC, washed away.
- Worked well under blade-on application.
- Overall performance of the material was good.

Item 350 - Type "DD" Atlanta Design & Materials
- Used for both potholes and blade-on applications.
- Material was difficult to get out of the truck at 50°F.
- Performed well in potholes, although difficult to work at low temperatures.
- Performed well for blade-on applications at 70°F.
- Would not prefer this material over existing options.

Item 350 - Type "FF" Brownwood Design & Materials
- Used for potholes and blade-on applications - The material was consumed within a month after it was received; therefore, stockpile workability was not recorded.
- Worked well in pothole.
- Did not test for blade-on application in this field test.

Item 350 - Host District Design
- The district did not test any new locally produced winter patching material.

District - 4 Amarillo

UPM - (Spec ????)
- Used for potholes only.
- Good stockpile workability, lasts for over a year.
- Works well in small confined holes which do not exceed 2' x 2' in size.
- Used in both wet and dry holes, and it remained for a few months.
- Used as a temporary measure, until season changes, when HMAC is used.
- Does not prefer the material.

Instant Road Repair (Spec. 3563)

- Used for potholes only.
- Displays similar stickiness as UPM.
- Construction procedures similar to UPM.
- Performance in pothole appear to be better than UPM.
- Provides a good surface finish.

New LRA

- Used for potholes only.
- Material was delivered in 55 gallon drums.
- Too sticky to work with.
- Used in a few potholes, and it pushed out.
- Tests were conducted at temperatures ranging from 60 to 70°F.
- Not satisfied with the difficulty of working with this material.

Item 330 - Type "CC"

- Used for both potholes and blade-on applications.
- Worked very well in potholes.
- Gave good performance in blade-on applications.
- Excellent stockpile life (two years).

Item 330 - Type "D"

- Used for blade-on applications only.
- Could not evaluate stockpile workability, as all the material was utilized within three weeks.
- Excellent material for blade-on application.
- Performed well under high traffic conditions.

Item 330 - Type "AA"

- Used for potholes only.
- Top aggregate size is a major problem.
- Difficult to place, compact and finish the surface because of its top size.
- Would prefer not to use it again.

TTI Design

- Used for both potholes and blade-on applications.
- Material was more viscid and therefore more difficult to place than Item 330 - Type "CC".
- Performed well in dry holes.
- Performed well in blade-on applications.
- Could not evaluate stockpile workability, as all the material was consumed within three weeks.
- Overall performance was generally acceptable.

Item 350 - Type "DD" Atlanta Design

- Used for both potholes and blade-on applications.
- Did not perform well in either potholes or for blade-on applications, as the material "pushed out" and disintegrated, after only 10 days.
- Would not use the material again.

Item 350 - Type "FF" Brownwood Design

- Used for both potholes and blade-on applications.
- Material easy to work with.
- Performed well in dry potholes.
- Worked well under blade-on application.
- Good stockpile workability.
- Overall performance of this material was very good.

Item 350 - Host District Design

- Used for both potholes and blade-on applications.
- Material selected under this category was a Type "FF".
- Very difficult to work, as it formed clumps.
- Gave good performance once it was laid and compacted.
- Material was set in the stockpile, and it took four hours to get it into the truck.

District - 5 Lubbock

UPM - (Spec ????)

- Used for potholes only.
- Material was found to be too "sticky" and difficult to work.
- Performed well in potholes.
- Material was very expensive.
- The district does not require a wet-weather patching material, because it does not experience much rain.

Instant Road Repair - (Spec. 3563)

- Used for potholes only.
- Material as sticky and as difficult to work as UPM.
- Did not perform well, because of excessive settlement and tendency to "push out".
- The material did not adhere to the edges of the hole.
- The district does not require a wet-weather patching material.

New LRA

- Used for potholes only.
- Material very sticky.
- Performance similar to UPM.
- The district does not require a wet-weather patching material.

Item 330 - Type "CC"

- Used for both potholes and blade-on applications.
- Material provides good workability in the field.
- Excellent performance in both potholes and blade-on applications.
- Provides good texture and surface finish.
- Provides good stockpile workability.

Item 330 - Type "D"

- Used for blade-on applications only.
- Good mix to work with, with respect to handling, compaction, and surface finish.
- Excellent stockpile workability.

Item 330 - Type "AA"

- Used for potholes only.
- Used in potholes with depth greater than 2".
- Aggregate top size is a major problem.
- Top size needs to be raked out for smooth finish.
- Provides good stockpile workability.

TTI Design

- Used for both potholes and blade-on applications.
- Material hardened on the stockpile within two weeks, and could not be removed.
- Material was not tested further.
- Results are inconsistent with those experienced in other districts.

Item 350 - Type "DD" Atlanta Design

- Used for both potholes and blade-on applications.
- Pothole repair and performance was satisfactory.
- Did not test in blade-on application.
- Material hardened on the stockpile, and a pick-axe was needed to rework the mix.

Item 350 - Type "FF" Brownwood Design

- Used for both potholes and blade-on applications.
- Performed well in both potholes and blade-on applications.
- Overall performance was very good.
- Stockpile workability was very good.

Item 350 - Host District Design

- Used for potholes only.
- Material selected was a Type "FF".
- Stockpile workability was satisfactory.
- Some of the potholes repaired by this material failed completely because of stripping; whereas, others performed reasonably well.

District - 7 San Angelo

UPM - (Spec ????)

- Used for potholes only.
- The potholes are prepared before using UPM.
- Used in 2" depth holes.
- Performed well in both dry and wet potholes.
- Compaction was done by means of a truck.
- The district does not require a wet-weather patching material because it does not experience much rain.

Instant Road Repair (Spec. 3563)

- Used for potholes only.
- Did not like using the material from five gallon buckets.
- Experienced shoving problems, after placing in potholes.
- The material was found to be too expensive.
- Would prefer not to use the material in future.

New LRA

- The district did not receive this material.

Item 330 - Type "CC"

- Used for both potholes and blade-on applications.
- Stockpile workability good for no more than one season.
- Water and asphalt emulsion are sometimes used to rejuvenate the material.
- Works well in potholes.

Item 330 - Type "D"

- Did not receive this material.

Item 350 - Type "AA"

- Did not receive this material.

TTI Design

- Did not receive this material.

Item 350 - Type "DD" Atlanta Design

- Used for potholes only.
- Stockpile workability good for one season.
- Material performed well in potholes.
- Material is normally used for its maintenance work.

Item 350 - Type "FF" Brownwood Design

- Used for blade-on applications only.
- Very good stockpile workability.
- Blade-on applications are normally done in summer.
- Blade-on applications generally last for two to four years.

Item 350 - Host District Design

- The district did not test any material prepared locally.

District - 8 Abilene

UPM - (Spec ????)

- Used for potholes only.
- "Dump and run" is the only procedure used.
- Worked well in both wet and dry holes.
- Have even used it in potholes with water running over the road.
- Excellent stockpile workability.
- Gives excellent overall performance.

Instant Road Repair (Spec. 3563)

- The district did not receive this material.

New LRA

- Used for potholes only.
- Material was found to be very sticky and "messy".

- Stockpile workability limited to one season, as the asphalt in the material started flowing out of the stockpile in summer.
- Handling and performance characteristics similar to UPM.
- Excellent performance in potholes.

Item 330 - Type "CC"

- Used for both potholes and blade-on applications.
- This material was considered to have the best workability.
- Used under dry conditions.
- Performed very well on both potholes and blade-on applications.

Item 330 - Type "D"

- Used for blade-on applications only.
- Performed well in overlay, blade-on and patching.
- Gives good finish.
- Very good stockpile workability.

Item 330 - Type "AA"

- Used for potholes only.
- Did not have enough time to evaluate stockpile workability, as all the material was consumed within a month.
- Used in holes with depth greater than 3".
- Used one time as a base material and failed. Reason was attributed to sub-grade failure.
- Worked very well in wet potholes.

TTI Design

- Did not receive this material.

Item 350 - Type "DD" Atlanta Design & Materials

- Used for both potholes and blade-on applications.
- Worked satisfactorily in potholes, although difficult to handle and compact.
- Failed completely under blade-on applications because of problems related with spreading the material.

- Material was found to have its best workability in the summer.
- Workability in the stockpile during colder weather was not good, because the material tended to form clumps.

Item 350 - Type "FF" Brownwood Design & Materials

- Used for both potholes and blade-on applications.
- Slight clumps were formed when temperatures fell below 45°F.
- Excellent performance in potholes, blade-on, and edge patching.
- Would prefer using it in the future.

Item 350 - Host District Design

- Used for both potholes and bade-on applications.
- Used a Type "D" material, with MC-800.
- The material performed well in potholes during winter; however, it pushed out as the warmer months approached.
- Performed well in blade-on applications.
- Stockpile workability was good.

District - 11 Lufkin

UPM - (Spec ????)

- Used for potholes only.
- Works well in wet potholes.
- Used the "dump and run" procedure.
- Works well in pothole with size up to 3′ x 3′.
- Have problems with the material during freeze/thaw.
- Good stockpile workability, which lasts for almost a year.

Instant Road Repair (Spec. 3563)

- Used for potholes only.
- Procedure for construction similar to UPM.
- Does not like the material in buckets. Too difficult to remove.
- Overall performance of the material satisfactory.

New LRA

- Used for potholes only.
- Performance similar to UPM, although slightly more viscous.
- Performed well in both wet and dry potholes.
- Good stockpile life.

Item 330 - Type "CC"

- The district did not receive this material.

Item 330 - Type "D"

- The district did not receive this material.

Item 330 - Type "AA"

- The district did not receive this material.

TTI Design

- Used for both potholes and blade-on applications.
- Performed reasonably well.
- Some of the maintenance personnel liked working with the material, while others did not.
- Good stockpile workability.

Item 350 - Type "DD" Atlanta Design

- The district did not receive this material.

Item 350 - Type "FF" Brownwood Design

- The district did not receive this material.

Item 350 - Host District Design

- Material selected for this category was a Type "D" specification.
- Used for both potholes and blade-on applications.
- Works well in temperatures above 35°F.
- Quality of material varies, depending on the vendor.
- Compaction with a roller rather than a truck is required before it will sufficiently set up.

## Summary of Field Test Results

The performance of UPM, Instant Road Repair, and New LRA, which have the capability to be used in wet potholes was characteristically similar. Districts that used all three of these materials in their field tests, tended to consider the cost of UPM and Instant Road Repair to be too high, but having reasonably good handling characteristics. Although the price appears to be considerably less, the New LRA was considered to be too sticky and difficult to place even though it performed well in-service. Engineering personnel at Amarillo and Lubbock were not inclined to use these materials in the future as their districts do not receive much rain.

The three Limestone Rock Asphalt materials tested (Item 330 Type "CC", "D", and "AA") were well received by the districts. Although these materials did not perform well in wet potholes, their stockpile workability and performance under dry conditions was considered exceptional. However, general complaints were voiced against the coarse material (Type "AA"), as the top size made it difficult to work with in the shallower potholes and the coarser aggregate needed to be raked out.

The TTI Design was tested in only four districts; Fort Worth, San Angelo and Abilene did not receive this material. The material gave good-to-excellent overall performance in Wichita Falls, Amarillo and Lufkin. However, in Lubbock the maintenance personnel could not get the material off the stockpile as it had completely set up. This phenomenon was found to be atypical, and samples of materials from Lubbock and Wichita Falls were analyzed in the laboratory to ascertain this enigma, as discussed later in laboratory results.

Item 350 - Type "DD" Atlanta Design did not perform well in the field. Characteristic complaints were made regarding stockpile workability, tendency to shove, and disintegration under traffic. San Angelo was the only district where the material reportedly performed well.

Item 350 - Type "FF" Brownwood Design gave exceptional overall performance in all districts that tested the material. This material was touted as being a new "find" for future use.

LABORATORY TEST PROGRAM

Samples of each test mixture were molded using the Texas gyratory shear compactor and the specified procedures (30). Molding temperature was controlled at approximately 100°F. Relatively high air voids were obtained for some of the materials (Table 3). The viscosity of the different binders at this temperature had a significant effect upon the air voids of the molded specimens (Table 4).

The resilient modulus values measured for the TTI Design from Wichita Falls and the laboratory, were the highest over a range of temperatures from -13°F to 104°F (Table 3). Figures 3a and 3b show that UPM and New LRA exhibited the lowest values at high temperatures and, further, that there was little difference in resilient modulus of the other mixtures at all temperatures.

Hveem stability of the specimens shows a slight degree of variation (Figure 4). With the exception of UPM and Item 350-Type "DD" Atlanta Design, which gave low values, all other materials exhibited stability values above 35. Hveem stability is largely dependent upon interparticle friction of the aggregate and not particularly sensitive to changes in the rheological properties of the binder. Hveem stability is, however, quite sensitive to binder content.

Marshall stability of the specimens portrays an unusually large degree of variation (Figure 5), with Item 330-Type CC and Type AA exhibiting the highest stabilities, while, Item 350-Type DD Atlanta Design and Type FF Brownwood Design the lowest. Figure 6 illustrates the Marshall flow for the materials.

Tensile strengths of the materials varied considerably (Table 5, Figure 7). Higher values were witnessed for Item 330 Type "CC" and "AA, and for TTI Design at Wichita Falls and the laboratory. The lowest value was obtained for UPM. This test is quite dependent upon binder or mastic viscosity and film thickness.

Indirect tension tests were performed on a second set of specimens after moisture treatment (Table 5). Tensile strength ratios were calculated by dividing measurements after moisture treatment by those obtained on unexposed specimens. The results are plotted in Figure 8. UPM displayed the lowest susceptibility to moisture compared to the other materials

Table 3. VMA, Resilient Modulus, Hveem and Marshall Stability of Test Specimens.

| Test Materials | Air Void Content, percent | VMA, percent | Resilient Modulus, 1000 psi -13 F | 32 F | 68 F | 77 F | 104 F | Hveem Stability | Marshalls Stability, lbs. | Marshalls Flow, 0.01" |
|---|---|---|---|---|---|---|---|---|---|---|
| UPM – Type 1 | 2.65 | 11.7 | 1276 | 527 | 98 | 94 | 14 | 22 | 900 | 17 |
| Instant Road Repair | 14.25 | 19.4 | 1189 | 678 | 208 | 178 | 35 | 41 | 1088 | 11 |
| New LRA | 3.4 | 13.2 | 1228 | 368 | 54 | 42 | 16 | 35 | 893 | 20 |
| Item 330 – Type CC | 10.9 | 19.3 | 1446 | 563 | 277 | 239 | 59 | 40 | 2020 | 14 |
| Item 330 – Type D | 8.2 | 16.4 | 1154 | 576 | 206 | 168 | 39 | 37 | 1208 | 13 |
| Item 330 – Type AA | 13.2 | 21.2 | 1336 | 851 | 342 | 322 | 76 | 43 | 2426 | 15 |
| TTI Design (Wichita Falls) | 7.05 | 14.8 | 2390 | 1240 | 595 | 528 | 73 | 36 | 1052 | 14 |
| TTI Design (Lubbock) | 10.55 | 13.9 | 1343 | 879 | 269 | 242 | 52 | 41 | 1190 | 15 |
| TTI Design (Laboratory) | 5.4 | 15.7 | 2410 | 1368 | 656 | 477 | 81 | 48 | 1465 | 15 |
| Item 350 – Type DD Atlanta Design | 10.05 | 15.3 | 1818 | 710 | 134 | 112 | 18 | 27 | 389 | 12 |
| Item 350 – Type DD Atlanta Design & Materials | 8.7 | 13.4 | 1403 | 876 | 179 | 140 | 32 | 45 | 924 | 19 |
| Item 350 – Type FF Brownwood Design | 9.55 | 15.6 | 1669 | 1046 | 259 | 187 | 35 | 38 | 648 | 18 |
| Item 350 – Type FF Brownwood Design & Mat'ls | 11.75 | 16.6 | 1915 | 912 | 300 | 198 | 55 | 46 | 805 | 20 |

Table 4. Results of Extraction/Recovery on Test Specimens.

| Test Materials | Bitumen Content, percent | Penetration at 77 F | Viscosity at 140 F, poise |
|---|---|---|---|
| UPM - Type 1 | 6.07 | 218 | 534 |
| Instant Road Repair | 5.12 | 81 | 2094 |
| New LRA | 6.10 | too soft | 363 |
| Item 330 - Type CC | 8.91 | 124 | 1980 |
| Item 330 - Type D | 8.94 | 44 | 2018 |
| Item 330 - Type AA | 9.10 | 68 | 5607 |
| TTI Design (Wichita Falls) | 6.20 | 43 | 1491 |
| TTI Design (Lubbock) | 4.38 | 38 | 4032 |
| TTI Design (Laboratory) | 4.82 | 81 | 712 |
| Item 350 - Type DD Atlanta Design | 3.19 | 59 | 3853 |
| Item 350 - Type DD Atlanta Design & Materials | 2.21 | 104 | 703 |
| Item 350 - Type FF Brownwood Design | 2.85 | 81 | 1023 |
| Item 350 - Type FF Brownwood Design & Matl's | 3.60 | 75 | 1173 |

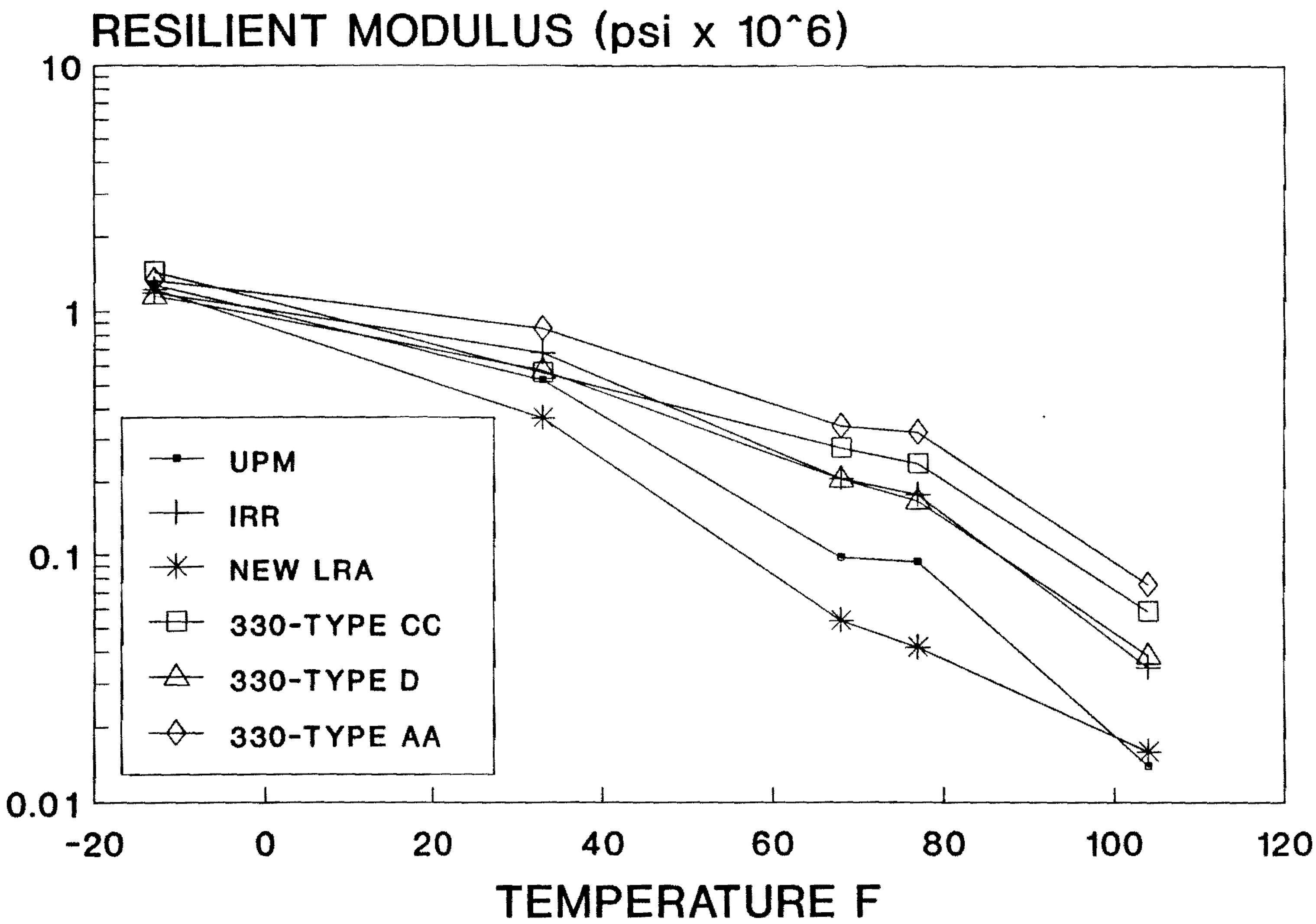


Figure 3a. Temperature vs. Resilient Modulus.

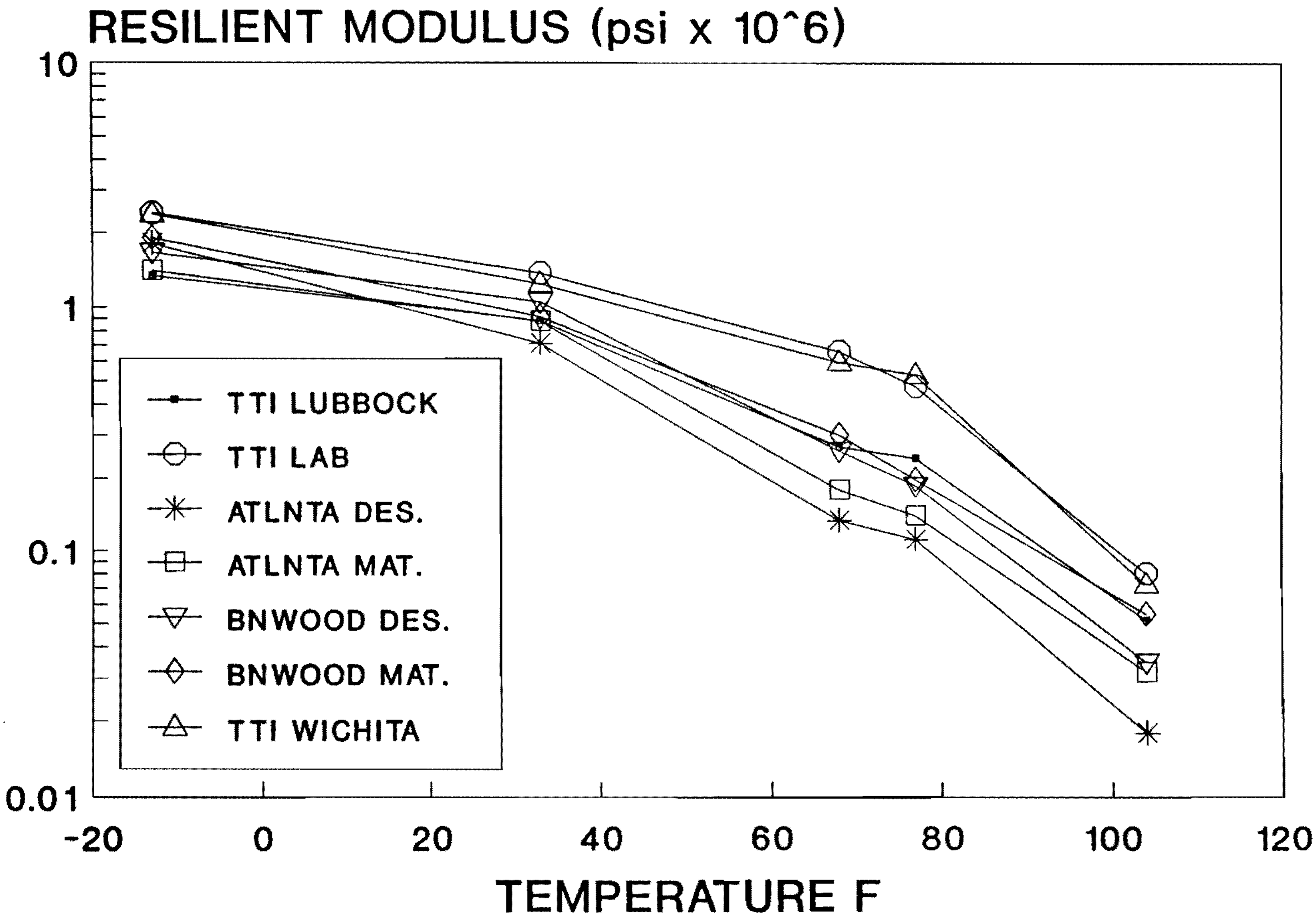


Figure 3b. Temperature vs. Resilient Modulus.

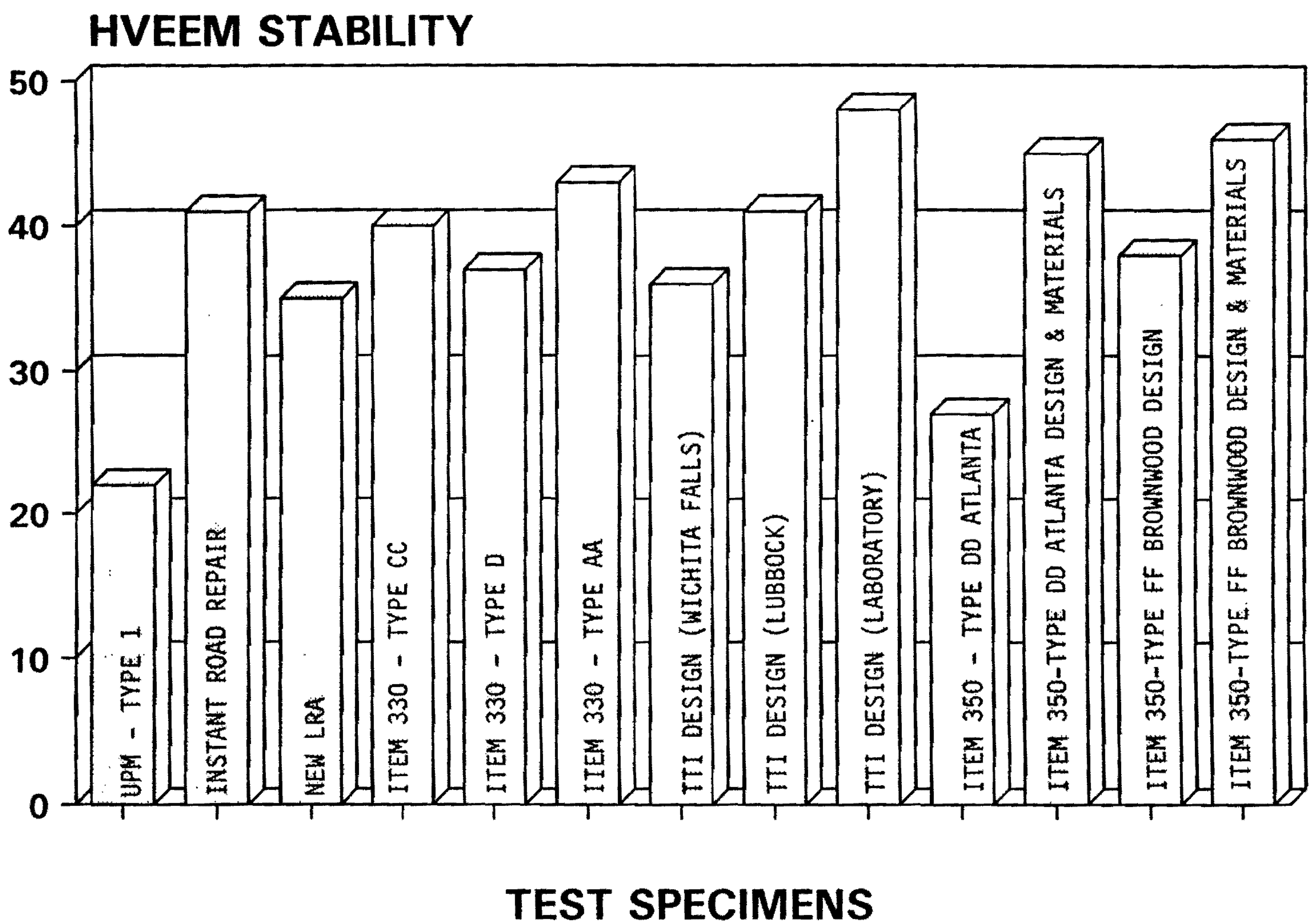


Figure 4. Hveem Stability of Test Specimens.

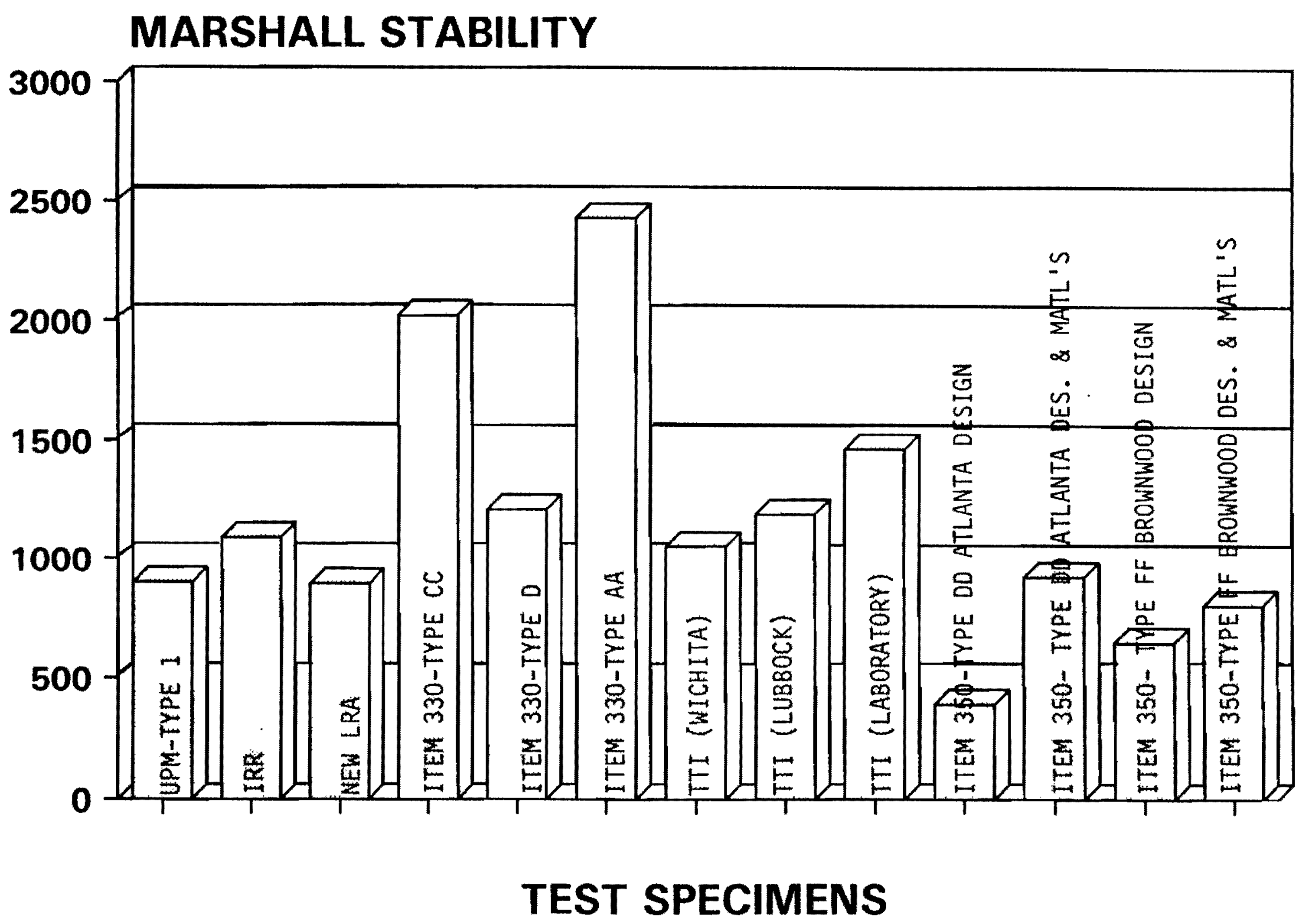


Figure 5. Marshall Stability of Test Specimens.

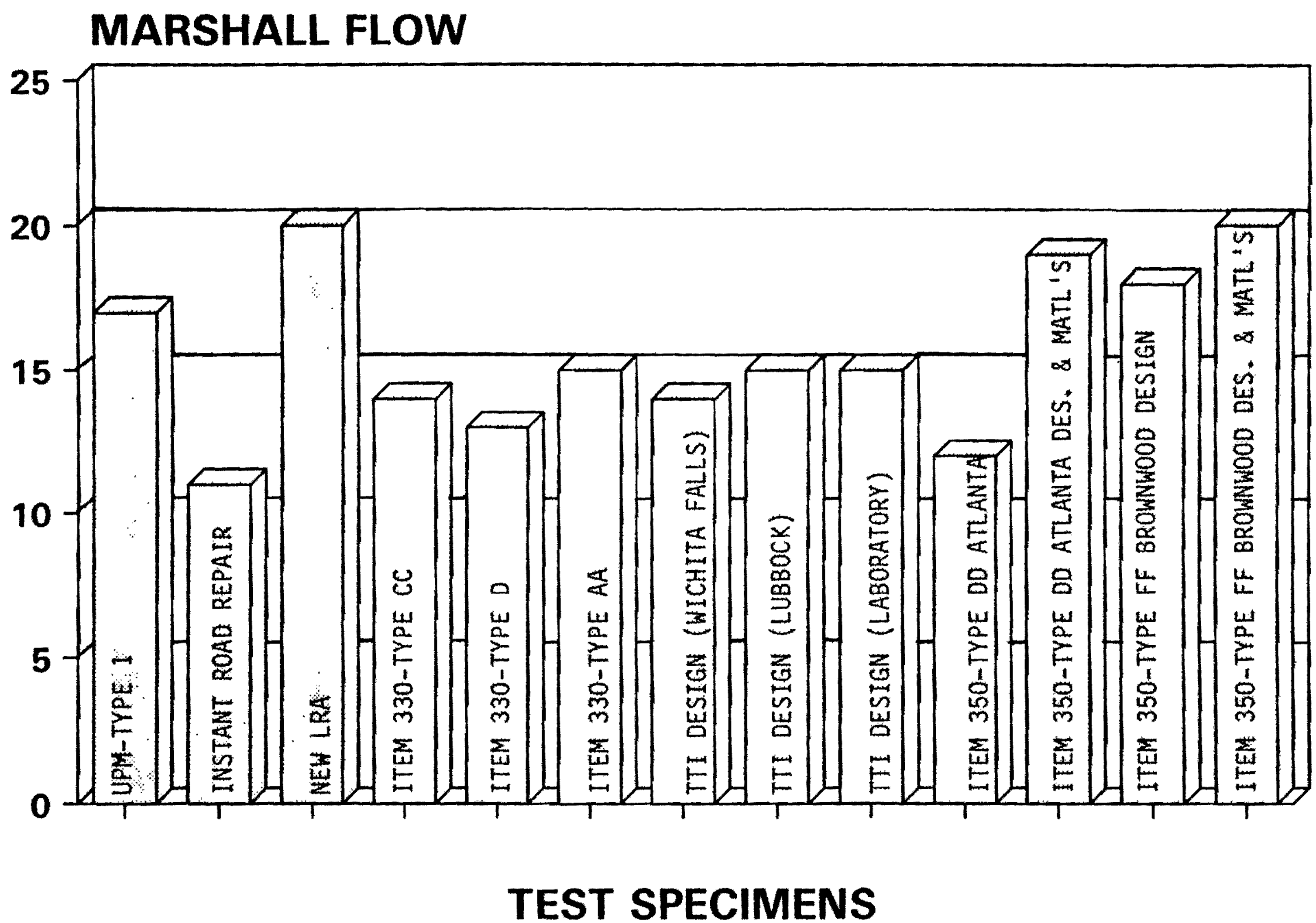


Figure 6. Marshall Flow of Test Specimens.

Table 5. Properties of Test Specimens Before and After Moisture Treatment.

| Test Materials | Before Moisture Treatment | | After Moisture Treatment | | Tensile Strength Ratio |
|---|---|---|---|---|---|
| | Air Void Content, (%) | Tensile Strength, (psi) | Air Void Content, (%) | Tensile Strength, (psi) | |
| UPM - Type 1 | 2.2 | 30 | 2.3 | 23 | 78 |
| Instant Road Repair | 13.7 | 61 | 14 | 22 | 37 |
| New LRA | 3.5 | 53 | 3.6 | 22 | 42 |
| Item 330 - Type CC | 12 | 107 | 11.6 | 47 | 44 |
| Item 330 - Type D | 8.4 | 68 | 7.9 | 24 | 36 |
| Item 330 - Type AA | 13.1 | 128 | 12.3 | 63 | 50 |
| TTI Design (Wichita Falls) | 7.2 | 175 | 8.2 | 62 | 36 |
| TTI Design (Lubbock) | 10.5 | 67 | 11 | 10 | 15 |
| TTI Design (Laboratory) | 5.7 | 167 | 5.2 | 87 | 52 |
| Item 350 - Type DD Atlanta Design | 9.3 | 65 | 9.4 | 18 | 27 |
| Item 350 - Type DD Atlanta Design & Materials | 8.7 | 45 | 8.2 | 25 | 57 |
| Item 350 - Type FF Brownwood Design | 9.4 | 71 | 9.7 | 15 | 21 |
| Item 350 - Type FF Brownwood Design & Matl's | 10.7 | 65 | 10.6 | 39 | 59 |

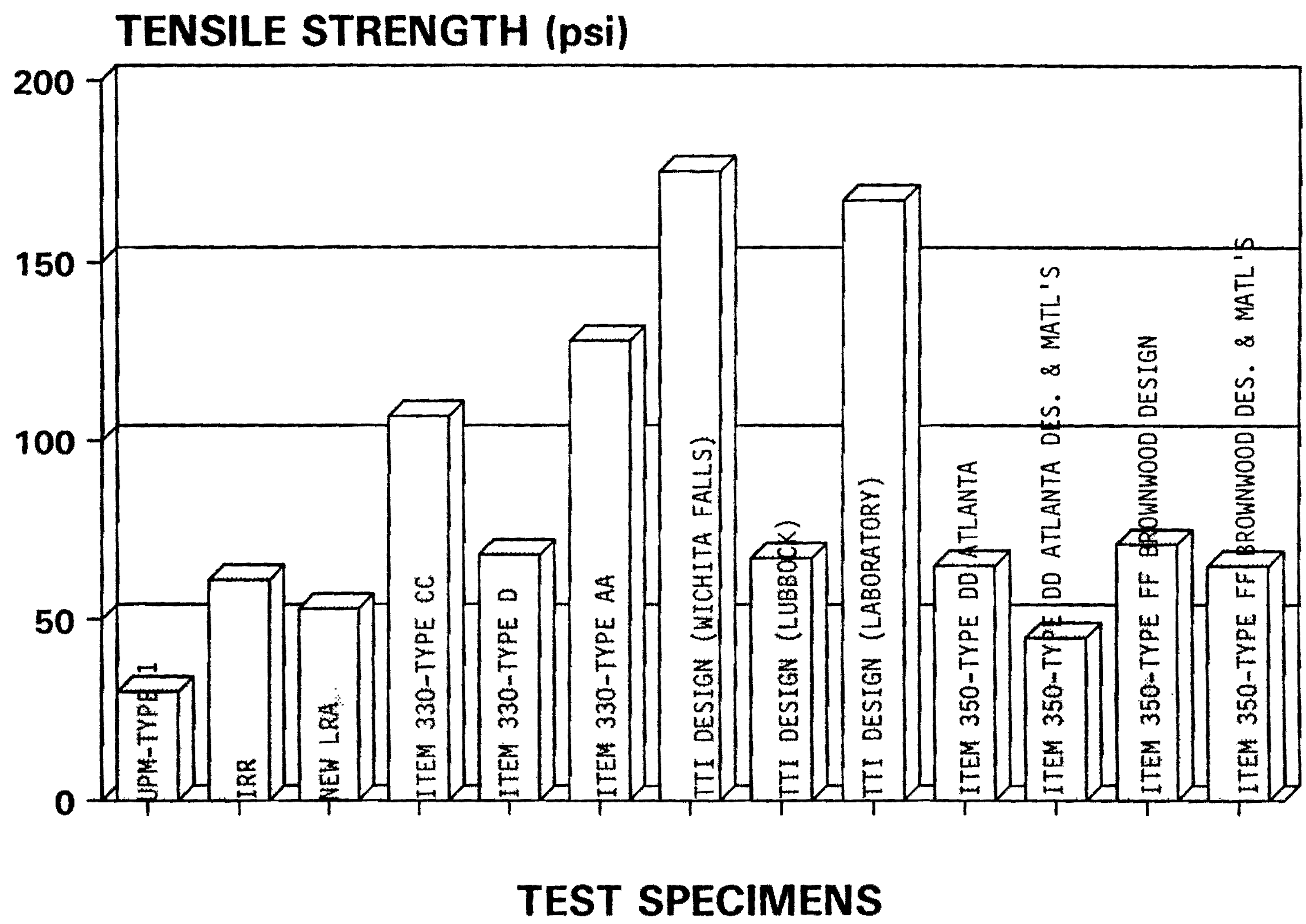


Figure 7. Tensile Strength (Dry) of Test Specimens at 77°F and 2 in/min.

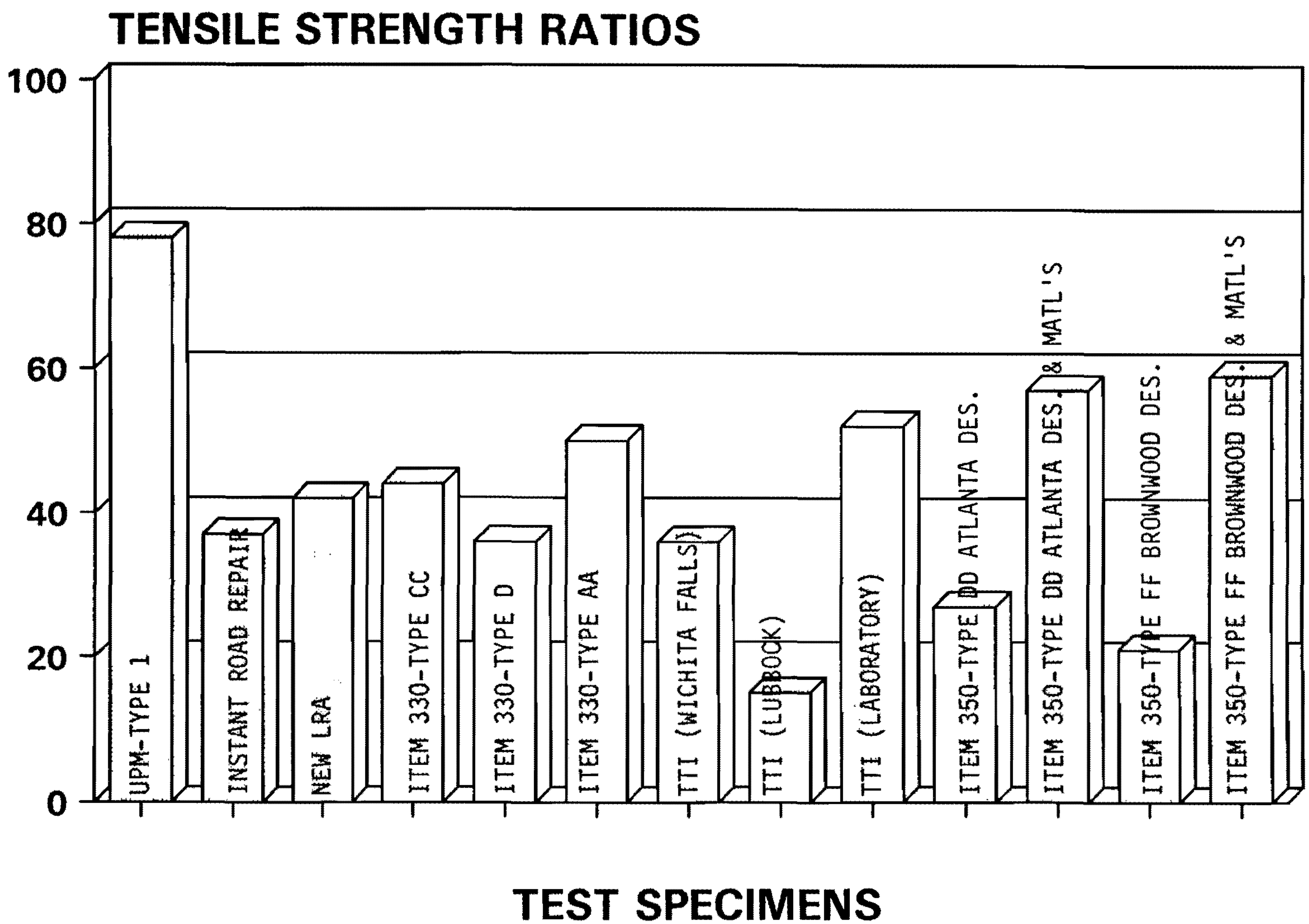


Figure 8. Tensile Strength Ratio

studied. This was most likely due to its low void content, thick asphalt films, and the type of additives used in the mix design.

Results of extraction/recovery of bitumen on test specimens, and the resulting viscosity and penetration values are presented in Table 4. The high values obtained for LRA materials (Item 330) is indicative of the natural bitumen content present in the aggregate. The high viscosity value of the TTI Design from Lubbock may be one of reasons for the material setting up in the stockpile.

Results of sieve analysis of aggregates obtained after the extraction process are presented in Appendix 4. Generally, all materials conformed to specifications, with the exception of the material from Lubbock (TTI Design), where the amount of material passing the #200 sieve was 8 percent compared to a maximum of 4 percent allowed for in the specifications. This deviation was compounded by a high viscosity bitumen, which finally resulted in a high viscosity mastic, leading to the material completely setting up in the stockpile.

### Summary of Laboratory Test Results

There is a general similarity in the test results of UPM and New LRA. This would indicate that New LRA could meet specifications and prove to be a suitable alternative to UPM for use in wet potholes. This could result in removal of UPM from the sole source proprietary item list.

The TTI Design has been successful for material obtained from Wichita Falls and the one prepared in the laboratory. Reasons for the material failing to perform in Lubbock have been discerned to be deviations from the specification by the vendor. This specification with minor modification can also be used in-place of LRA to offer competitive bids.

All other materials have performed reasonably well in the laboratory tests.

## CURRENT LRA PROCUREMENT POLICY

The sole source designation for procurement of LRA was established during the Summer of 1987. In December 1987, only three districts (Amarillo, Lubbock and Childress) were approved by the administration to purchase LRA for winter use. In October 1988, Abilene was allowed to purchase 4000 tons of LRA, and again in August 1989, Abilene and Wichita Falls were also given approval to purchase LRA on a no alternate basis for winter use. Further, in July and September of 1990, the San Angelo and Odessa Districts were respectively approved by the administration.

At this writing, only the above seven districts can purchase LRA, with suitable justification all other districts can purchase LRA on a case-by-case basis.

It has also been recommended (32,33) that all requisitions for hot mix-cold laid asphalt concrete, Item 350, show as an alternate, cold mix-cold laid limestone rock asphalt, Item 330, unless the latter is not desired. This was done to enhance competition as well as afford the districts the opportunity to receive LRA.

## CONCLUSIONS AND RECOMMENDATIONS

Based on reports from the districts and observations made during site visits to stockpiles and test sections, and subsequent laboratory testing of materials obtained from the field trials, the following conclusions and recommendations are tendered.

### CONCLUSIONS

1. This program identified several materials in addition to LRA which can be utilized for cold/wet weather maintenance. However, there are currently no products available in Texas which can compete directly with LRA as specified in Item 330.

2. The TTI Design which is a hot mix-cold laid material has been successful in tests performed during this program and may be used as a generic design for both pothole and blade-on applications. Furthermore, LRA could provide an alternative to this specification.

3. Personal preferences for some materials in certain cases among district engineering personnel played a major role in the evaluation of materials. As such, there were incidents where half the personnel in one district preferred using a particular material, while the other half did not.

4. Incidents of Item 350 materials being vendor sensitive were reported in some districts. Although materials would meet the specifications, their performance would be erratic from one batch to the other or from one vendor to another.

5. In the field test plan, materials were to be placed when ambient temperatures were at or below 40°F. Although a significant number of the tests were carried out at temperatures, above 40°F, many tests units were placed at temperatures near 40°F and thus provided useful data for evaluation.

6. One of the major benefits of this study has been the exposure of districts to materials that were never used by them before.

7. As the performance of UPM and New LRA were generally the same during field trials and under laboratory tests, New LRA could provide the necessary competition to UPM which has been declared as a sole source proprietary

item. The handling problems with New LRA will have to be resolved before it can enjoy a general approval. Vulcan has advised TTI that this activity is now in progress.

8. Limestone Rock Asphalt materials continued to give overall good performance and were popular in most of the districts. Major handicap other than the sole source procurement restrictions is shipping costs.

9. The Brownwood Item 350-Type FF mixtures with emulsion binders performed very well in the three districts in which it was tested. Lubbock, which had not used this material prior to this program, plans to make it part of next year's procurement.

RECOMMENDATIONS

1. Because a significant portion of the maintenance activity for this study was done during uncharacteristic warm temperatures, a new series of field tests should be conducted. This should be preceded by a fine tuning of the new LRA and TTI mix designs. The new field test should be limited to no more than 3 districts and should be carried out at temperatures at or below 40°F.

2. Consideration should be given to specifying materials on a volume basis. The state could realize an advantage in the greater quantity of delivered materials offered by mixtures with low unit weights that cover equivalent areas/depths of pavement.

3. Since this study uncovered no new cost effective cold mix-cold laid materials to compete with Item 330, it is recommended that the latter be permitted to be purchased on an either/or basis with Item 350 as presented in Reference 33.

4. On the basis of the favorable results of the New LRA mixtures it is recommended that it be considered as a competitive procurement to UPM for pot-hole repair, thus removing their respective sole source designation for this activity. Because of the difficulty experienced by some maintenance crews in handling the new LRA mixture it is recommended that this deficiency be rectified by the vendor. Until then there will be a general reluctance to use LRA even though it performs well in service. Vulcan is dealing with this problem at this writing.

5. Any new study dealing with cold weather maintenance materials should allow for the development of a test method for quantifying stockpile workability.

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**APPENDIX 1**

Proposed Test Matrix by District

**TABLE A**

**PROPOSED TEST MATERIALS**

**BY DISTRICT**

| POTHOLES | 2 | 3 | 4 | 5 | 7 | 8 | 11 |
|---|---|---|---|---|---|---|---|
| 1. UPM - Type I | x | x | x | x | x | x | x |
| 2. Instant Road Repair | x | x | x | x | x | x | x |
| 3. New LRA | x | x | x | x | x | x | x |
| 4. Item 330 - Type CC | x | x | x | x | x | x | x |
| 5. Item 330 - Type AA | x | x | x | x | x | x | x |
| 6. TTI Design | x | x | x | x | x | x | x |
| 7. Item 350 - Type DD Atlanta Design | x | | x | x | x | | x |
| 8. Item 350 - Type FF Design & Materials | | x | | | | x | |
| 9. Item 350 - Type FF Brownwood Design | x | | x | x | x | | x |
| 10. Item 350 - Type FF Brownwood Design & Materials | | x | | | | x | |
| 11. Item 350 - Host Districct Design | x | x | x | x | x | x | x |
| 12. Local Vendor Design | x | x | x | x | x | x | x |

## TABLE B

## PROPOSED TEST MATERIALS BY DISTRICT

| | 2 | 3 | 4 | 5 | 7 | 8 | 11 |
|---|---|---|---|---|---|---|---|
| **BLADE-ON** | | | | | | | |
| 1. Item 330 - Type CC | x | x | x | x | x | x | x |
| 2. Item 330 - Type D | x | x | x | x | x | x | x |
| 3. TTI Design | x | x | x | x | x | x | x |
| 4. Item 350 - Type DD Atlanta Design | x | | x | x | x | | x |
| 5. Item 350 - Type DD Atlanta Design & Materials | | x | | | | x | |
| 6. Item 350 - Type FF Brownwood Design | x | | x | x | x | x | x |
| 7. Item 350 - Type FF Brownwood Design & Materials | | x | | | | x | |
| 8. Item 350 - Host District Design | x | x | x | x | x | x | x |
| 9. Local Vendor Design | x | x | x | x | x | x | x |

**APPENDIX 2**

Copies of Maintenance Data Sheets

Project 1176-9
MAINTENANCE DATA SHEET

## I. IDENTIFICATION

Date_______________

Highway No. ___________ District _____________ County _____________

Mile Post or Section Limits: From _____________ to _____________

Repair Identification No: _________________

Lane_________________

Direction ____________

ADP

Maintenance Crew Chief: ___________________ Repair Date _______________

## II. EXISTING PAVEMENT DATA

Pavement Type: (Asphalt Mix, Seal Coat, Concrete)

_______________________________________________________

Date of Last Construction: __________________________________________

Type of Paving Material: ___________________________________________

General Condition: ________________________________________________
(including on-site photos)

**STOCKPILE EVALUATION**

Date ______________ Location ______________________________

| Sampling & Evaluation | Initial | Midpoint (1-2 mos) | Final |
|---|---|---|---|
| Ambient Temperature, °F | ____ | ____ | ____ |
| Weather | | | |
| Clear | ____ | ____ | ____ |
| Partly Cloudy | ____ | ____ | ____ |
| Cloudy | ____ | ____ | ____ |
| Rain | ____ | ____ | ____ |
| Stockpile Condition | | | |
| Dry | ____ | ____ | ____ |
| Damp | ____ | ____ | ____ |
| Wet | ____ | ____ | ____ |
| Stockpile Workability | | | |
| Easy to Load | ____ | ____ | ____ |
| Difficult to Load | ____ | ____ | ____ |
| Impossible to Load | ____ | ____ | ____ |
| Hand Workability | | | |
| Easy to spread & Compact | ____ | ____ | ____ |
| Difficult to Spread & Compact | ____ | ____ | ____ |
| Impossible to Spread & Compact | ____ | ____ | ____ |
| Stripping in Stockpile | | | |
| None | ____ | ____ | ____ |
| Slight | ____ | ____ | ____ |
| Considerable | ____ | ____ | ____ |
| Formation of Crust | | | |
| None | ____ | ____ | ____ |
| Slight (thickness ?) | ____ | ____ | ____ |
| Hard | ____ | ____ | ____ |

Comments ______________________________________________

# MAINTENANCE DATA LOG

| Repair ID (*) | Method (**) | Date | Dimensions (LXWXD) | Surrounding Pavement Condition(***) | Material/Spec | PERFORMANCE (****) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | >1 wk | 1 mo | 2 mo | ≥4 mo |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## LEGEND

**REPAIR ID***

2-P-1
- SERIAL NUMBER
- TYPE OF REPAIR { P = POT HOLE, B = BLADE ON }
- DISTRICT

**METHOD****

PREP = PREPARED
D/R = DUMP AND RUN

**PAVEMENT*** CONDITION**

DRY
DAMP
WET

**PERFORMANCE******

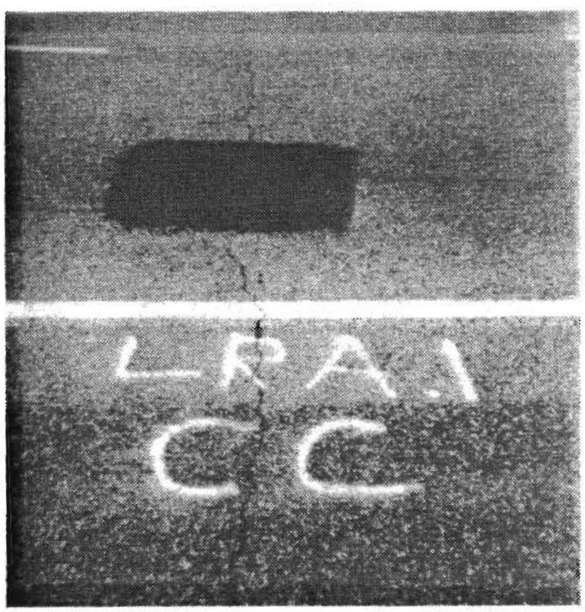
P = PASS
PF = PARTIAL FAILURE
F = FAIL

# APPENDIX 3

Selected Illustrations of Field Tests

Pothole repair in progress with UPM


Pothole "prepared" with tack coat




Repaired with Item 330 - Type CC

Edge Raveling

After patching with Brownwood Design

Blade-on application in progress

Potholes being repaired with New LRA

Compaction with truck tires

Blade-on application using Item 330-Type D

Blade-on application using Atlanta Design

## APPENDIX 4

Sieve Analysis of Aggregates

## SIEVE ANALYSIS OF AGGREGATES

### General

The particle size distribution of fine and coarse aggregates for each material was determined in accordance with ASTM C 136-84a method. These aggregates were obtained after extracting the binder.

### UPM

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 99.5 |
| Passing # 4 | 55 |
| Passing # 10 | 27 |
| Passing # 40 | 16 |
| Passing # 80 | 11 |
| Passing # 200 | 3.6 |

### Instant Road Repair

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 95.5 |
| Passing # 10 | 47 |
| Passing # 40 | 16 |
| Passing # 80 | 8 |
| Passing # 200 | 5 |

New LRA

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 99 |
| Passing # 4 | 55 |
| Passing # 10 | 27 |
| Passing # 40 | 15 |
| Passing # 80 | 9 |
| Passing # 200 | 5 |

Item 330 - Type "CC"

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 76 |
| Passing # 10 | 61 |
| Passing # 40 | 36 |
| Passing # 80 | 18 |
| Passing # 200 | 4 |

Item 330 - Type "D"

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 88 |
| Passing # 10 | 61 |
| Passing # 40 | 38 |
| Passing # 80 | 15 |
| Passing # 200 | 4 |

Item 330 - Type "AA"

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1½" | 100 |
| Passing 1¼" | 95.7 |
| Passing 7/8" | 90 |
| Passing 3/8" | 85 |
| Passing # 4 | 71 |
| Passing # 10 | 61 |
| Passing # 40 | 34 |
| Passing # 80 | 18 |
| Passing # 200 | 6 |

TTI Design (Wichita Falls)

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 96 |
| Passing # 4 | 75 |
| Passing # 10 | 54 |
| Passing # 40 | 29 |
| Passing # 80 | 12 |
| Passing # 200 | 3 |

TTI Design (Lubbock)

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 97.6 |
| Passing # 4 | 70 |
| Passing # 10 | 46 |
| Passing # 40 | 27 |
| Passing # 80 | 16 |
| Passing # 200 | 8 |

TTI Design (Laboratory)

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 64 |
| Passing # 10 | 43 |
| Passing # 40 | 28 |
| Passing # 80 | 15 |
| Passing # 200 | 1.5 |

Item 350 - Type "DD" Atlanta Design

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 99.8 |
| Passing # 4 | 77 |
| Passing # 10 | 51 |
| Passing # 40 | 32 |
| Passing # 80 | 21 |
| Passing # 200 | 4 |

Item 350 - Type "DD" Atlanta Design & Materials

| Sieve Information | Percent by Weight |
|---|---|
| Passing 1/2" | 100 |
| Passing 3/8" | 95 |
| Passing # 4 | 62 |
| Passing # 10 | 41 |
| Passing # 40 | 27 |
| Passing # 80 | 13 |
| Passing # 200 | 5 |

Item 350 - Type "FF" Brownwood Design

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 77 |
| Passing # 10 | 39 |
| Passing # 40 | 22 |
| Passing # 80 | 13 |
| Passing # 200 | 6 |

Item 350 - Type "FF" Brownwood Design & Materials

| Sieve Information | Percent by Weight |
|---|---|
| Passing 3/8" | 100 |
| Passing # 4 | 77 |
| Passing # 10 | 38 |
| Passing # 40 | 23 |
| Passing # 80 | 10 |
| Passing # 200 | 2 |