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16. Abstract

Texas Department of Transportation (TxDOT) maintenance personnel have noted problems with a commonly used, stockpiled maintenance mix known as Item 334, Hot-Mix Cold-Laid Asphalt Concrete Paving Mixture (HMCL). It is generally used by maintenance personnel as a blade-on/level-up material and as a pothole repair material. Performance problems include stripping in the stockpile, a tendency towards instability in hot weather, and a lack of winter workability.

The objective of this research project was to identify a series of simple but meaningful laboratory tests and acceptance criteria for HMCL patching materials that will ensure reasonable stockpile life and field performance. A literature review was conducted to identify published information on patching materials with a particular emphasis on test procedures that have been developed for maintenance mixtures. A survey was performed of maintenance personnel in all of the TxDOT district offices to identify problems.

Several different HMCL mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregates (crushed gravel and crushed limestone) and three types of binders (AES-300S, MC-800, and MC-800 with diesel) for a total of six different mixtures. Laboratory tests indicated that mixtures designed at 92 percent density had Marshall stabilities and unconfined compressive strengths as high or higher than those designed at 95 percent density.

Field mixtures were evaluated in the laboratory as a function of stockpile age. Several simple test procedures were evaluated such as the rolling sieve cohesion test and various workability test procedures.

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EVALUATION OF TEXAS DOT ITEM 334, HOT-MIX, COLD-LAID ASPHALT CONCRETE PAVING MIXTURES

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DISCLAIMER

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CHAPTER 1.0 INTRODUCTION

1.1 BACKGROUND

Pothole patching and surface repair of asphalt pavement remains one of the most commonly performed maintenance operations for most highway agencies, especially in areas where cold winters and warm, wet springs contribute to accelerated, perpetual pavement failures every year. The Strategic Highway Research Program (SHRP) H-106 research study (Wilson and Romine, 1993) showed that while improving the quality of the materials used for pavement repair increases the cost of these materials, it also extends the life of the repair and is a cost-effective strategy.

Asphalt paving technologists around the country continuously strive to improve the quality of these materials; however, the expectations placed on patching materials often exceeds the technology. It is desirable for patching materials to be *workable* in both winter and summer. *Workability* refers to the ease with which a mixture can be handled, shoveled, and raked. It can be gained by using an adequate amount of relatively soft binder. If the binder is too soft, however, the mixture can be susceptible to instability problems in the warmer months. Certain aggregates such as sands and uncrushed gravels can also improve mixture workability but can contribute to pushing and shoving under traffic.

Since the binder is the portion of a bituminous mixture which is temperature susceptible, it is the source of winter workability problems. It is logical to assume that if a stockpiled mix has a high binder content (which is susceptible to cold temperatures), it will be a cohesive mass in cold, winter months. Therefore, a lower binder content could give a mix better workability in winter months. However, this better winter workability could be at the sacrifice of mixture cohesion and stripping resistance.

The Texas Department of Transportation (TxDOT) purchases cold-applied bituminous patching materials under several specifications which are discussed below.

Specification Item DMS 9200.001 High Performance Asphaltic Concrete Pothole Patching Mix (Guaranteed): This specification is for asphaltic concrete mixture intended primarily as a cool to cold, wet-weather, high performance, pothole patching mix for maintenance. It is primarily a crushed stone asphaltic concrete with asphalt additives. The supplier of the material must guaranty the performance of the mix to meet certain requirements as described in the specification.

Specification Item DMS 9200.002 Asphaltic Concrete Patching Material (Stockpile Storage): This specification is for an asphaltic concrete mixture intended as a cold weather stockpile patching mix for maintenance. It is either an open, dense, or gap-graded mixture composed of a crushed stone with asphalt additives. Maintenance personnel use it primarily for small-area pavement repairs such as potholes. Item 334 mixtures can also be purchased under this specification but must conform to the gradations specified in Item 334 which produce dense-graded mixtures.

Specification Item DMS 9200.003 Containerized Asphaltic Concrete Patching Material: This specification is for containerized asphalt concrete mixtures intended for cold, wet weather repair of small pavement areas.

Specification Item 332 Limestone Rock Asphalt Pavement: Limestone rock asphalt aggregate has an average bitumen content of 5 to 9 percent of naturally impregnated asphalt. It is a dense-graded aggregate, typically cold-mixed in a mixing plant with a flux material, and is suitable for surface courses or level-up courses. It can be stockpiled and is used routinely for maintenance applications.

Specification Item 334 Hot-Mix Cold-Laid Asphaltic Concrete Pavement: This mixture consists of a dense-graded aggregate and asphaltic additive blended in a hot-mix plant. It is designed with asphaltic binders allowing it to be stockpiled and applied cold. It is used primarily for maintenance applications.

Most of the problems with TxDOT maintenance mixtures occur with *Item 334, Hot-Mix Cold-Laid Bituminous Asphalt Paving Mixture,* hereafter referred to as HMCL, and is the subject of this research study. HMCL is generally used as a blade-on/level-up material and not as a pothole repair material (except when necessary). Most districts tend to use this material in the warm months (summer and early fall) prior to the following year's seal coat program (when the repairs will be covered by a seal coat). Most maintenance personnel report that the repair should be in place several months to allow adequate curing prior to sealing with a seal coat.

While many of the districts report good performance of this material, others note that performance is inconsistent. Primary complaints noted include:

- stripping,
- tends to *push* and rut in hot weather, and
- unworkable in winter and too rich in summer.

1.2 OBJECTIVES

The objective of this research study was to identify a series of simple but meaningful laboratory tests and acceptance criteria for HMCL patching materials which will ensure reasonable stockpile life and field performance.

1.3 RESEARCH APPROACH

At the onset of this research study, a literature review was conducted to identify published information on patching materials with a particular emphasis on test procedures which have been developed for maintenance mixtures. A survey was performed of maintenance personnel in all of the TxDOT district offices to determine:

(1) types of patching materials used in district,
(2) material formulations (binders and aggregates used),
(3) materials which perform well and in what applications,
(4) materials which perform poorly and in what applications, and
(5) material sources.

Several different HMCL mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregates (crushed gravel and crushed limestone) and three types of binders (AES-300S, MC-800, and MC-800 with diesel) for a total of six different mixtures. The objective of this laboratory effort was (1) to evaluate the properties of mixtures fabricated at different densities (in addition to 95 percent density as currently required), and (2) to evaluate the suitability of laboratory tests to differentiate between mixtures with different degrees of workability and cohesion.

1.4 REPORT ORGANIZATION

The results of this research study are presented in Chapters 2 through 7. Chapter 2 contains the literature review, and Chapter 3 is a summary of the district survey responses. Chapter 4 presents the results of the laboratory study on the mixtures designed at different densities using different types of aggregates and binders. Chapters 5 and 6 present the information on the field sampled materials, and Chapter 7 lists the conclusions of the study.

Recommendations resulting from this study regarding laboratory tests and acceptance criteria are presented in a separate summary report: 1717-S.

CHAPTER 2.0 LITERATURE REVIEW

2.1 VIRGINIA TRANSPORTATION RESEARCH COUNCIL (1995)

A recent study (Prowell and Franklin, 1995) was conducted by the Virginia Transportation Research Council (VTRC) on cold mixes for winter pothole repair. In this study, 13 proprietary cold-mix patching materials were evaluated for performance. Materials used in this study are shown in Tables 1 and 2. In addition, a Virginia Type P cold mix and HMA were also included. The Type P mix is a stockpile material produced with medium cure (MC-400) cut-back. The gradation specifications for the Type P mix is as follows:

Sieve Size, mm	Percent Passing
12.5	100
9.5	95 - 100
4.75	35 - 50
2.36	Max 20
0.6	Max 10
0.075	Max 3

Two test sections were placed to measure material performance, and a third was placed to evaluate workability. Forty potholes, 3800 mm in diameter and 75 mm deep, were made in the right wheel path at each test site. The *pothole* was cleaned with compressed air prior to being backfilled with cold mix. Thirteen materials were included, with three replicates of each. The first test section was placed in July 1994, the second in February 1995, and the final in March 1995.

Laboratory tests were performed: coating, stripping test, boil test, draindown, workability, and adhesion. The coating test (Wilson and Romine, 1993b) was used to ensure that a sufficient residual binder content was present to coat the aggregates completely and was primarily a design test. All of the materials passed the coating test (>90% coated).

Two forms of stripping tests were performed. In the first, a 100 g sample is placed in a 1 L jar of distilled water 60 °C for 16 to 18 hours (Wilson and Romine, 1993b). Then the percentage that remains coated is visually estimated. All of the materials passed this stripping test. VDOT's VTM 13 (Boil Test) was also performed. A 200 g sample is placed in a beaker of boiling water for 10 minutes. The sample is drained and visually compared to an unconditioned sample. The percentage that remains coated is recorded. Efforts were made to correlate these results to ratings obtained in the test sections; however, the correlation was poor.

A draindown test (AASHTO TP42-94) is normally run as part of the design procedure to determine the upper limit for the residual binder content. In this test, a 1000 g sample is placed in an aluminum pie plate in a 60 °C oven for 24 hours. Then, the pan is inverted to remove all of the aggregate particles and the weight of the residual asphalt is determined (Wilson and Romine, 1993b). The draindown is calculated as a percentage of the sample's initial binder content. According to the SHRP criteria, 4 percent is the maximum allowable. Prowell and Franklin (1995) found that the 4 percent limit may be too stringent and recommend 8 percent since two of the best performing materials, UPM and HEI-WAY, had draindown results in the 4 percent - 8 percent range.

The cohesion test (Wilson and Romine, 1993b) involves compacting a cold-mix sample with five blows of the Marshall hammer. The extruded sample is placed in a 305 mm diameter sieve with 25.4 mm openings. A cover is placed on the sieve, and the sieve is rolled back and forth 20 times on its side. To pass this test, the weight of the material retained after rolling must be greater than 60 percent of the initial weight. All of the materials passed this test.

Workability was examined using two methods. The first method was the SHRP workability test (Wilson and Romine, 1993b) where a sample is loosely placed in a 102 mm cubical box with a 10 mm hole centered on one side. A soil penetrometer with a round nose adapter 10 mm in diameter is pressed through the hole into the material. The value from the penetrometer is recorded as the workability reading. All of the mixes passed this test. A simple linear regression was performed using the PTI penetrometer and it was determined that the test may be used to estimate workability of the material. However, Kandhal and Mellot (1981) suggested the use of the spatula test for workability where a sample is cooled to -7 °C and the ability to break up the material with a 200 mm spatula is observed. Once the researchers became experienced with the materials, it was felt that this was a more sensitive test. The penetrometer readings are subject to the rate at which the penetrometer is inserted into the workability box. The test can also be affected by the proximity of large aggregate particles. Controlling the amount of compaction when " loosely " packing the material in the sample box also affects the results. However, Prowell and Franklin (1995) determined the SHRP workability test to have value since it produces a numerical result and is not entirely subjective. Since several of the materials that fell into the marginal range had poor workability ratings in the field, it is felt that the acceptable criterion should be a penetration number less than 3.0.

Subjective rankings of workability by maintenance personnel showed workability to be independent of temperature.

Table 1. Approved VDOT Proprietary Cold-Mix Patch Products (after Prowell and Franklin, 1995).

Company Name	Product Name	Description	Cost/Ton Cold Mix
National Paving and Contracting	Perma Patch	Proprietary cold mix supplied in bags	$258
US Pro-Tec Co.	QPR-2000	Proprietary binder mixed with approved aggregates supplied in bags	$317
Koch Materials Co.	Styrelf Stockpile Patch Mix	Proprietary polymer-modified binder	$30-35
Unique Paving Materials (Sylvax)	Cold-Mix UPM	Proprietary binder mixed with approved aggregate supplied in bags	$217 ($50-65 in bulk)

Table 2. Candidate Proprietary Cold-Mix Products for VDOT (after Prowell and Franklin, 1995).

Company Name	Product Name	Description	Cost/Ton Cold Mix
American Stone Mix	Sakrete	Proprietary cold mix supplied in bags	$172
Suit-Kote, S.E., Inc.	MacPatch CM-300	Proprietary binder mixed with local approved aggregates	$230
Optimix, Inc.	Optimix Cold Patch	Proprietary binder mixed with local approved aggregates	$50-55
Heilman Pavement Specialties	HEI-WAY	Latex-modified emulsion produced as proprietary cold mix	$40-50
Tough Patch USA	Tough Patch	Proprietary product with 5-year guarantee supplied in buckets	$1,120
Sylcrete Corporation (Flinn Paving Co.)	Sylcrete EV Cold Mix	Proprietary binder mixed with local approved aggregates	$47-53
ReCLAIM, Inc.	RePAVE	Proprietary mix produced from recycled roofing scrap, AC-20, and solvents supplied in bags	$240
Fiberized Products	FiberPave	Standard state mix with polypropylene fibers	$35-45
Seaboard Asphalt Products Co.	Bond-X	Proprietary binder mixed with locally approved aggregates	$32-45

At the time the final report was written, all of the materials had survived except the Virginia Type P mix. Conclusions of Prowell and Franklin (1995) are as follows:

- Proprietary, high-quality cold-mix patching materials performed significantly better than the Virginia Type P mix.
- The evaluation system and performance model developed in this study may be used to rank potential cold mixes. In order to compare the overall performance of each product, a performance rating equation was developed. The equation combined the ratings for bleeding, dishing, edge disintegration, pushing and shoving, raveling, and workability. Survivability and stability (pushing and shoving) were identified as the most important properties for a good cold-mix.
- Potholes greater than 50 mm in depth should be filled and compacted in two lifts to reduce dishing.
- Laboratory tests alone are insufficient to screen potential cold mixes at this time. They do provide a valuable tool for design and quality control that should improve the quality of the material.
- Solvent extractions may not be accurate for determining residual binder contents for cold-mix. This was because VTRC had difficulty verifying the manufacturer's reported residual binder contents with reflux solvent extractions.

Recommendations of the study include the following:

- HEI-WAY, Sylcrete EV, and Bond-X should be added to VDOT's Special Provision for High Quality Cold Patching Materials.
- The special provisions should be separated into two categories: one for materials supplied as a complete proprietary cold mix, typically in buckets or bags, and one for proprietary binders that are mixed with local aggregates. A design procedure should be adopted for the second group.
- The gradation set forth below is proposed:

Sieve Size	Percent Passing
9.5 mm	95 - 100
4.75 mm	75 - 95
2.36 mm	10 - 40
0.075 mm	0 - 3

- The following design procedure is proposed:
    1. Use a proprietary binder from VDOT's Special Provision for High Quality Cold-Mix.
    2. Use the proposed aggregate gradation.
    3. Determine the residual binder content using the following tests:

Coating Test	> 90 percent coated
Stripping Test	> 90 percent coated
VTM 13 (boil test)	> 85 percent coated
Draindown Test	< 8 percent
Workability Test	< 3.0 at 4 °C

2.2 SHRP H-106 STUDY (1993)

The most comprehensive study on pothole patching materials was performed by ERES Consultants under the Strategic Highway Research Program: H-106 (Wilson and Romine, 1993a). This study evaluated the effectiveness of several pothole patching materials and methods. Eight test sites were installed throughout the United States and Canada, and the performance of the patches was monitored at those sites. Greenville, Texas (FM 1570), was included as one of these sites.

The materials which were placed at each location are shown in Table 3 (Wilson and Romine, 1993a). The UPM High Performance Cold Mix, QPR 2000, and Perma-Patch are proprietary materials. The PennDOT 485, Penn DOT 486, and modified HFMS-2 are cold-mixes produced according to the specifications of state departments of transportation.

Besides these materials, each agency provided some of their *everyday* cold-mix material so that direct comparison could be made between the H-106 materials and the types of material being used on a daily basis by different agencies across the country.

Sets of experimental patches were also placed using spray injection patching devices. These devices included the Durapatcher, the RoadPatcher, and the Rosco Asphalite 200. These devices carry virgin aggregate and asphaltic materials to the site of the pothole, blow out any water or debris, and then shoot both the aggregate and asphalt into the hole, creating a patch.

At each field installation site, approximately 10 patches of each material were placed. To install the patches, potholes were created by removing existing patches. Once potholes were opened, the adverse moisture condition was created by filling the holes with water.

Performance of the Texas materials is shown in Table 4. Note that none of the patches of the local Texas material survived to 62 weeks and that as little as 20 percent survived five weeks after installation. Wilson and Romine do not refer to the local Texas material by specification; however, maintenance personnel in the district recall that the material was HMCL (either Type D or Type FF) produced with an MC-800 since these were the only materials used in the district during that time frame.

Table 3. Material and Procedure Combinations (after Wilson and Romine, 1993a).

Patch Type	Material	Procedure	Sites Installed							
			CA	IL	NM	ON	OR	TX	UT	VT
A[a]	UPM High-Performance Cold Mix	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
B		Edge seal	✓	✓	✓		✓	✓	✓	✓
C		Semipermanent	✓	✓	✓	✓	✓	✓	✓	✓
D	PennDOT 485	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
E	PennDOT 486	Throw-and-roll	✓	✓	✓		✓	✓	✓	✓
F	Local material	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
G	HFMS-2w/Styrelf	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
H	Perma-Patch	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
I	QPR-2000	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
J	Spray injection	Spray injection	✓	✓	✓	✓		✓	✓	✓
K	QPR 2000	Edge seal					✓			
L		Semipermanent				✓	✓			
M	PennDOT 485	Edge seal					✓			
N		Semipermanent				✓	✓			
X	Local material	Surface seal		✓						
X	Local material	Propane torch					✓			

[a] Control patch type for all sites.

Table 4. **Summary of Patch Survival - FM 1570 Greenville, Texas** (after Wilson and Romine, 1993).

Patch Material (Procedure)	Percent of Patches Surviving at Given Evaluation				
	Eval. 1 (5)*	Eval. 2 (13)*	Eval. 3 (26)*	Eval. 4 (62)*	Eval. 5 (84)*
Local Material (TAR)	20	20	20	0	0
UPM (TAR)	100	90	90	67	67
UPM (ES)	100	100	100	100	100
UPM (TAR)	100	100	100	80	80
HFMS-2 (TAR)	100	100	100	100	100
Perma-Patch (TAR)	100	90	90	50	50
UPM (TAR)	100	100	100	100	67
QPR 2000 (TAR)	100	100	100	100	100
PennDOT 485 (TAR)	100	100	100	80	80
UPM (TAR)	100	100	100	90	90
UPM (SP)	100	100	100	90	90
PennDOT 486 (TAR)	100	100	100	20	20
UPM (TAR)	100	100	100	60	60
		Eval. 2 (8) *	Eval. 3 (21) *	Eval. 4 (57) *	Eval. 5 (79) *
Spray Injection		100	100	100	100
UPM (TAR)		100	100	100	100

Procedures: **TAR** - Throw-and-roll **ES** - Edge seal **SP** - Semipermanent

*(Time since installation given in weeks for each evaluation)

A summary of performance of the different material types for all of the test sites is shown in Figure 1. Patch failure rate based on the type of repair for all test sites is shown in Figure 2. These failure rates are based on the last performance evaluation, which was between 75 and 85 weeks after installation.

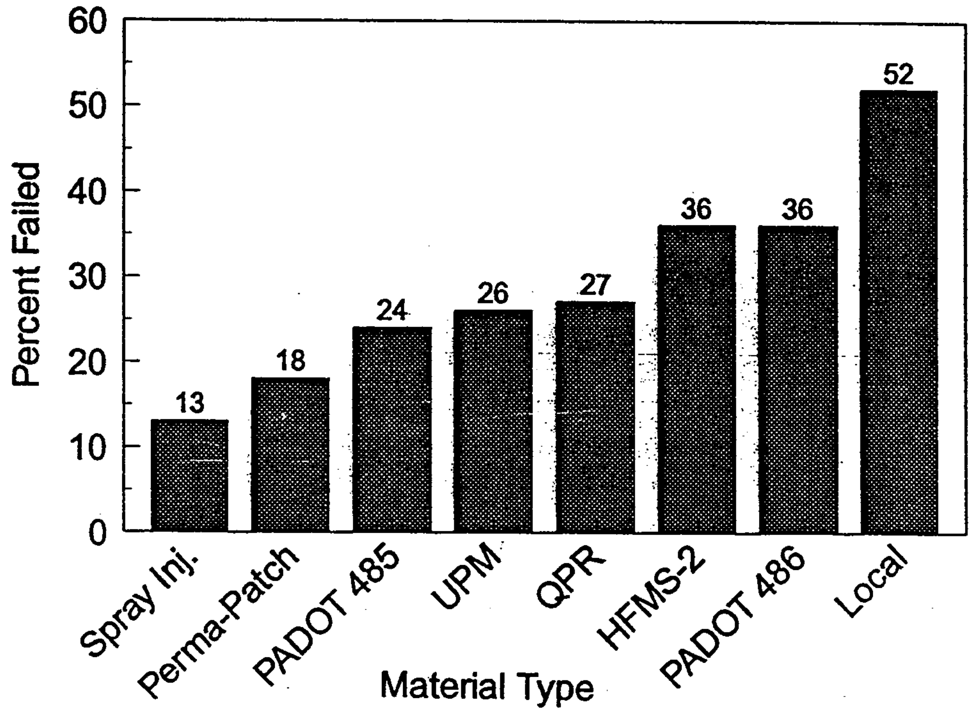

Figure 1. Patches Failed by Material (after Wilson and Romine, 1993a).

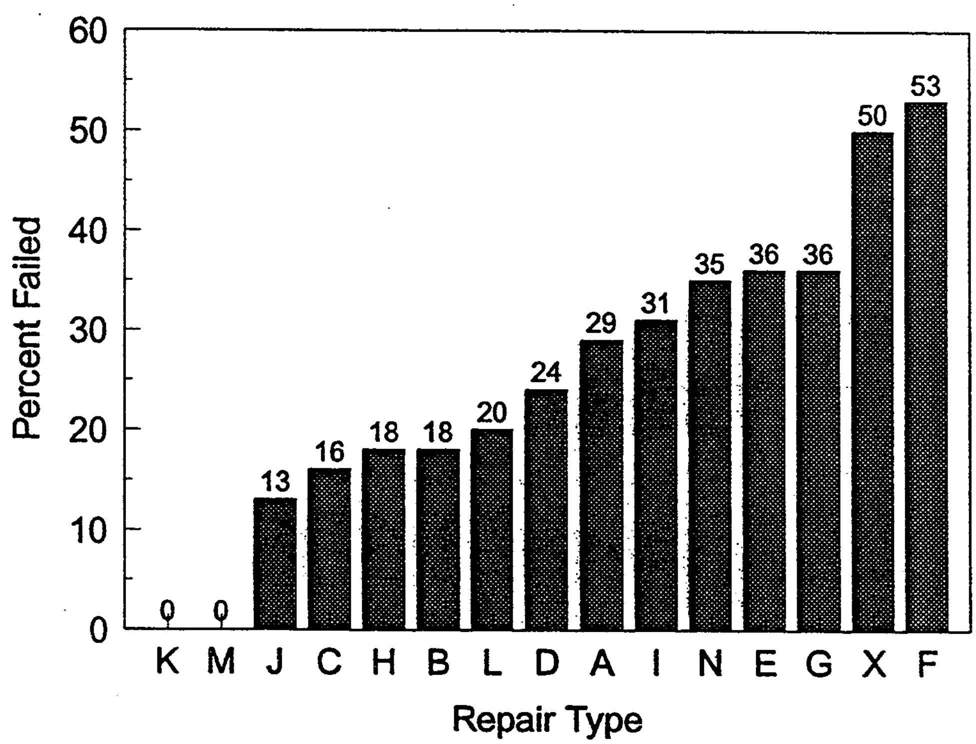

Figure 2. Patches Failed by Repair Type (after Wilson and Romine, 1993a).

The most important aspect of this study was the determination of the cost-effectiveness of the different materials. At several of the test sites, inexpensive materials were compared with better quality patch materials. The cost of the better material was as much as four times that of the less expensive material, yet the overall cost of the patching operation per cubic foot was almost five times less for the better quality material as a result of the longer service life of the patches. In situations where traffic control is necessary to shut down lanes while repairs are being made, the manpower and equipment costs are an even larger portion of the total patching costs. Since the major cost of pothole repair appears to be labor, equipment, and traffic control, significant savings can be obtained by using more effective materials and methods (Wilson, 1993).

2.3 MINNESOTA DOT

Minnesota recommends a patching mix similar to PennDOT 485 (Smith et al., 1991):

- *Gradation:*

1/2 in sieve	100 percent passing
3/8 in sieve	95 to 100 percent passing
No. 4 sieve	75 to 100 percent passing (or 50 to 85)
No. 10 sieve	10 to 35 percent passing (or 25 to 50)
No. 40 sieve	0 to 8 percent passing (or 5 to 25)
No. 200 sieve	0 to 3 percent passing

  Hydrated lime is sometimes added.
- *Aggregate shape:* 100 percent crushed.
- *Binder:* MC-250 or MC-800
- *Anti-stripping additives:* Tests are conducted to determine the appropriate type.

This mixture has performed very well, similarly to Sylvax UPM, and costs much less ($30/ton versus $65/ton).

2.4 1986 FHWA STUDY

A study on improved methods for patching on high-volume roads was completed in 1986 (Smith et al., 1991; Rissel, 1986). The objectives of the study were (1) to determine the type of defects on high-volume roads that require repair and can be repaired by patch-type methods; and (2) to identify current patching methods that are efficient and produce effective, safe, and relatively permanent repairs on high-volume roads. Also within the scope of the study were evaluations of current and newer patching methods and suggestions for improving them. In every case, *patching methods* were defined in a broad context and included consideration of materials, equipment, and techniques.

The researchers searched both published and unpublished literature to determine the processes that are most suitable for the repair of high-volume roads. They evaluated procedures, materials, and equipment. Visits were made to more than 30 sites in nine states (including Texas) where pavement repairs of various types were being made (on both bituminous concrete and portland cement concrete). The researchers visited state transportation departments, cities, and toll authorities.

There were a number of discrepancies in the reported adequacy of various materials. For example, one material that was reported to be satisfactory in New Jersey for repair of PCC was considered to be only marginally acceptable in Georgia. The same was true for materials used for bituminous pavement repairs. Discussions were held with a number of inspectors and evaluations of materials by those who were actually using it and observing it in the field were . inconclusive. The authors note that there are a number of possible reasons for poor reports about materials, such as a bad first experience, using it in thicknesses beyond those recommended, not following all of the manufacturers' recommendations precisely, marginal conditions during placement, and adding aggregate to stretch the use of a fairly expensive material.

The authors state that one of the more successful patching procedures for bituminous pavement involved the use of several different makes of equipment to heat the pavement in situ. It was also observed that many patches were made when deterioration was well advanced, and thus a considerable effort was required to complete the repairs. It appeared that less costly and time-consuming procedures would have sufficed if preventive maintenance measures had been taken.

The research revealed a growing interest (in 1986) in the use of engineering fabrics to control reflective cracking when patching bituminous concrete prior to overlaying. The authors found these materials to have good potential for improving the longevity of patches. However, there are many types of materials available and the knowledge of their relative merits is limited.

The researchers found that a common problem at ramp terminals and at traffic lights is shoving and rippling. The authors recommend a proprietary material (Ralumac) which is a latex modified emulsion mix designed to fill ruts up to 63 mm deep and can be feathered easily. A second material with the trade name Trinidad Lake Asphalt, a natural asphalt used as an admixture in various percentages in bituminous concrete, also appears to maintain high stability in bituminous concrete mixes having relatively high percentages of asphalt. The New York Port Authority has used it successfully in paving locations where horizontal thrust loads are very high and where shoving would ordinarily occur.

The study also mentioned a number of specialized patching machines, which were new to the market at that time, developed by the private sector; however, researchers recommend additional research to determine life-cycle costs of patching using these types of machines.

Field observations indicated a great difference in the efficiency of crews in terms of work done per unit of time. The major portion of the apparent discrepancies resulted from the way the work and crews were managed rather than from any difference in basic procedures, personnel capability, or equipment. They also found that there was no reasonable way in which the cost of patching operations could be compared between states due to the wide variety of ways that overhead and equipment costs are calculated, as well as other accounting factors mandated by state laws or regulations.

2.5 PENNSYLVANIA TRANSPORTATION INSTITUTE (1987)

This substantial study included laboratory and field evaluations for stockpiled patching mixtures (Anderson et al., 1987). The study focused on binder improvements while recommending an aggregate having the following characteristics based on other research:

- crushed angular particles,
- maximum of 1 to 2 percent passing the No. 200 sieve, and
- 0.5 in maximum aggregate size.

The following six materials were utilized in field trials:

- MC-800, a conventional cutback used in control mixes;
- MC-800L, a latex-modified MC-800;
- HFMS-2, a conventional high-float, medium setting emulsion;
- HFMS-2L, modified with latex;
- HFMS-2B, modified with butyl rubber; and
- HFMS-2BF, modified with butyl rubber and fibers.

The above binders were used to prepare mixtures that had an aggregate gradation meeting the specification limits of the PennDOT 485 specification. MC-800 is the binder typically used for the PennDOT 485 mixture. Further description of the PennDOT 485 mixture is presented in Section 2.8 of this report. The actual gradation used for the mixes was as follows:

Sieve Size	Percent Passing
9.5 mm	100
4.75 mm	85
2.36 mm	15
0.075 mm	1.0

A total of 410 repairs were made in Pennsylvania in the spring of 1986. Both the control mix (MC-800) and an experimental mix were used on any given day.

Results from field trials indicated that all of the experimental and control mixtures performed very well during stockpiling, transport, and placement. No stripping problems were experienced. Some loss in low-temperature workability was noted with the butyl modifier, but this was offset by the addition of fibers.

After one year, performance evaluations showed significant differences among materials. The latex-modified binders, MC-800L and HFMS-2L, had an excessive amount of drainage which was attributed to the latex separating from the asphalt. The MC-800L did not perform as well as the standard control mixture and was not recommended for further study.

The most successful binders were those based on the HFMS-2 emulsion. The butyl-modified high-float emulsion, especially with the addition of fibers, has the characteristics necessary to produce a mix with significantly improved performance and to be a cost-effective replacement for conventional cutbacks or emulsions.

2.6 OHIO DEPARTMENT OF TRANSPORTATION (1986)

Nine experimental patching materials were evaluated in cold, wet weather conditions (Wilson et al., 1993; Kumar and Majidzadeh, 1986). The results are shown in Table 5. The HPM (Sylvax UPM) proprietary material and PennDOT 485 performed very well. The ODOT 921 cold mix performed fair to good. Conclusions are listed below:

- Field tests indicate that only two materials have shown satisfactory performance: HPM cold-mix and PennDOT 485. Both materials appear to be well suited to high traffic volume highways. Both of these materials were subjected to a wide variety of patching situations. The HPM and PennDOT cold-mix material had fewer or no failures, compared to the standard cold mix material, when placed in poorly conditioned potholes.
- The HPM material and the PennDOT 485 cold mix performed well under all installation conditions. The HPM performed just as well or better in the *as found* holes with no preparation versus the prepared holes, under wet conditions versus dry, or with minimum compaction versus compacted.
- The study shows that cold-mix material designed on a rational basis will perform satisfactorily over a long period of time.
- The performance of reheated hot-mix was not satisfactory in cold, wet weather installation.
- Hot-mix patching material is not suitable for cold, wet weather patching. The preferred alternative, therefore, is to use cold-mix materials. This study established that HPM and PennDOT 485 cold mix are two materials that can perform satisfactorily in cold, wet weather patching.

Table 5. Summary of Results Obtained from Ohio Department of Transportation Experimental Study of Patch Life (after Smith et al., 1991; Kumar and Majidzadeh, 1986).

	Performance (%)		
Material & Description	Good	Fair	Failure
Tar & Stone	0	0	100
Sulfur asphalt hot mix (Sulf-a-Bond, premanufactured hot mix with sulfur blended into binder)	0	0	100
Heated 404 mix (hot mix stored during summer is used by heating in a portable heater)	0	23	77
Perma Pave cold mix (Instant Road Repair)	0	38	62
Latex rubber asphalt cold mix	33	0	67
Heated ODOT 921 cold mix (with MC-250 or MC-800)	36	18	46
Standard ODOT 921 cold mix (with MWS 300 binder)	55	10	35
Penn DOT 485 cold mix (open-graded mix with less than 2 percent passing #200, MC-250, crushed aggregate, plus antistrip agent)	81	10	9
HPM cold mix (Sylvax UPM, proprietary)	91	8	1

2.7 CITY OF TORONTO, ONTARIO

The Department of Public Works utilizes a fleet of self-contained, radio-equipped, mobile units (hot-boxes) to provide hot-mix for all seasons of the year (Smith et al. 1991, Osborne 1988). Potholes are dried out using a torch. Repairs performed in such a manner are reported as very good. A cost analysis comparing conventional cold mix patching with infrared AC hot-mix patching showed that the cold-mix patching procedure was 70 percent more costly per square yard.

2.8 PENNSYLVANIA DOT (1981)

PennDOT's 485 mix consists of the following characteristics (Wilson et al., 1993; Kandahl and Mellot, 1981; PennDOT Bulletin 27):

- *Gradation:* Open graded,

	Specified	Preferred
3/8 in sieve	100 percent passing	100 percent passing
No. 4 sieve	40 to 100 percent passing	85 to 100 percent passing
No. 8 sieve	15 to 40 percent passing	10 to 40 percent passing
No. 16 sieve	--	0 to 10 percent passing
No. 200 sieve	0 to 2 percent passing	0 to 2 percent passing

- *Aggregate shape:* Crushed
- *Binder:* A minimum residual binder content of 4.5 percent is recommended. The use of a cutback asphalt or emulsified-cutback asphalt is used depending upon the time of year. A high-float emulsion is approved for year-round use. The binders that are approved for use are listed below and specifications for these binders are shown in the Appendix. Also included in the Appendix are the specifications for the 485 mix in addition to some of the required laboratory tests. PennDOT personnel interviewed in the 1717 research study indicated that MC-400 and E-10 were the binders predominantly used for this mix.

Class of Material	Type of Material
MC-400	Cut-back petroleum asphalt
MC-800	Cut-back petroleum asphalt
MC-400E	Cut-back petroleum asphalt
ME-400	Emulsified cut-back asphalt
ME-800	Emulsified cut-back asphalt
E-10	Emulsified asphalt
E-12	Cationic emulsified asphalt
RT-4-C	Coal Tar
RT-6-C	Coal Tar

Materials MC-400, ME-400, and RT-4-C shall be used between November 1 and March 1. Bituminous materials MC-800, ME-800, and RT-6-C shall be used between March 1 and October 31. Bituminous materials MC-400E may be used throughout the year.

Materials MC-250, MC-800, ME-250, and ME-800 shall be treated with antistripping agents to meet the requirements of the wet coating test, the static immersion test, and the stripping test performed with the job aggregate. Materials E-10 and E-12 shall pass the dry and wet stone-coating test on the job aggregate (tests shown in the Appendix).

The contractor shall furnish the sample of the job aggregate to the bituminous supplier for the coating and stripping tests specified in PennDOT Bulletin 25 and also obtain a certificate that the bituminous material has been treated to suit the job aggregate. This certificate shall be produced when required by the engineer.

- *Antistrip Agent:* This is selected after testing with the aggregate that will be used. Bituminous suppliers are required to conduct the wet coating test, static immersion test, and stripping test using the job aggregate. The contractor is required to perform a water resistance test and the workability test on the mixture. Amount and type of anti-stripping agents are not specified or even recommended by PennDOT personnel as this is determined by the mix producer.
- *Preparation:* The mix is produced in hot mix plants using heated, dried aggregate.

2.9 VALUE ENGINEERING STUDY BY FOUR STATES (1978)

This study recommended several improvements for patching procedures and determined that hot AC mixtures should be used in all cases where available. Hot-mix material makes a better, longer-lasting patch than the other materials tested. Economically, it seems the most feasible material to use within a 25-mile radius of a plant. For cold weather patching, heating the stockpile mix is recommended (Smith et al., 1991; Niessner, 1978).

MC-250 seems to provide the best stockpile mix, in terms of workability, but is not recommended for patching potholes in warm weather.

2.10 NATIONAL SCIENCE FOUNDATION (1977)

A field test was conducted in 26 cities throughout the country in 1977 to compare the performance and cost of Sylvax UPM with conventional cold mix patches, each placed using temporary procedures (Smith et al., 1993; National Science Foundation, 1977). In this study, the local governments of the Urban Technology System (UTS) participated in a field test of Sylvax UPM and compared it directly with normally used patching materials in their jurisdiction. Each city or county was provided with one ton of Sylvax UPM to be used on "potholes of their choice". Each was asked to use some of their normal patching mix (not described in the report) in similar potholes under similar traffic and environmental conditions. A few of the cities (particularly in the Southwest) had insufficient potholes to provide for a meaningful test. A total of 219 UPM patches and 99 conventional cold-mix patches were placed and monitored over a period of 12 months in these cities.

The conclusions of this study indicated that four out of five Sylvax UPM patches were still fully functional after one year of use. The standard cold mix experienced one failure for every two patches applied.

This study also indicated that the conventional cold-mixes failed at a constant rate over the 12-month period, while the UPM patches primarily failed within the first three months and then practically no additional patches failed for the remaining nine months. In addition, the Sylvax UPM worked best in medium-sized potholes (0.1 to 1.0 cubic feet) with solid edges and bases. The standard cold-mix seemed to have greater failures as the size of the pothole got larger.

In those locations where the hot-mix can be installed in potholes during the winter months, it should be used. The hot-mix has a better lasting rate than either the Sylvax UPM or the standard cold-mix.

A cost study showed that even though the initial cost for UPM was higher ($35/ton versus $15/ton), when the failure rates are considered, the effective cost per ton was lower for UPM ($106 for cold mix versus $94 for UPM). This cost was calculated as described herein: Using the material costs of $35/ton for the UPM and $15/ton for the conventional mix, along with the performance data compiled in the referenced report and information available from DOT records and files, a comparative cost effectiveness analysis can be prepared utilizing the format prescribed in the Public Technology, Inc. publication, *Street Patching Operations Decision Process* (June 1976). As indicated in Table 6, Sylvax UPM has a material cost per ton which is more than twice as expensive as the standard cold patch. However, after adding the associated labor costs, equipment costs, and an average performance factor for each of the two materials, it can be seen that total patching operations cost per ton of installed material are reduced by $12.00 when Sylvax is used as opposed to standard cold-mix.

2.11 NEW YORK STATE DOT (1971)

Use of preheated asphalt mix and an infrared pavement heater have produced long-lasting patches (Smith et al., 1991; Briggs, 1971). Patches have lasted seven to ten times longer than those made with conventional cold mix.

Table 6. Comparative Cost-Effectiveness (after National Science Foundation, 1977).

	Standard Cold Patch		Sylvax UPM
Material Cost per Ton	$15.00	(A)	$35.00
Number of Persons on Crew	4		4
Daily Wages per Crew	$231.00		$231.00
Labor Overhead Rate	32%		32%
Average Daily Labor Cost per Crew	$304.92		$304.92
Average Daily Material Tonnage per Crew	8 tons		8 tons
Labor Cost per Ton Installed	$38.12	(B)	$38.12
Average Daily Equipment Hours	8		8
Equipment Hourly Charge Rate	$5.00		$5.00
Average Daily Material Tonnage per Crew	8 tons		8 tons
Equipment Cost per Ton Installed	$5.00	(C)	$5.00
Total Material + Labor + Equipment Cost	$58.12	(A+B+C)	$78.12
Average Performance (All Conditions)*	54.5%		83.1%
Effective Cost per Ton Installed**	$106.36		$94.00

**Average performance is obtained from test data and is defined to be equal to: 1.0 minus the Failure Rate.*

*** A comparison of the Effective Cost per Ton Installed is determined in the following way:*

$$\frac{\text{Total Material + Labor + Equipment Cost}}{\text{Avg. Performance (All Conditions)}} = \text{Effective Cost per Ton Installed}$$

Thus, for Standard Cold Patch:

$$\frac{\$58.12}{0.545} = \$106.36$$

And , for Sylvax UPM:

$$\frac{\$78.12}{0.831} = \$94.00$$

CHAPTER 3.0 DISTRICT SURVEY RESULTS

A survey was conducted at the onset of the research study to determine the following information for each district:

- What patching/pothole materials are used?
- What are material formulations, i.e., binder and aggregates?
- Describe materials which work well and in what applications.
- Describe materials and applications which do not work.
- What are material sources?

To assist in this effort, copies of purchase requisitions were obtained from the General Services Division from 1995 to present for CMD 9200.001 and CMD 9200.002.

A summary of the pertinent information obtained from this survey is presented in Tables 7, 8, and 9. Table 7 provides information on patching/pothole materials and applications. Table 8 includes information on materials and applications which have been problematic, and Table 9 provides a list of material sources.

Fifteen districts submitted requisitions through General Services for either 9200.001 or 002 materials in 1995/96. Most of the materials purchased under these requisitions were "pothole" materials. A few were the Item 334 purchased under 9200.002. However, most districts still purchase Item 334 under the standard specification number.

Most of the districts were pleased with the *pothole* materials purchased under 9200.001 or 002. A few problems are noted, but overall good performance was reported for cold, wet conditions for this material. These materials are not used for blade level-ups, only for potholes. Most districts that use the containerized material were pleased with its performance as a pothole repair material.

HMCL (Item 334) is still used by many districts as a blade-on/level-up material. In general, most of the problems appear to be with this material. Performance is inconsistent, as noted in the following tables.

LRA is also used by many districts. It is used as a winter blade-on material, as well as year-round by some districts. Performance is good in most applications, as noted.

Several districts report using hot-mix as a blade-on material in summer months, which is more reliable than HMCL.

Table 7. Patching/Pothole Materials Used by TxDOT Districts and Applications Which Perform Well.

District	*Materials*	*Applications*
Abilene	9200.002 SCM-I, Gradation II	Used strictly for winter pothole repair. Sometimes transfer to buckets to haul in maintenance vehicles for emergency repair. This combination (SCM-I, Grad II) closest to *old UPM.* Use ~ 250 tons/yr.
	LRA	Primary maintenance mix for this district. Use for potholes, small hand patches (20-30 sq. yds).
	Item 334, Type D or F, sometimes C	For use in summer only as a blade material.
Amarillo	LRA, Type CC and D	Used for all purposes in winter.
	Item 340	Used in summer for patching/potholes/level-up. Cheaper than HMCL.
	Containerized	Use small quantity. Works well but expensive.
	Item 334	Used a little in summer in northern counties.
Atlanta	9200.002 SCM-I Gradation II	Like original UPM. Works very well as pothole material but not in shallow potholes. Need 3 to 4 rock thicknesses. Use ~2000 tons/yr.
	LRA	Most consistent. Good workability and performance. Used to be more expensive than HMCL but now competitive. Used for planned, scheduled level-ups to prepare for seal coat program. Can use year-round but mostly for winter.
	Item 334, AC-3 in summer AC-1.5 in winter MC-800 w/diesel (winter)	Wide range of success. Aggregates are siliceous. Works well from May on. Good above 60 °F.
Austin	Item 334, Type D AES-300 or AC-3	Used for summer patching. No problems.
	LRA, Type CC	Used for winter maintenance. No problems.
	Containerized, 9200.003	Use small quantity, works well.

Table 7. Patching/Pothole Materials Used by TxDOT Districts and Applicatons Which Perform Well. (Continued)

District	*Materials*	*Applications*
Beaumont	9200.002 AES-300P Gradation I	Works very well for winter pothole repair. Use about 1200 tons/yr.
	Item 334 AES-300	Variable performance. Used for blade-on.
	LRA	LRA is preferred blade-on material, but Vulcan can't compete on freight.
	Item 340	Used for warm-weather material when possible.
Brownwood	Item 334, AES-300, Type F	Primary patching material. Strips bad. Sometimes okay but mostly have stripping problems.
	LRA	Works great when we can get it. Does not know why they can't get it. Vulcan will not ship it to them.
	9200.002, CMA or SCM-I, Grad II or Grad III	Works well for winter pothole or wet, summer conditions. No problems.
Bryan	9200.002 AES-300S, Gradation II	Used for winter pothole repair. If designed and produced correctly performs very well. Last year's material, however, was a bad batch. Gave it all away under Rider 42. Use about 1500 tons/yr.
	LRA	Three counties use LRA on a limited basis for blade-on patchwork.
	Item 340	For summer use or whenever plants are running.
	HMCL	Used for blade-on material. Since hot-mix is used now, HMCL is used less.
Corpus Christi	Containerized	Works well but expensive and proprietary.
	LRA	Used for winter maintenance. Performance is fair as a pothole material (wet conditions).
	Item 340	Used in summer when near hot-mix plant.
	Item 334, AES-300 HFRS-2 (winter) HFRS-2p (summer)	Works well, no problems. Does not allow cutbacks for safety reasons.

Table 7. Patching/Pothole Materials Used by TxDOT Districts and Applicatons Which Perform Well. (Continued)

District	***Materials***	***Applications***
Childress	9200.002 Item 334, Type D and F AES-300	Primary maintenance mix. Used in warm weather for all purposes.
	LRA	Used for winter maintenance.
Dallas	9200.002 SCM-I Gradation II	Used for winter pothole repair.
	LRA	Used for level-up year-round.
	Item 334	Used for warm weather level-up but using less and less because letting *level-up* contracts where contractor provides hot mix.
El Paso	9200.002 SCM-I Gradation II	Used for pothole repair mostly in winter. Works well in wet conditions.
	LRA	LRA is preferred blade-on material.
	HMCL	Also used for blade-on. Best in warm conditions.
Fort Worth	9200.001	Good results with 001 as pothole material. Lifespan in stockpile ~2 years. Best patching material in a long time.
	Item 334, Type F, AES-300 or CMS-2	Good for shallow patches. Tends to push in hot weather.
	Item 340	For overlay.
	LRA	Good year-round material but not for high-traffic areas (shoves). Good for overlay in winter.
Houston	IRR	Very high quality, good performance for potholes.
Laredo	LRA, CC or DD	Performs well for level-up or patching.
	Item 334 MC-800	Used in warm weather for level up or patching. Performance not as good as LRA.
	9200.003	For cold, wet conditions.

Table 7. **Patching/Pothole Materials Used by TxDOT Districts and Applicatons Which Perform Well. (Continued)**

District	*Materials*	*Applications*
Lubbock	9200.002/Item 334 Type F, AES-300S	First year to use AES-300 without latex. Can not yet report on performance.
	Homemade mix	Used very successfully in southern counties where blow sand is available. Used for warm weather and winter all-purpose mix. (Recipes provided.)
	LRA	Used successfully for winter repair (all purpose).
Lufkin	9200.001	Used for winter pothole repair. Performance good.
	LRA	Used year-round as blade-on material. Requisition for 62,000 tons this year.
	Item 340	Have a standing requisition for hot mix. Used in summer in place of HMCL.
Odessa	LRA	Use LRA almost exclusively year-round. Works great under all conditions. Use small quantity of HMCL.
Paris	9200.002 SCM-I Gradation II	Used in cold weather for wet potholes. ~ 2000 tons per year. About 200-300 tons per section.
	Item 334 , Type D AC-3 in summer MC-800 with and w/out diesel (winter) AES-300P	Performance is variable.
	LRA	Prefer LRA over 334. Performance is consistent.
	Item 340	Used for summer maintenance.
Pharr	Item 334	Used extensively most of the year, tends to get unworkable in winter and too rich in summer.
	LRA, Type CC	Like this material better than HMCL but it's more expensive ($32/ton vs $22/ton for HMCL).
San Angelo	LRA	Used year-round.
	UPM	Cold, wet weather pothole repair.
	Item 334, AC-3	Warm weather.
San Antonio	Item 334, Type D HFRS-2 (Comal Co.)	Performs very well, year-round. Spray the bottom of pothole with EA-11, then apply patching mix.
	Containerized	Works well in winter or summer, wet conditions.

Table 7. Patching/Pothole Materials Used by TxDOT Districts and Applicatons Which Perform Well. (Continued)

District	*Materials*	*Applications*
Tyler	9200.002 SCM-I, Gradation I	Used for winter pothole repair. Performance good depending on who makes it. Use about 600 tons per year.
	LRA	Good year-round material. Used more than any other type.
	HMCL	Used less than in the past. Being replaced by hot mix.
	Item 340	Use a lot of hot mix in *PROPATCH* machines (but not for wet/cold conditions).
Waco	9200.002 CMA Gradation II	Good performance for winter pothole repair. CMA works well. Had a bad batch this year but it was replaced and is okay now (thinks design was bad, not CMA). The closer the mix gets to UPM the better but a good mix for the price at $35/ton. Use ~15-20,000 tons/yr.
	Item 334, Type D or F, AC-3 with or without diesel, or AES-300	Used for warmer temperatures as a blade mix. AES-300 seems to give better results.
	LRA	Use a lot of LRA. Good performance, workability.
	Item 340	Use in summer for blade-on material because it's cheaper.
Wichita Falls	9200.002 SCM-I Gradation II	This material is as good as has been found for winter pothole repair.
	Item 334, Type D or F, MC-800	Used 10 months out of the year for leveling.
	Item 340, Type D or F	Used for leveling.
Yoakum	9200.002 SCM-I Gradation II	Winter pothole repair.
	LRA	Used year-round for blade-on material.

Table 8. Patching/Pothole Materials Used by TxDOT Districts and Applications Which Have Performed Poorly.

District	*Problem Materials and Applications*
Abilene	Item 334 with MC-800: too stiff for winter use, crusts over.
Amarillo	No problems.
Atlanta	9200.002 for potholes works well in the right places. Will not work in thin lifts, unconfined areas. Not good for shallow potholes (need 3-4 rock thicknesses). In Item 334, used to use AES-300p. At first, thought it successful but upon careful evaluation of performance, determined it was not working at all. Problems with pushing and rutting. Variable success with Item 334. 9200.002: Use of CMA asphalt was a disaster. Stripped within 30 minutes of production.
Austin	No problems.
Beaumont	Inconsistent performance with Item 334. Use AES-300 (don't allow cutbacks). Hardens in stockpile. If it has enough asphalt, tends to shove. LRA is preference.
Brownwood	Item 334 with AES-300 sometimes strips badly. Okay most of the time. Still the primary material used.
Bryan	Last year's mix (9200.002) was bad. Gave most of it away under Rider 42. Not sure what was problem (think it was bad design, low on asphalt). Performance of 9200.002 (AES-300S, Grad II) can be good but it is inconsistent depending on supplier. LRA used on a limited basis. Not good for wet potholes. Have different climatic conditions across the district. What works in one area may not work in another. Would be ideal to use different mixes for different climatic areas, but don't have guidance.
Corpus Christi	Containerized: works well but expensive and proprietary.
Childress	Item 334: Primary patching material but have problems. Tends to strip, can't meet density and stability requirements, comes out of hole. Used to use AC-10 with primer but producers don't want to handle 2 products. Use AES-300 now, just as good. Problem with design procedure: calls for 13% asphalt, selecting asphalt content by guess and experience. Containerized materials too expensive.

Table 8. Patching/Pothole Materials Used by TxDOT Districts and Applicatons Which Have Performed Poorly. (Continued)

District	*Problem Materials and Applications*
Dallas	LRA not good for potholes, only level-up. Some problems with 9200.002 (pushing in hot weather). Prefer to go back to containerized/guaranteed.
El Paso	LRA not good for wet potholes.
Fort Worth	Item 334: pushes in hot weather. LRA: not good in high traffic, tends to shove.
Houston	No problems to report.
Laredo	No problems to report.
Lubbock	Don't use UPMs or containerized due to high cost. In Item 334, used AES-300S with 1.5% latex. Latex not a good idea. Poor workability. Like their homemade mix.
Lufkin	9200.002: CMA asphalt. Material went to San Augustine (had to be removed). Item 334: using less of 334 and more LRA because stockpile life is so poor for HMCL.
Odessa	No problems to report.
Paris	Item 334: Variable performance. Have used MC-800 for winter use but having workability problems. Use AC-3 with and without diesel in summer mixes but performance varies depending on supplier. Sometimes get too much diesel and it's too soft. Because of variable performance trying to use more LRA.
Pharr	Item 334: Too rich in summer and unworkable in cold weather. Prefer LRA but still use 334 mostly.
San Angelo	Item 334: not good in cold, wet weather.
San Antonio	No problems reported.
Tyler	Quality of 9200.002 depends on supplier.
Waco	9200.002: Use CMA asphalt. Works good most of the time. Had a bad batch this year but it was replaced and is fine. Item 334: Variable performance, in particular with AC-3 modified with diesel. Different suppliers vary diesel content and get mixed results.
Wichita Falls	No problems to report (for blade leveling prefers HMCL to LRA).
Yoakum	No problems to report.

Table 9. Patching/Pothole Material Suppliers for TxDOT Districts.

District	*Material Suppliers*
Abilene	Vulcan, Ft. Worth, Kelly Pit (0218409)
Atlanta	Texarkana Asphalt Longview Asphalt Buster Paving Aggregates are siliceous either from Little River or Sawyer, Arkansas.
Austin	Gifford Hill, New Braunfels Colorado Materials, San Marcos
Beaumont	APAC (Fine aggregate- Colorado Materials, Hunter Pit Coarse aggregate, St. Genieve, Missouri)
Brownwood	Vulcan, Brownwood (Brownwood Pit 2302501)
Bryan	Central Texas Sitework, Bryan Young Brothers, Bryan (Aggr. Texas Crushed Stone, Georgetown) Gifford Hill, New Braunfels (Servtex Pit 1504603) East Texas Asphalt, Lufkin
Corpus Christi	Colorado Materials, San Marcos River City Materials (buys aggregate from everywhere, sometimes a problem)
Childress	Vulcan, (Black Lease Pit, Abilene 0822107) H. Shears, Altus, OK Zack Burkett, Wichita Falls
Dallas	APAC, Ft. Worth (TXI Aggr, Bridgeport Pit 0224904)
El Paso	Jobe Concrete Products, El Paso (Aggr: Jobe, McKelligon Pit) Pecos Materials
Fort Worth	Vulcan (Bridgeport Pit and Kelly Pit)
Lubbock	Williams and Peters, Lubbock (Aggr. R.E. Janes, Wood Pit in Slaton) Kerr Construction, Lubbock

Table 9. Patching/Pothole Material Suppliers for TxDOT Districts. (Continued)

Lufkin	Longview Asphalt, Nacogdoches Smith Plant, Huntsville East Tx Asphalt, Lufkin (Fine aggr: Tx Crushed Stone, Feld Pit, Georgetown, Coarse aggr. Eagle Mills, Arkansas 0050119)
Paris	Buster Paving, Paris Red River Asphalt, Meridian Oklahoma Sand and Gravel Texas Stone, Bridgeport Amis Materials, Stringtown Quarry (50407) Oklahoma Canadian Protective (Jagoe Public Const, Denton, Denton Pit)
Pharr	Ballinger Construction Company (Valley)
San Antonio	Gifford Hill, New Braunfels Colorado Materials, San Marcos
Tyler	East Texas Asphalt, Lufkin Longview Asphalt, Longview
Waco	Vulcan (Kelly Pit) Young Brothers Vulcan (Brownwood Pit)
Wichita Falls	Canadian Protective Products, Canada (Aggr: Jagoe-Public, Denton) Industrial Limestone, Seabrook (Gifford Hill Pit, Bridgeport) Vulcan, Fort Worth (Kelly Pit 0218409)
Yoakum	Colorado Materials Industrial Limestone, Seabrook Tx, (Gifford Hill Aggr, New Braunfels 1504603) Gifford Hill, New Braunfels S. Texas Asphalt, Knippa (Aggr. SW Aggr, Knippa Pit)

CHAPTER 4.0 LABORATORY TESTS

4.1 OBJECTIVE OF LABORATORY EXPERIMENT

Several different HMCL (Item 334) mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregate and three types of binders for a total of six different mixtures. Objectives of this laboratory experiment were to:

- Evaluate the properties of mixtures fabricated at different densities (in addition to 95 percent density as currently required in the specification).
- Evaluate suitability of laboratory tests to differentiate between mixtures with different degrees of workability and cohesion.

According to TxDOT specifications for Item 334, mixtures shall be designed at an optimum density of 95 percent. However, some field personnel and material producers have suggested that better cold-weather workability could be achieved if the density requirement were lower. In fact, LRA (Item 332), which has a proven performance history of good winter workability, has a relatively low lab molded density of 88 percent. The asphaltic binder in stockpiled maintenance mixes is the component in the mix which is susceptible to temperature: the binder is stiff in cold weather and soft in warm weather. Therefore, less binder in the mix resulting from a lower density requirement will likely provide for better workability in the winter. However, this better workability may be at the expense of cohesion.

4.2 EXPERIMENT DESIGN

The mixtures shown in Table 10 were produced and tested in the laboratory.

Table 10. Laboratory Experiment Design.

Asphaltic Binder	Crushed Gravel			Crushed Limestone		
	89% Density	92% Density	95% Density	89% Density	92% Density	95% Density
MC-800	X	X	X	X	X	X
MC-800 with Diesel	X	X	X	X	X	X
AES-300S	X	X	X	X	X	X

4.3 MATERIALS USED

Two types of aggregates were chosen for the laboratory mixture designs. One mixture was designed from a crushed limestone material from the Hunter Pit of Colorado Materials near San Marcos. The other aggregate was a crushed gravel from Fordyce near Corpus Christi. These were chosen to represent the range of aggregate types available for use in manufacture of HMCL. All of the aggregates were sieved into individual size fractions and then recombined to obtain the gradation shown in Figure 3. Specific gravities for these aggregates were measured as follows:

Crushed Limestone	
Coarse Aggregate Bulk Specific Gravity	2.667
Fine Aggregate Bulk Specific Gravity	2.632
Crushed Gravel	
Coarse Aggregate Bulk Specific Gravity	2.597
Fine Aggregate Bulk Specific Gravity	2.577

There are several asphaltic binders that can be used for the manufacture of HMCL according to TxDOT specifications. Three binders were chosen that were thought to adequately represent the different types of binders available for use in production of HMCL: AES-300, MC-800, and MC-800 with diesel. The AES-300 was supplied by Koch Materials, and the MC-800 was supplied by Lion Asphalt. Diesel was added to the MC-800 in the laboratory. The AES-300 supplied by Koch Materials was actually designated AES-300S, which is for stockpiled mixtures. It meets the requirements of AES-300 but contains a small amount of SBS polymer (1.5 percent) to improve the mixture stability for early use.

4.4 MIXTURE DESIGN

Mixtures were designed according to TxDOT Test Method Tex-204-F. The mixture gradation was patterned after a mix that was in production at Colorado Materials (Hunter Pit) near San Marcos, Texas. The aggregate gradation which was used for both aggregate sources is shown in Figure 3.

A total of six different mixture designs were performed:

- Crushed River Gravel with AES-300S;
- Crushed River Gravel with MC-800;
- Crushed River Gravel with MC-800/diesel;
- Crushed Limestone with AES-300S;
- Crushed Limestone with MC-800; and
- Crushed Limestone with MC-800/diesel.

Laboratory data regarding each mixture design are shown in Figures 4 through 9.

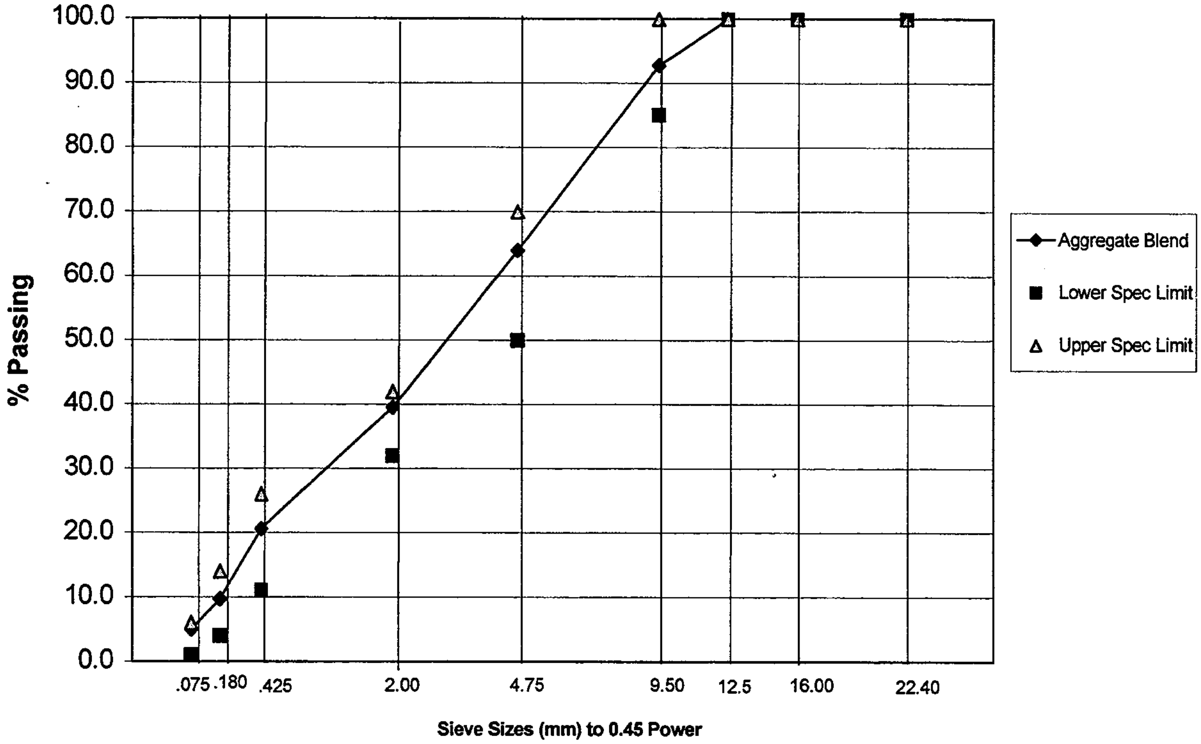

Figure 3. Aggregate Gradation for Laboratory Fabricated Mixture Designs.

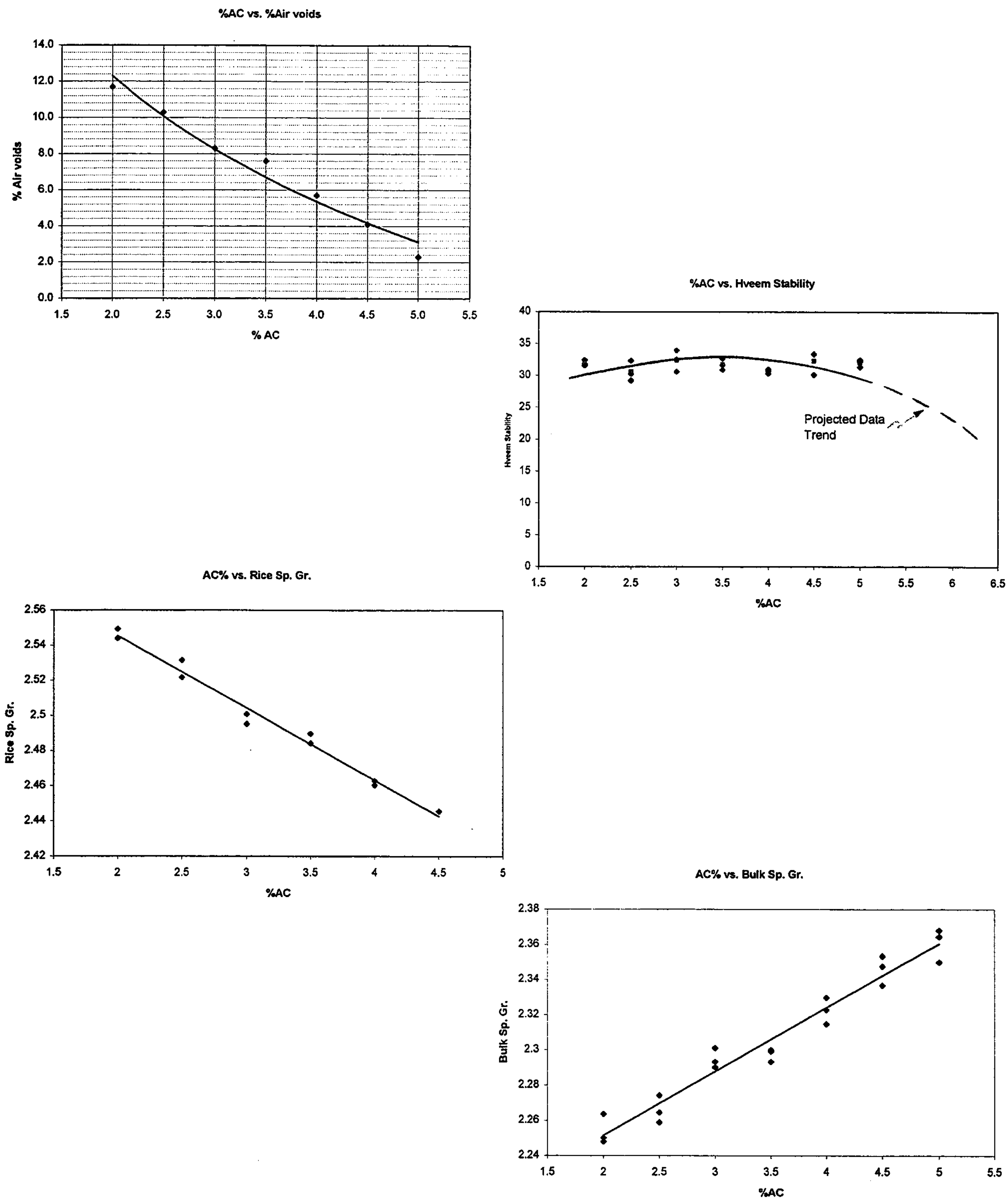

Figure 4. Laboratory Mixture Design Data for Crushed River Gravel and AES-300S.

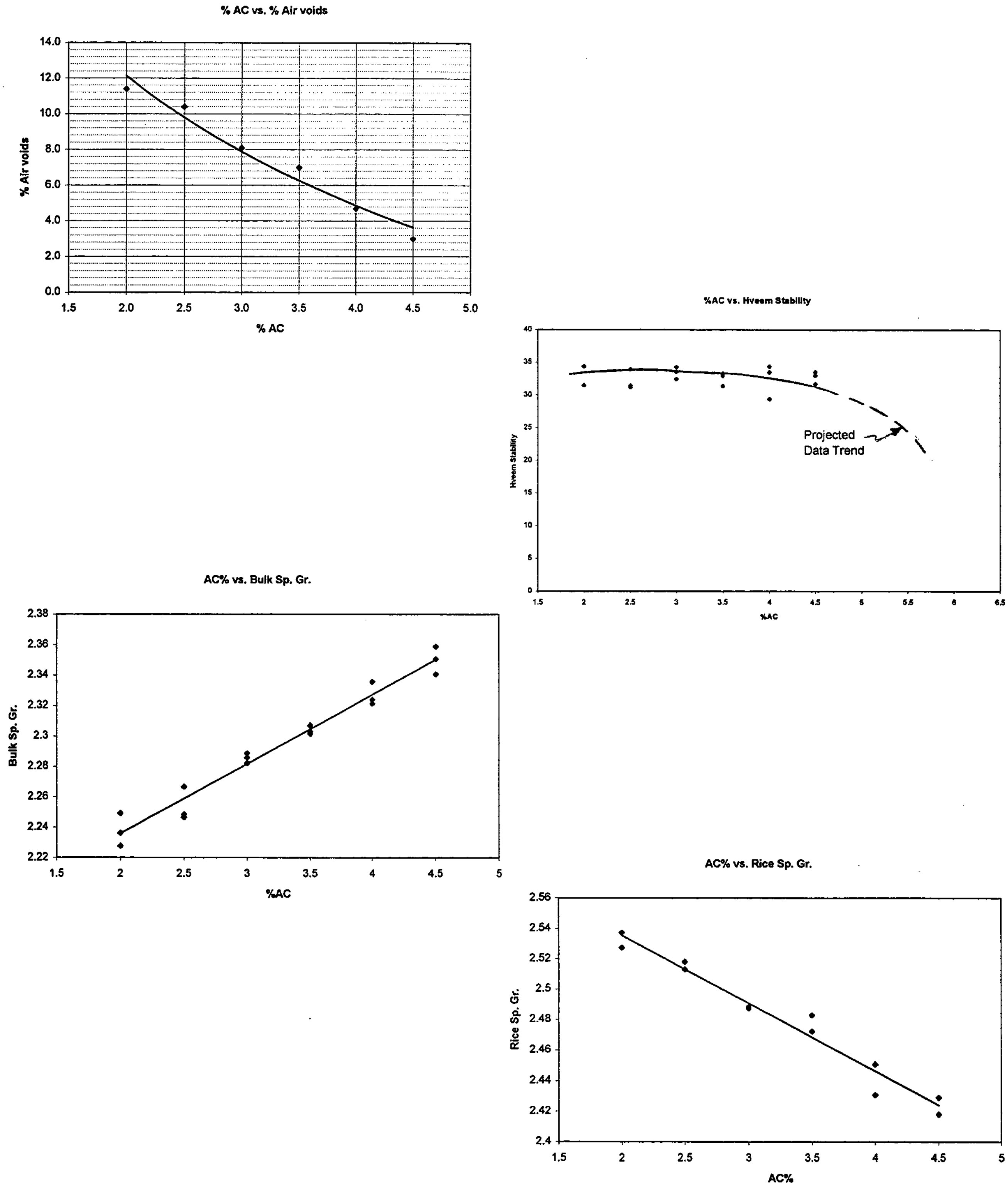

Figure 5. Laboratory Mixture Design Data for Crushed River Gravel and MC-800.

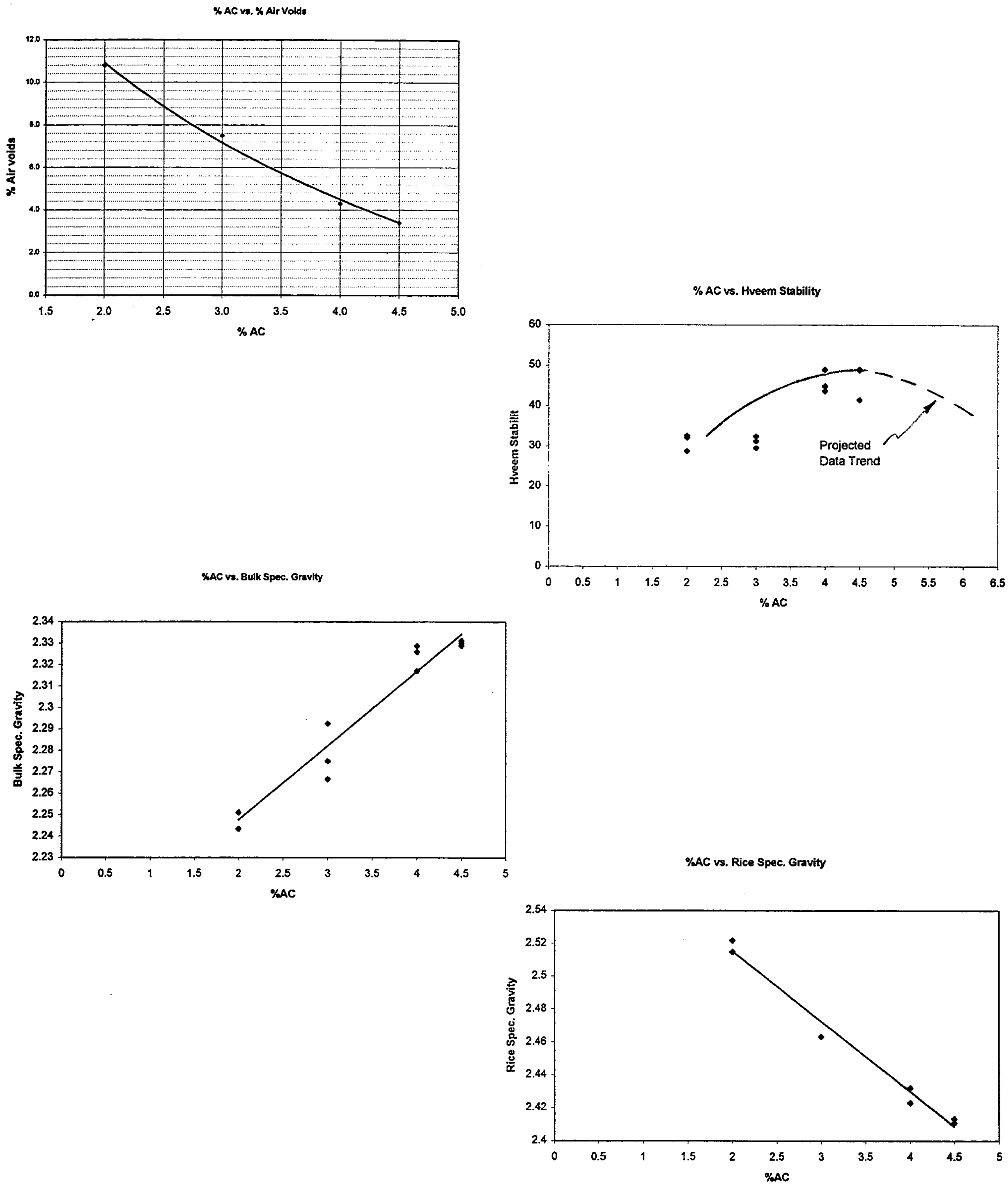

Figure 6. **Laboratory Mixture Design Data for Crushed River Gravel and MC-800 with Diesel.**

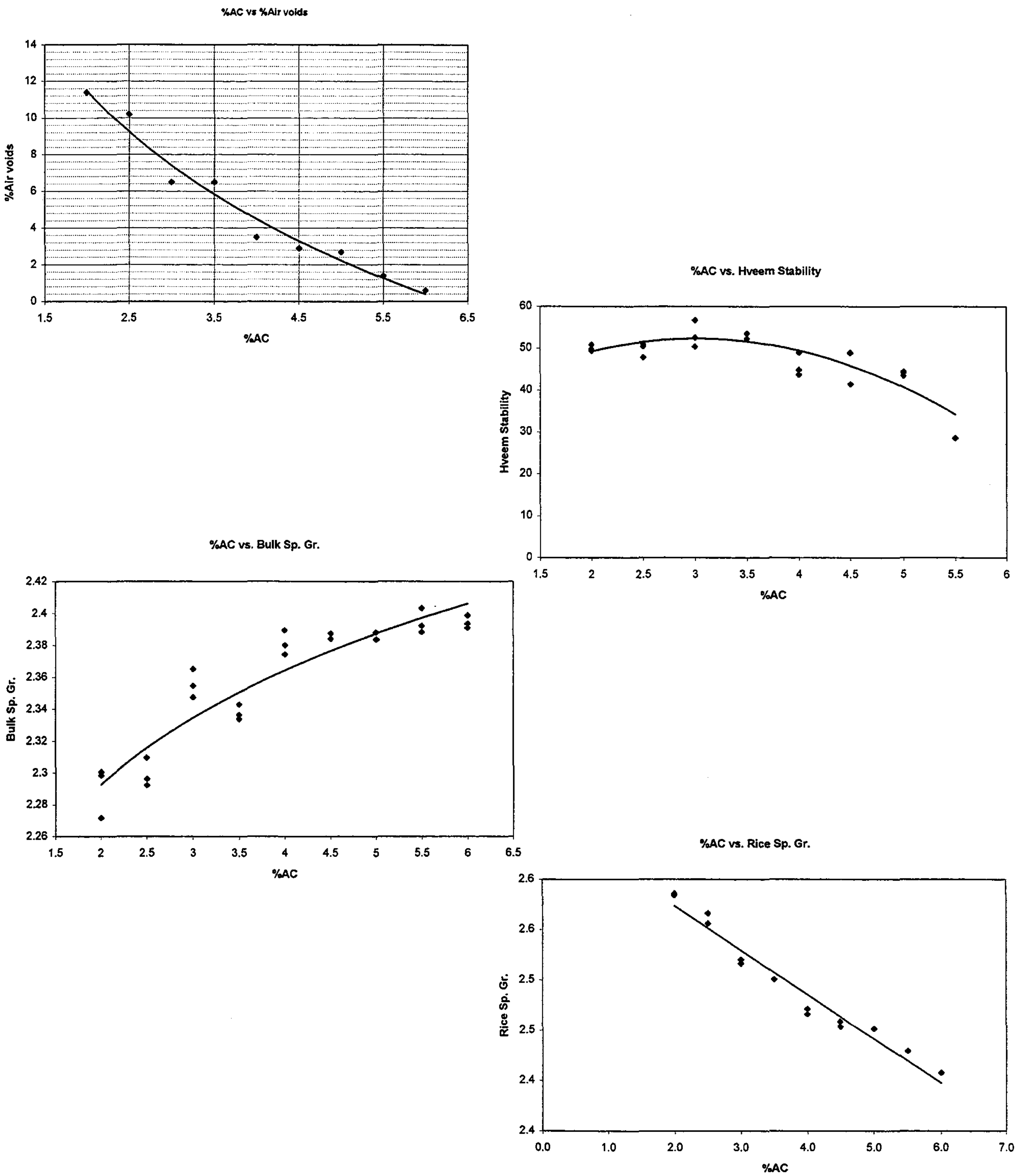

Figure 7. Laboratory Mixture Design Data for Crushed Limestone and AES-300S.

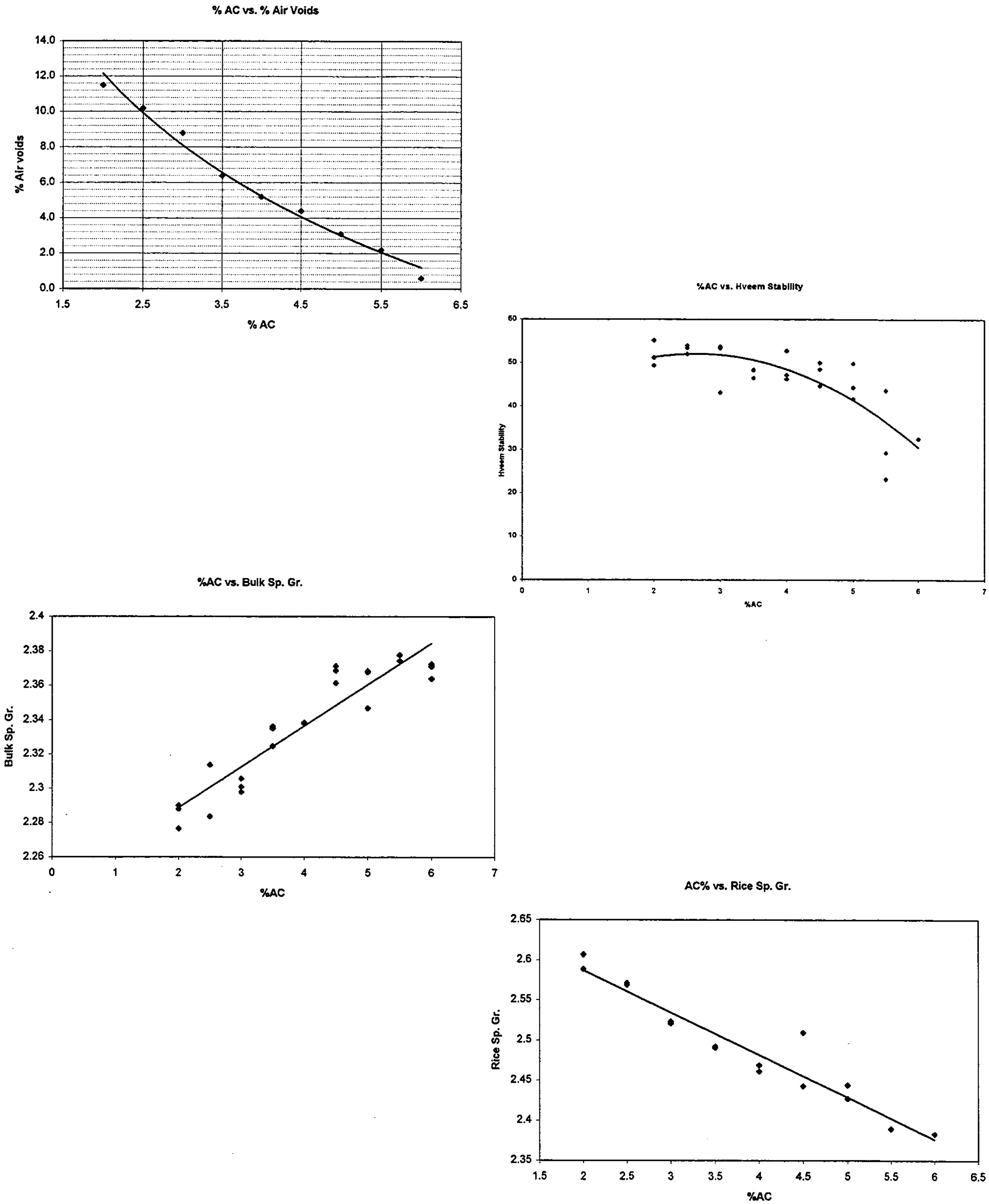

Figure 8. Laboratory Mixture Design Data for Crushed Limestone and MC-800.

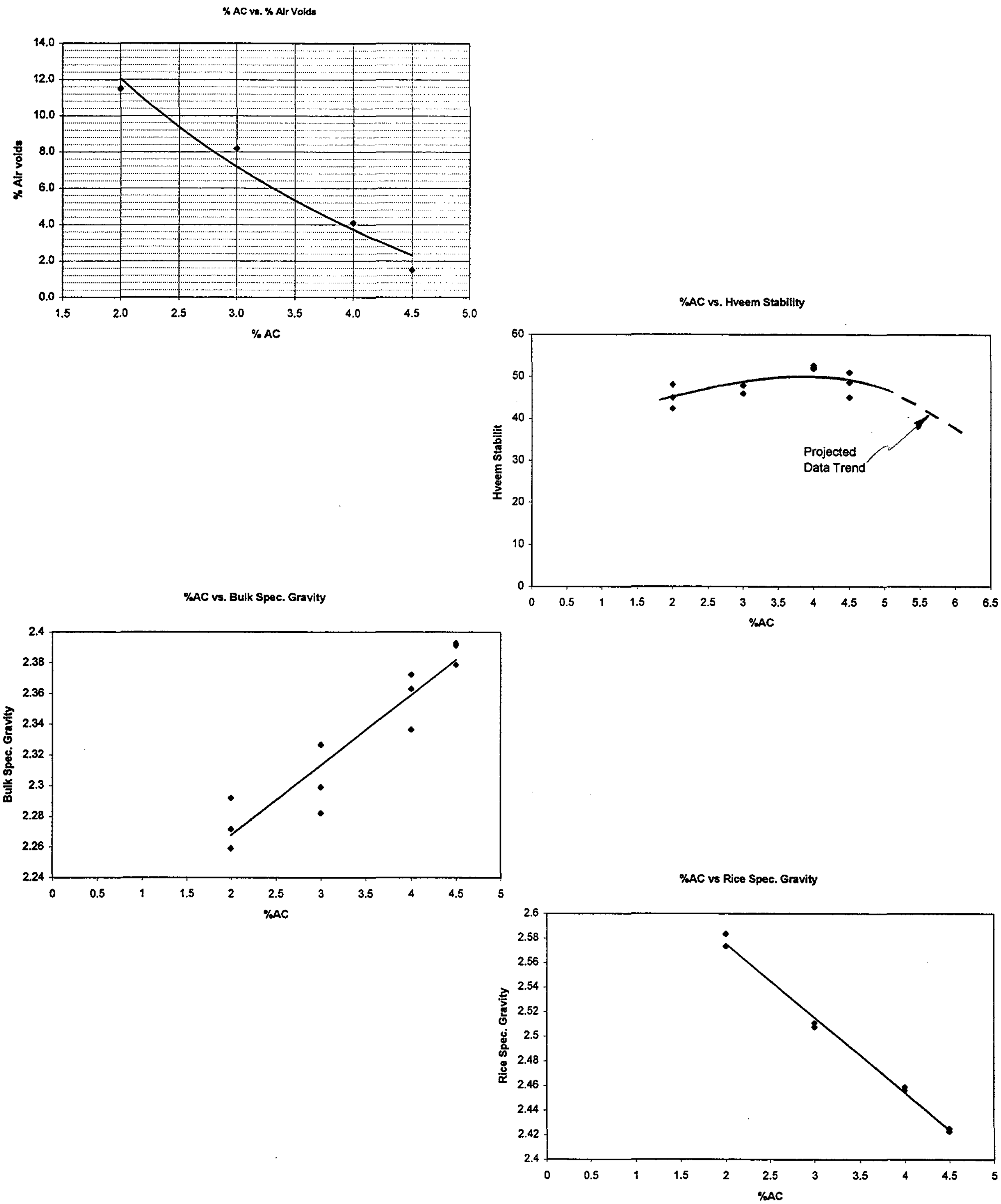

Figure 9. Laboratory Mixture Design Data for Crushed Limestone and MC-800 with Diesel.

Prior to compaction of samples, mixtures were cured in a 60 °C forced air oven until a constant weight was achieved (about 96 hours). Samples were then compacted according to TxDOT Test Method Tex-206-F.

Asphalt contents were selected corresponding to 89, 92, and 95 percent densities as shown in Figures 10 and 11 for each mixture, and samples were fabricated at these asphalt contents. The residual asphalt contents that were actually used for mixture fabrication are shown in Table 11 below.

Hveem stabilities as a function of asphalt content are included in Figures 4 through 9. Hveem stability data typically decrease as asphalt content increases above optimum (defined at 95 percent density) as shown in Figures 7 and 8. However, Hveem stabilities below the optimum asphalt content can be relatively stable (unaffected by lower asphalt content). Since these mixtures were designed at 95 percent density and below, Hveem stability data shown in Figures 4, 5, 6, and 9 are relatively constant as asphalt content changes. Because the asphalt content go beyond optimum in Figures 7 and 8, the Hveem stability show the expected trend. Also, note that asphalt contents are shown every 0.5 percent, rather than the more typical 1.0 percent.

Table 11. Asphalt Contents Used for Mixture Fabrication.

Aggregate Type	Density, percent	Asphalt Content Used for Fabrication of Samples at Specified Densities, percent		
		AES-300S	MC-800	MC-800w/diesel
Crushed Gravel	89	2.27	2.23	2.00
	92	3.00	3.00	3.00
	95	4.00	4.00	4.00
Crushed Limestone	89	2.00	2.25	2.00
	92	2.83	3.00	3.00
	95	3.80	4.00	4.00

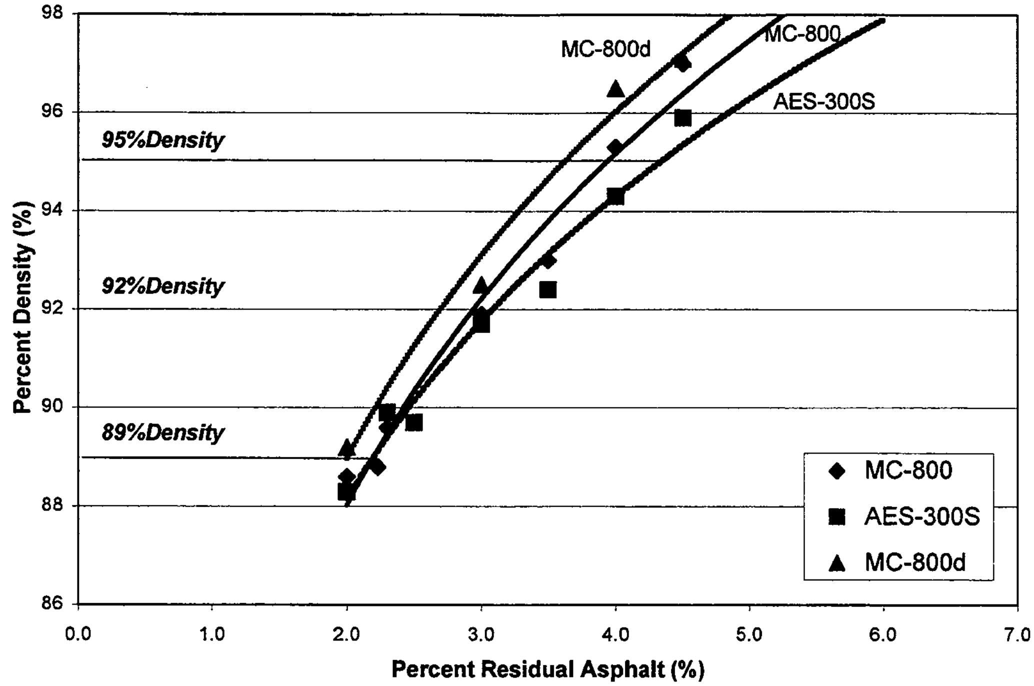

Figure 10. Mixture Design for Gravel Aggregate Mix

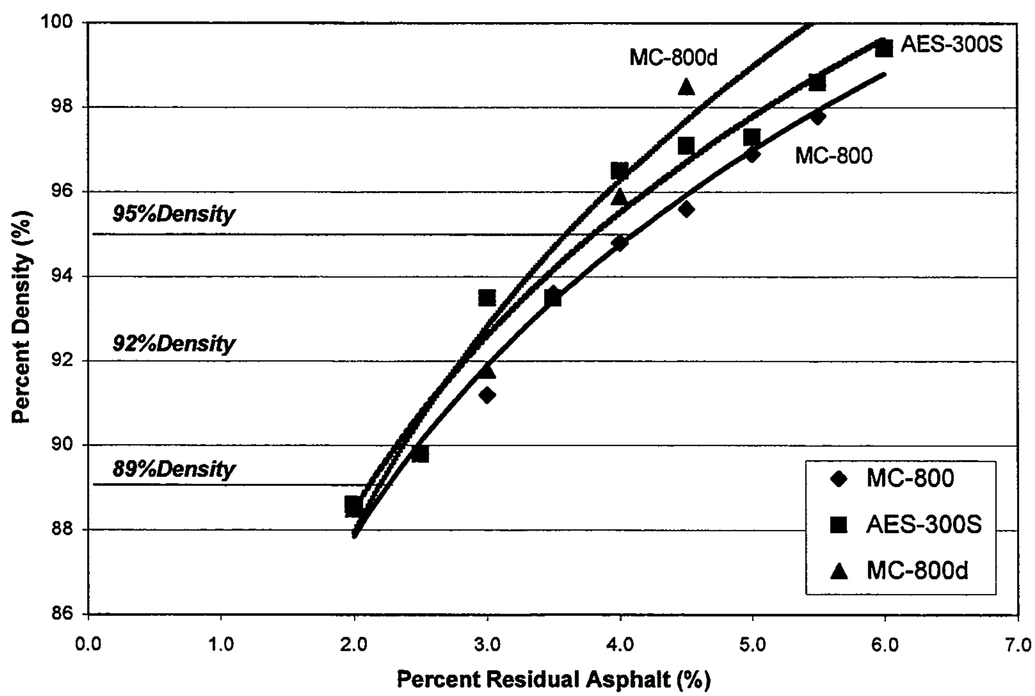

Figure 11. Mixture Design for Limestone Aggregate Mix.

4.5 LABORATORY TEST RESULTS

4.5.1 Laboratory Aging/Curing

Prior to laboratory testing of the mixtures designed above, samples were cured in a forced-air oven to a constant weight at 60 °C in a loose condition. These samples were mixed at an asphalt content corresponding to 95 percent density. Three samples of each mixture type were cured an extended length of time (more than 10 days) to monitor their specific weight loss characteristics (discussed below). Weight loss (moisture and volatiles) is a critical parameter when evaluating HMCL because it is directly related to workability. The rate of weight loss (weight loss vs. time) furnishes an index of the susceptibility to hardening or a loss of workability. These data are presented in several different manners in Figures 12 through 16 to illustrate some specific points.

Figures 12 and 13 show the weight loss rate for the limestone and gravel mixes, respectively. Test Method Tex-206-F states that HMCL mixtures should be cured to a constant weight at a minimum temperature of 60 °C prior to molding. These curves were used to establish the appropriate curing time for laboratory specimens prior to further laboratory testing. Based on this data, a curing time of 96 hours (4 days) was chosen for all six mixtures. However, notice that the weight loss for all mixtures continues well beyond 96 hours but at a much reduced rate.

These six laboratory mixtures were also compared with LRA mixtures (Item 332, Type D) obtained directly from the supplier. This mixture was cured also under the same conditions as described above and is compared with the laboratory-produced HMCLs in Figure 14. Test Method Tex-206-F states that LRA mixtures should be cured to a constant weight at 88 °C. However, for this comparison, the LRA mixture was cured at 60 °C similar to the laboratory-produced HMCL mixtures. Note that the LRA mixture has five times the weight loss of the HMCL mixtures. Since this was sampled at the plantsite, some of the weight loss could be due to moisture. However, these data compare well to data obtained in 1970 (Hargett, 1970) on similar materials as shown in Figure 15. In Figure 15, Item 352 refers to HMCL and Item 332 refers to LRA.

Figure 16 shows the same data presented in Figure 14, but the scale is magnified to show what happens within the first eight hours of curing. In Figure 16, it appears that the LRA material is slower to cure, which could be a direct indication that it is less susceptible to change in workability with time. This would confirm reports from the field regarding the excellent workability characteristics of LRA. The researchers are defining *cured* as that point when the mixture has lost all of its weight (or volatiles). Figure 16 indicates that the LRA is slower to reach a peak weight loss.

The curing rates of all six laboratory-produced mixtures are shown in Figure 17. While each mixture shows a different total weight loss, all mixtures show a peak weight loss at approximately the same point in time.

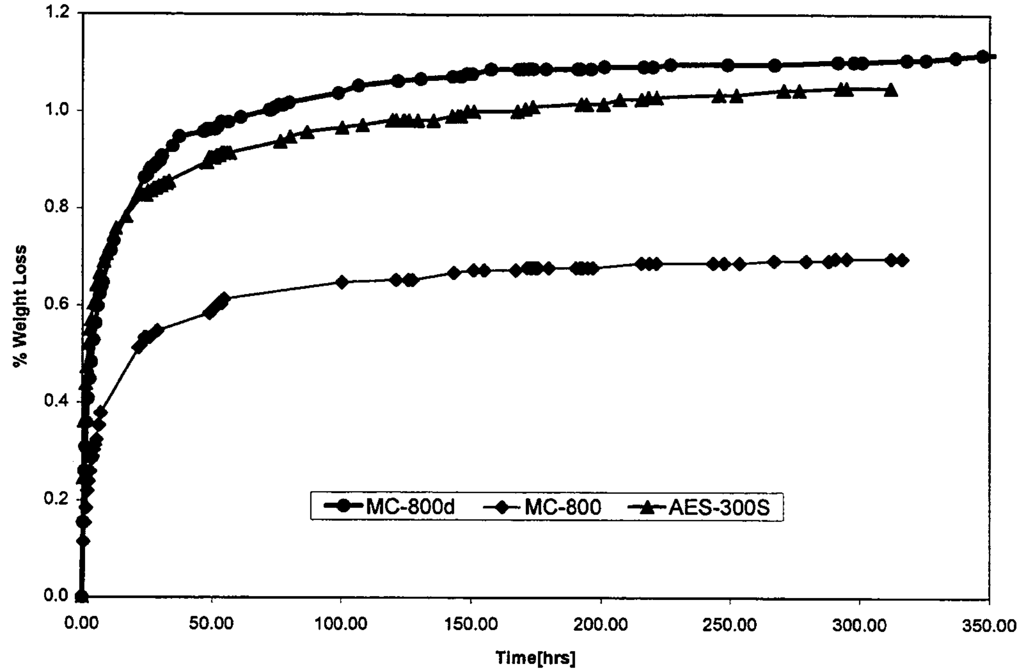

Figure 12. **Long-Term Curing Rate for HMCL Laboratory-Produced Mixtures Made with Crushed Limestone Aggregate.**

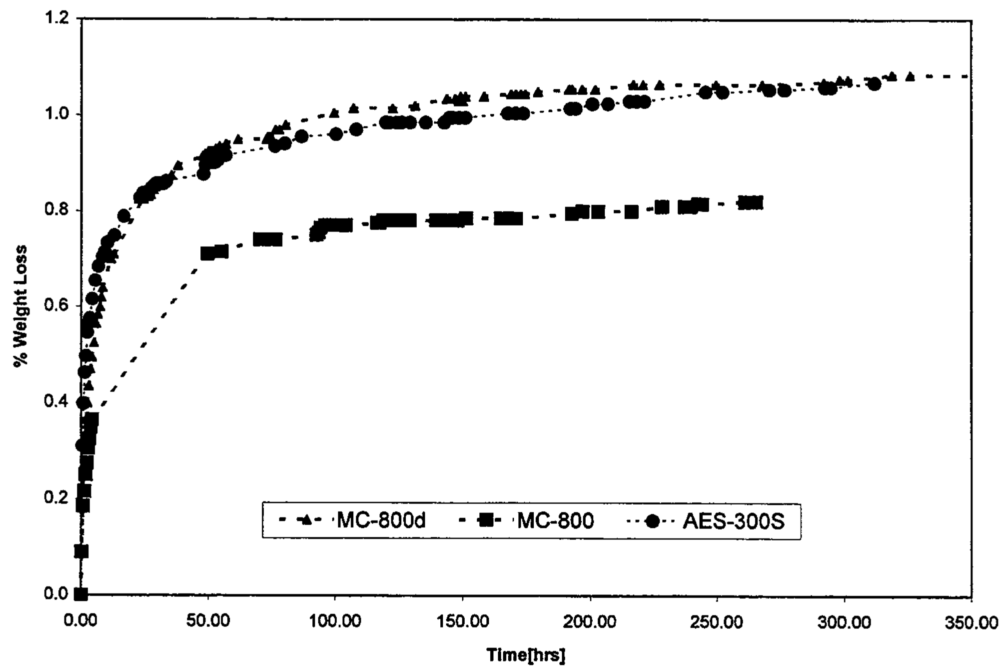

Figure 13. **Long-Term Curing Rate for HMCL Laboratory-Produced Mixtures Made with Crushed Gravel Aggregate.**

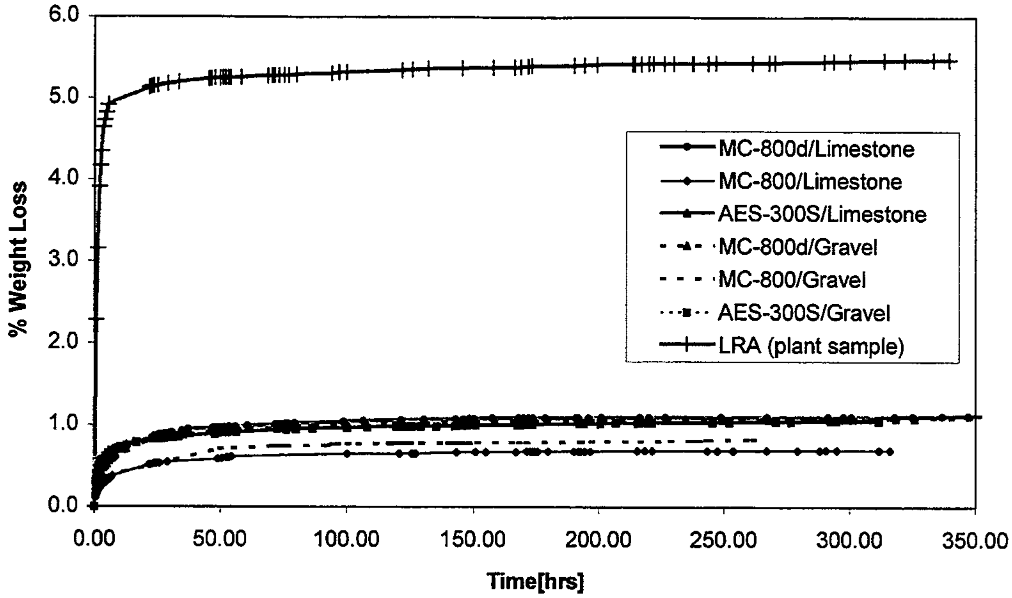

Figure 14. **Long-Term Curing Rate of Six Types of Laboratory-Produced HMCL Mixtures Compared to LRA Mixture.**

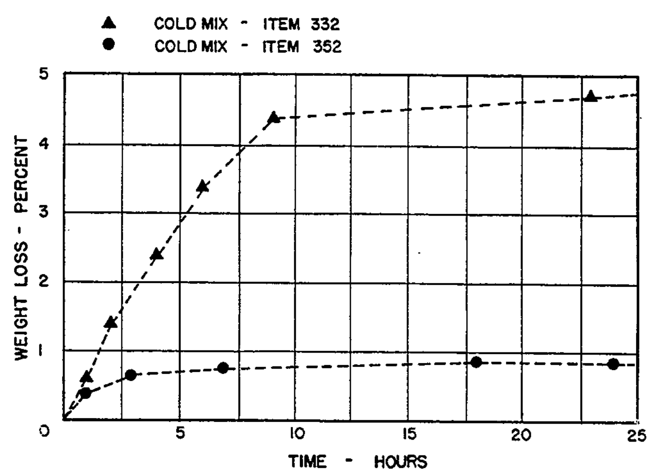

Figure 15. **Long-Term Curing Rate of Field Sampled HMCLs Compared to LRA from 1970 Study** (after Hargett 1970).

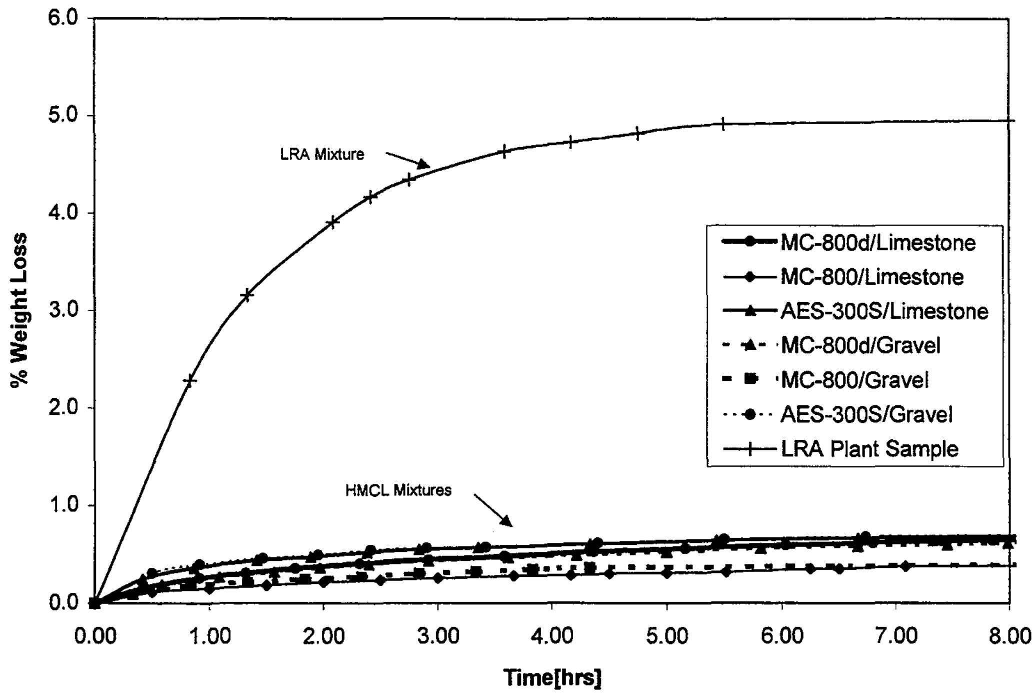

Figure 16. **Short-Term Curing Rate of Six Types of Laboratory-Produced HMCLs Compared to LRA Mixture.**

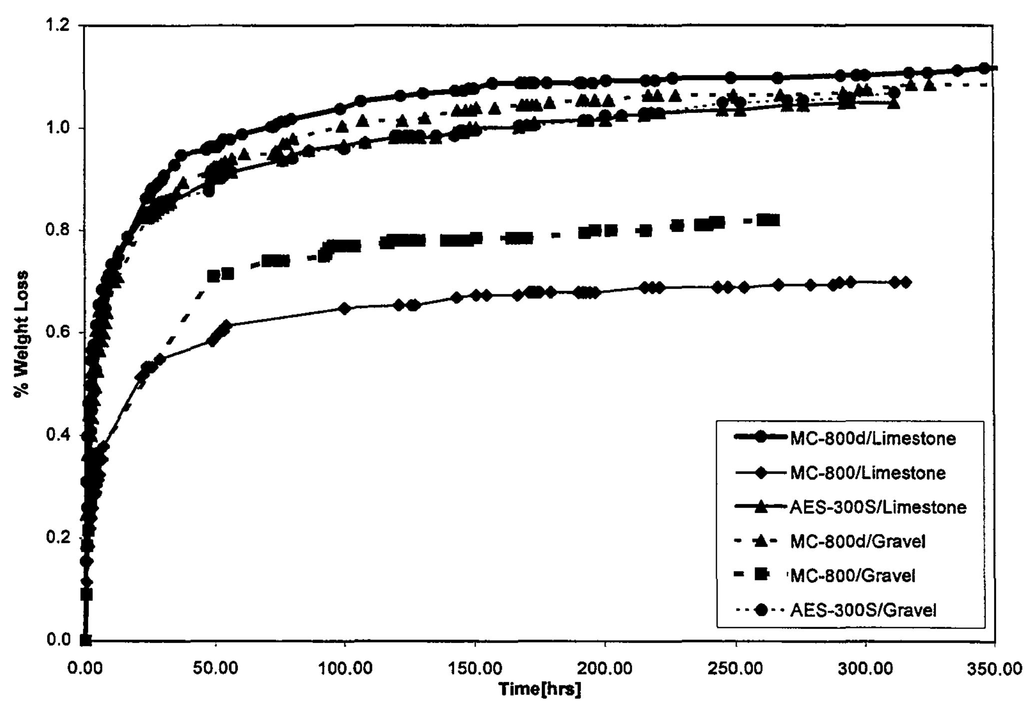

Figure 17. **Short-Term Curing Rate of Six Types of Laboratory-Produced HMCLs.**

The curing study was undertaken for two reasons: (1) to identify the amount of time needed to adequately cure samples prior to testing and (2) to compare the curing characteristics of different mixture types. One of the reasons that a stockpiled mixture would lose its workability is because the asphaltic binder has lost all of its volatiles; therefore, the rate at which a mixture loses its volatiles under controlled conditions might have some relationship to workability. Based on the results presented in Figure 17, it appears that all of the laboratory-produced maintenance mixtures reach a peak weight loss at approximately the same time.

Researchers thought it noteworthy that it takes a very long time to cure samples to a constant weight. Test Method Tex-206-F states that samples should be cured to a constant weight, which can depend on how often weight-loss readings are taken. As shown in Figure 17, even after three days of oven-curing, only about 90 percent of the total weight loss has occurred for some mixtures. The effects of different levels of curing on mixture properties were not investigated.

4.5.2 Hveem Stability

Hveem stability tests were performed on mixtures designed at 89, 92, and 95 percent densities. Mixtures were cured and molded according to Tex-206-F. Hveem stability tests were performed in accordance with TxDOT test method Tex-208-F. Results of the Hveem stability tests are shown in Table 12 and Figure 18. Each data point shown in Figure 18 represents an average of three samples.

The crushed limestone mixtures had a significantly higher stability than the gravel mixtures. These mixtures had stabilities ranging from 46 to 54. The gravel mixtures had stabilities ranging from 30 to 34. Hveem stability was not adversely affected by designing mixtures at lower densities (92 and 89 percent).

Table 12. Hveem Stability Data for Laboratory Mixtures.

Design Density	Crushed Limestone Mixes			Crushed Gravel Mixes		
	AES-300S	MC-800	MC-800 w/diesel	AES-300S	MC-800	MC-800 w/diesel
89%	49 51 50	50 44 45	42 48 45	NA 30 32	35 33 30	32 33 29
92%	52 54 56	43 54 53	48 48 46	31 34 33	33 33 32	31 30 32
95%	52 53 52	53 46 47	52 52 53	30 31 31	33 34 29	34 31 29

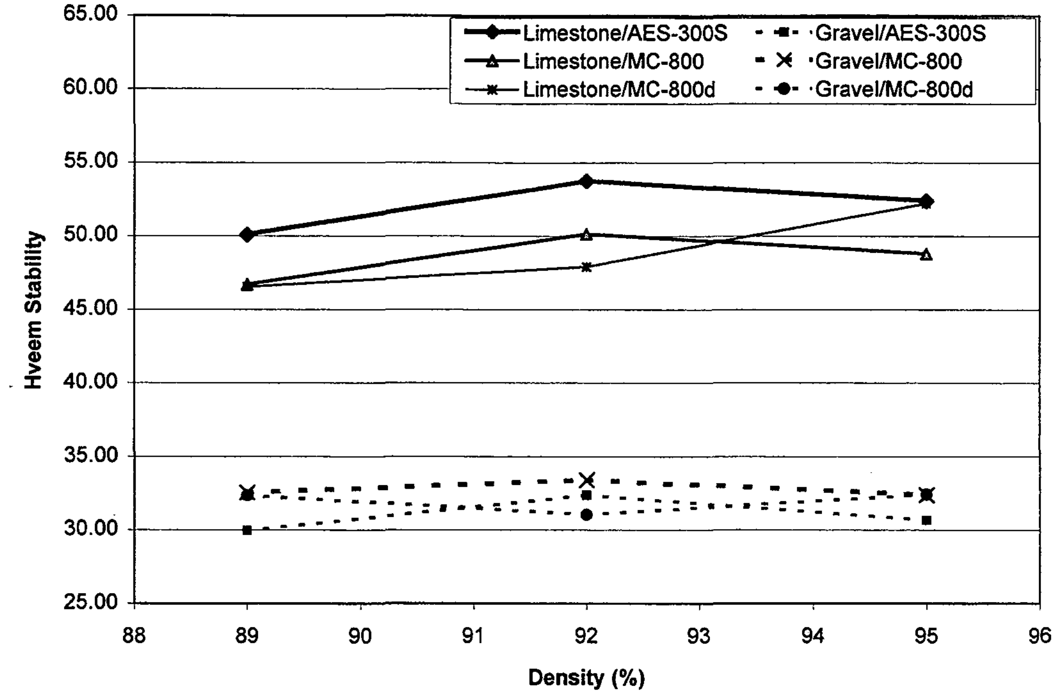

Figure 18. Hveem Stability versus Density for HMCL Laboratory Mixtures.

4.5.3 Marshall Stability

Marshall stability tests were also performed on mixtures designed at 89, 92, and 95 percent densities. These tests were performed in accordance with ASTM D 1559; however, the specimens were not immersed in a water bath prior to testing but were placed in a 60 °C oven for two hours. Results of the Marshall stability tests are shown in Table 13 and Figure 19. Each data point shown represents an average of three samples.

As in the Hveem stability data shown above, the crushed gravel mixes had significantly lower Marshall stabilities than the crushed limestone mixes. All of the gravel mixtures exhibited stabilities under 500 lb, while all of the crushed limestone mixtures had stabilities greater than 1200 lb. The gravel and limestone mixtures which were made with MC-800 had higher stabilities than those made with the MC-800 with diesel and the AES-300S.

For the gravel mixtures, the stability values were not as greatly influenced by density as for the crushed limestone mixtures. For the limestone mixtures, however, there is a definite stability *peak* at 92 percent density (for all three binders used.)

Marshall flow data are presented in Figure 20. There is no particular trend evident in this data set.

Table 13. Marshall Stability and Flow Data for Laboratory Mixtures.

Design Density	Crushed Limestone Mixes						Crushed Gravel Mixes					
	AES-300S		MC-800		MC-800 w/diesel		AES-300S		MC-800		MC-800 w/diesel	
	Stab. lb	Flow in/in	Stab. lb	Flow in/in	Stab. lb	Flow in/in	Stab. lb	Flow in/in	Stab. lb	Flow in/in	Stab. lb	Flow in/in
89%	2244 1452 500	13 12 15	1749 1716 1344	12 14 11	771 1651 1430	12 14 12	NA 266 217	NA 9 11	315 344 390	11 9 9	75 NA 52	11 NA 12
92%	1551 1386 2363	11 14 12	2442 2508 2112	15 15 15	1696 2200 1754	15 15 12	151 76 310	7 13 8	286 569 454	15 13 10	250 276 270	8 9 8
95%	1529 1598 1703	14 16 16	2154 1911 1782	15 14 15	1375 1616 1630	12 16 14	326 283 270	8 7 9	472 480 514	10 9 8	254 261 250	8 9 8

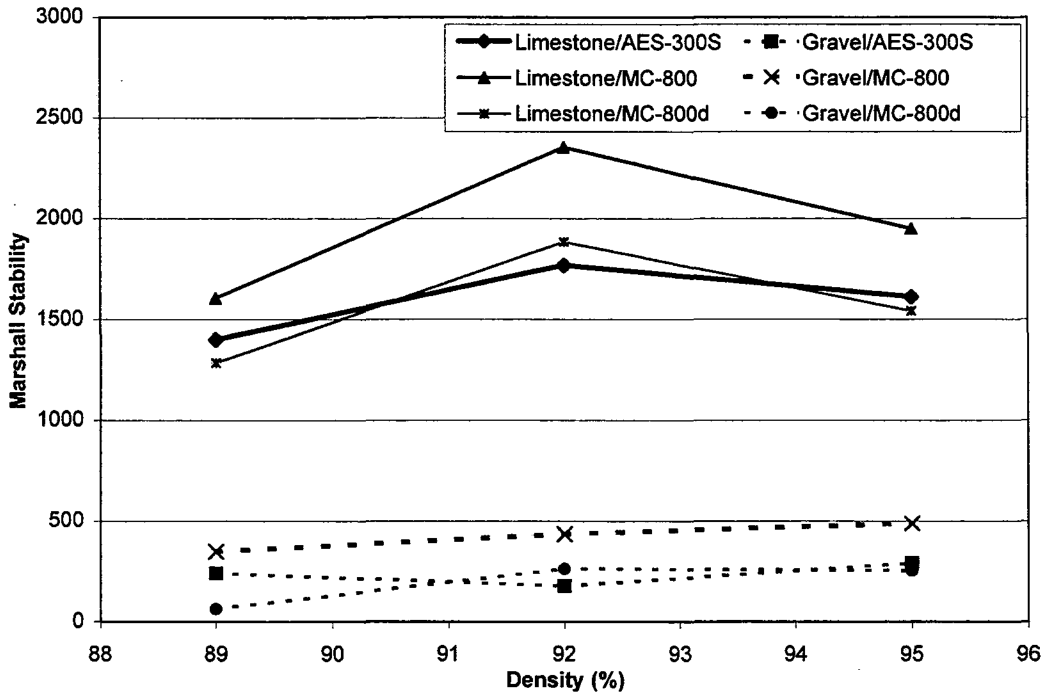

Figure 19. Marshall Stability versus Density for HMCL Laboratory Mixtures.

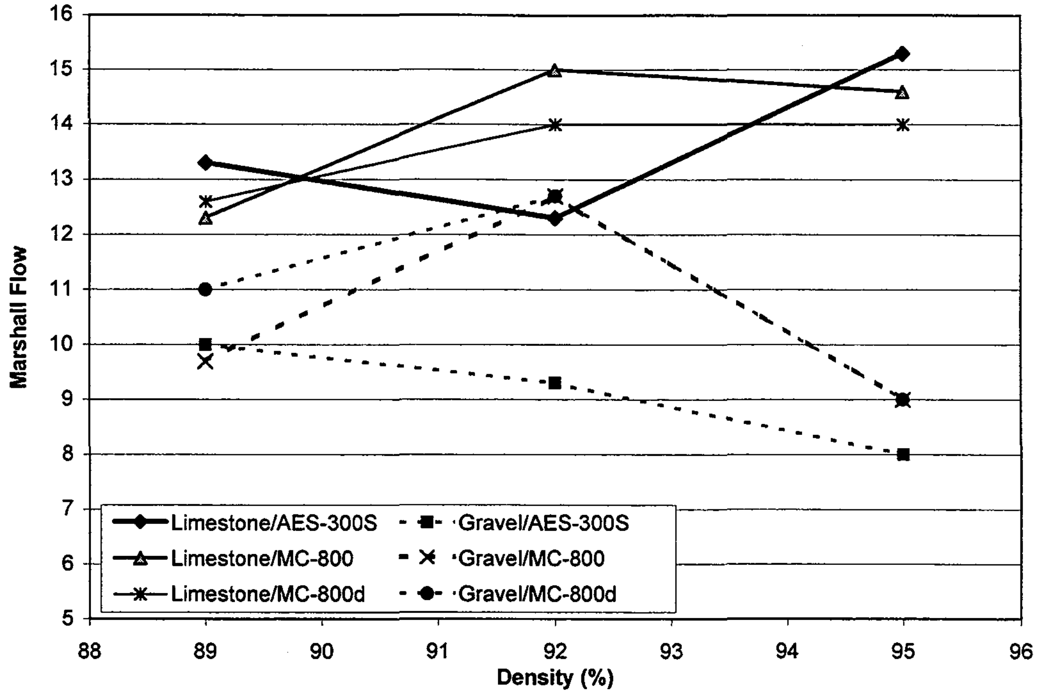

Figure 20. Marshall Flow versus Density for HMCL Laboratory Mixtures.

4.5.4 Unconfined Compression Test

Unconfined compression tests were performed on mixtures designed at 89, 92, and 95 percent densities. Samples were molded at a temperature of 38 °C using the motorized gyratory soils press. Operation of the press is described in Tex-126-E. Samples were compacted to produce a lightly compacted sample indicative of stockpile consolidation. About 6700 g of mixture were placed in a 152 mm diameter mold in three lifts, rodding once around the outside of the mold using a spatula. The mold was gyrated at a pressure of 345 kPa for one minute, and a leveling load of 1333 N was applied for 30 seconds (Estakhri and Button, 1995). The samples were then cooled for one hour prior to mold extrusion. This produced a sample of about 152 mm in height. More or less material is used as needed to produce a sample at the desired height of 152 mm. Unconfined compression tests were performed at 4 °C using a loading rate of 3.4 mm per minute to failure.

Results are shown in Table 14 and Figure 21. Each data point shown represents an average of three samples. The compressive strength of the limestone mixtures was greater than the gravel mixtures and, in general, samples designed at 95 percent density had the lowest strengths. For the limestone mixtures, there is a distinct difference in the strengths associated with different asphaltic binders, with the AES-300S having the highest strengths.

Table 14. Unconfined Compression Test Data on Laboratory Mixtures.

Design Density	Unconfined Compressive Strength, kPa					
	Crushed Limestone Mixes			Crushed Gravel Mixes		
	AES-300S	MC-800	MC-800 w/diesel	AES-300S	MC-800	MC-800 w/diesel
89%	1544 1668 1641	1050 1192 1561	1263 983 694	257 325 391	338 289 689	196 160 NA
92%	1472 1632 1486	1534 1326 1294	1134 889 1161	365 294 400	187 245 391	120 102 98
95%	1072 1499 1116	1201 1090 939	907 832 859	258 307 338	285 138 240	58 133 67

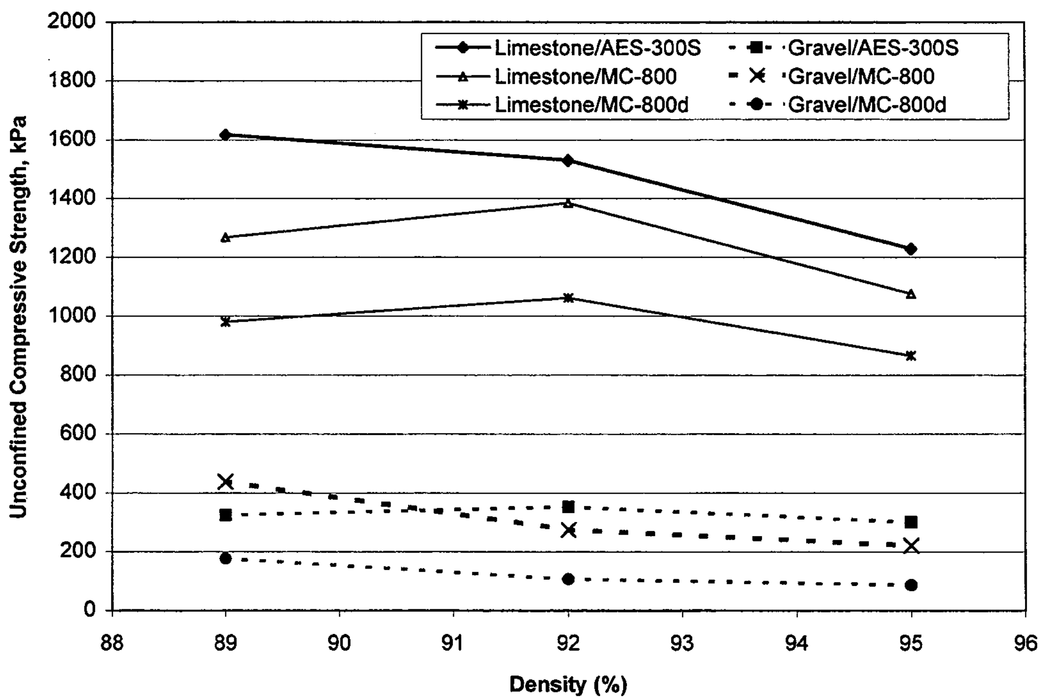

Figure 21. Unconfined Compressive Strength versus Density for HMCL Laboratory Mixtures.

4.5.5 Cohesion Test Results

In SHRP Report H-348, a cohesion test is recommended to quantify cohesion of cold mixes. The test should not be used to guarantee success of the material; rather, it can be used to indicate the potential for poor performance. The test is conducted by cooling 1200 g samples of cold mix to 4 °C. The mix is placed into a standard Marshall mold and compacted using five blows of a standard Marshall hammer to each side. The sample is then extruded and the weight recorded. The compacted sample is then placed along the bottom edge of a 305 mm diameter sieve (245.4 mm openings) while both the sieve and the sample are standing on end. A cover is placed on the sieve while it is still on end, and the sieve is rolled back and forth 20 times. With the sample still inside, the sieve is laid against the edge of a table allowing room for sample pieces to fall through the sieve openings (for 10 seconds). The remaining material is then weighed and reported as percent retained.

Results of this test are shown in Table 15 and in Figure 22. The data from this test generally showed that the cohesion decreased as density decreased (and asphalt binder decreased), as would be expected. Mixtures designed at 95 percent density generally had the best cohesion properties (89 to 95 percent retained), while the mixtures designed at 92 percent density saw a loss in cohesion with values ranging from 75 to 88 percent retained. A dramatic loss of cohesion was observed in the mixtures designed at 89 percent density, with values generally ranging from 10 to 39 percent retained. A minimum retention value of 60 percent is recommended in SHRP H-348.

Table 15. Cohesion Test Results for HMCL Laboratory Mixtures.

Design Density	Cohesion, percent retained					
	Crushed Limestone Mixes			Crushed Gravel Mixes		
	AES-300S	MC-800	MC-800 w/diesel	AES-300S	MC-800	MC-800 w/diesel
89%	55.6 30.7 27.8	66.7 77.4 66.5	0.0 23.5 24.3	11.6 27.6 42.1	37.2 32.4 26.8	6.7 16.4 9.1
92%	83.8 89.8 75.2	88.5 90.9 83.3	64.5 81.5 74.2	73.7 77.1 79.3	86.0 85.3 54.5	26.9 29.5 10.5
95%	88.7 79.7 99.4	99.1 97.3 92.7	95.5 96.9 95.0	63.0 72.1 49.4	78.3 94.9 94.1	45.4* 93.1 93.5

* Considered an outlier and not included in Figure 22.

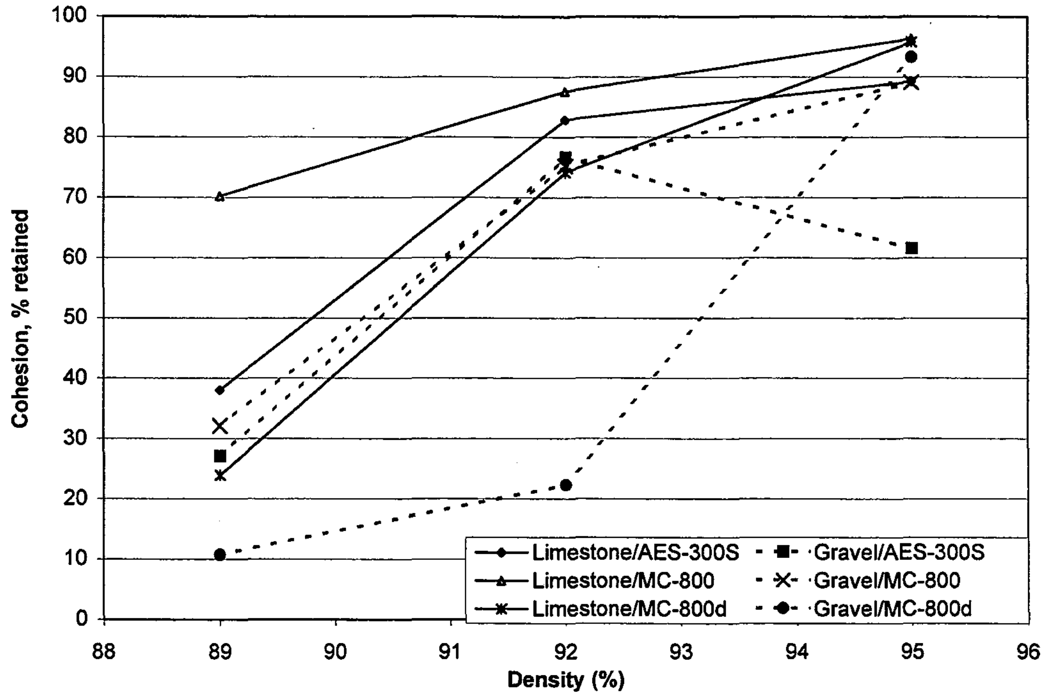

Figure 22. Cohesion Test Data versus Density for HMCL Laboratory Mixtures.

4.5.6 Workability Test Results

A workability test described in SHRP H-348 (Romine and Wilson, 1993) was also used to evaluate the laboratory mixtures. This test consists of a workability box (102 mm on all sides), a pocket penetrometer (used for soil testing), and a penetrometer adapter. Three samples of cold-mix (2500 g) are cooled to 4 °C and placed loosely into the box. The penetrometer (with adapter) is pushed through 10 mm holes in both sides of the box. The maximum resistance, as measured on the penetrometer, is recorded as the workability measurement. An average workability reading between three and four would be considered marginal, while a value over four should be rejected. Values under three are considered acceptable.

Results of this test are shown in Table 16 and Figure 23. No significant trends were observed for any of the mixtures. Values of workability for all of the mixtures were less than one and most of the values were less than 0.5. The SHRP Workability Test was developed for high-performance pothole patching materials and these materials produce higher workability readings than the TxDOT HMCL mixtures. Therefore, acceptable values for this test should be considerably lower for HMCLs. Wilson and Romine (1993b) state that this test should be used for acceptance of a cold mix but that the test does not guarantee success; rather it indicates the potential for poor performance.

Table 16. SHRP Workability Test Results for HMCL Laboratory Mixtures.

Design Density	Workability Value (SHRP Workability Box)					
	Crushed Limestone Mixes			Crushed Gravel Mixes		
	AES-300S	MC-800	MC-800 w/diesel	AES-300S	MC-800	MC-800 w/diesel
89%	0.2 0.5 0.0	0.5 0.1 0.0	0.3 0.1 0.2	0.3 0.5 0.0	0.0 0.0 0.3	0.5 0.9 0.8
92%	0.0 0.3 0.2	0.0 0.0 0.1	0.7 0.1 0.0	0.0 0.3 0.0	0.0 0.3 0.0	0.0 0.0 0.0
95%	0.4 0.0 0.2	0.3 0.2 0.2	0.1 0.2 0.1	0.4 0.0 0.0	0.5 0.5 0.2	0.3 0.0 0.2

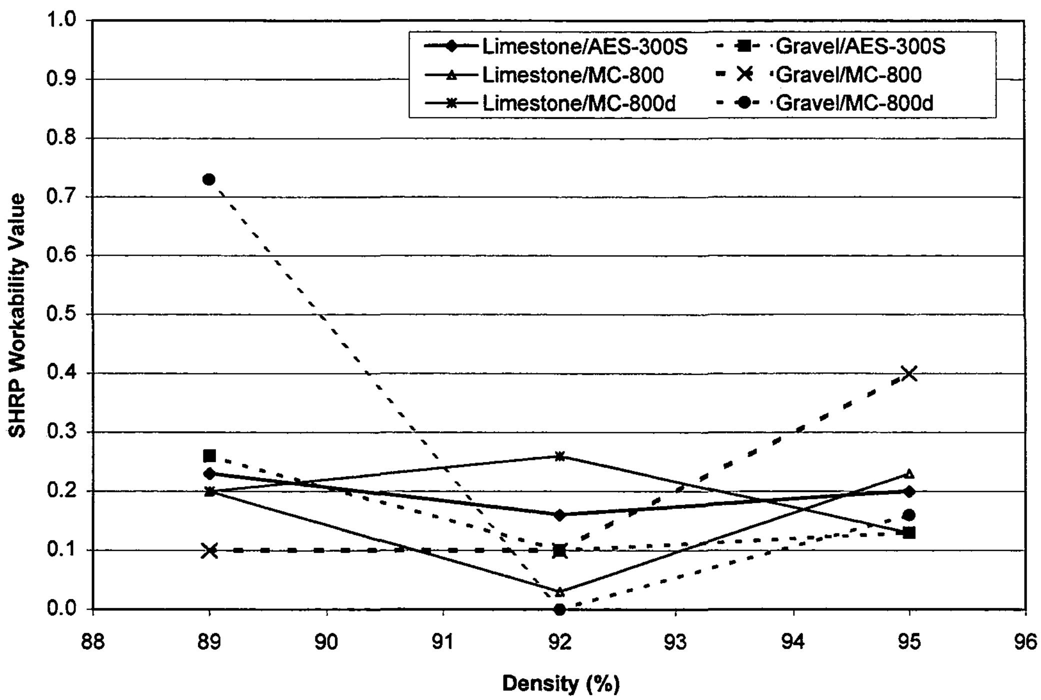

Figure 23. SHRP Workability Data versus Density for HMCL Laboratory Mixtures.

CHAPTER 5.0 PRELIMINARY FIELD/LABORATORY INVESTIGATION OF AGED STOCKPILES FOR WORKABILITY AND COHESION

5.1 OBJECTIVE OF PRELIMINARY FIELD/LABORATORY EVALUATION

The objective of this task of the research study was to establish the typical laboratory property test values of aged stockpiles of HMCL. These values were then compared to the performance information (both stockpile and in-service performance) of these patching mixes. Cohesiveness and workability measurements made on materials at various stockpile ages would provide expected laboratory values as a function of aging for use in developing acceptance criteria. Samples of HMCL material were obtained from TxDOT maintenance yards, and subjective performance evaluations were obtained from maintenance personnel familiar with the particular mix. Stockpiled materials sampled ranged in age from six to 10 months. Laboratory tests performed on the materials included:

- SHRP Workability Test,
- SHRP Cohesion Test,
- Modified Triaxial Test, and
- Unconfined Compression Test.

5.2 HMCL MIXTURES EVALUATED

Samples of HMCL were obtained from 10 different maintenance yards in the state. These locations are shown on the map in Figure 24 and the mixtures are labeled accordingly as A through K throughout this chapter. In addition, some samples of Limestone Rock Asphalt (LRA) patching materials were obtained for comparison purposes. The LRA samples were obtained from the Vulcan plant in Uvalde and included both fresh materials as well as some materials from experimental stockpiles, which were up to six years of age. The LRA samples are described below and labeled in the charts as follows:

- LRA1 - Type CC, fresh;
- LRA2 - Type D, fresh;
- LRA3 - Type CC, eight months old;
- LRA4 - Type CC with polymer, eight months old;
- LRA5 - Type CC with polymer, over-asphalted, eight months old; and
- LRA6 - Type CC, six years old.

Performance information on the above LRA materials was not available.

5.3 FIELD PERFORMANCE OF MATERIALS

Samples of the HMCL materials were obtained in late April, May, and June of 1997. At the time of sampling, ambient temperatures were at 25 °C or more; therefore, workability of these mixtures, which had been stockpiled through the winter, had been restored due to the warm temperatures. While the stockpiles had an outer crust that had to be removed with a front-end loader to obtain samples, the inner portions of the stockpiles had relatively good workability and were easily sampled. Maintenance personnel reported good field performance for all of the materials sampled, which had been in service from between six and 10 months.

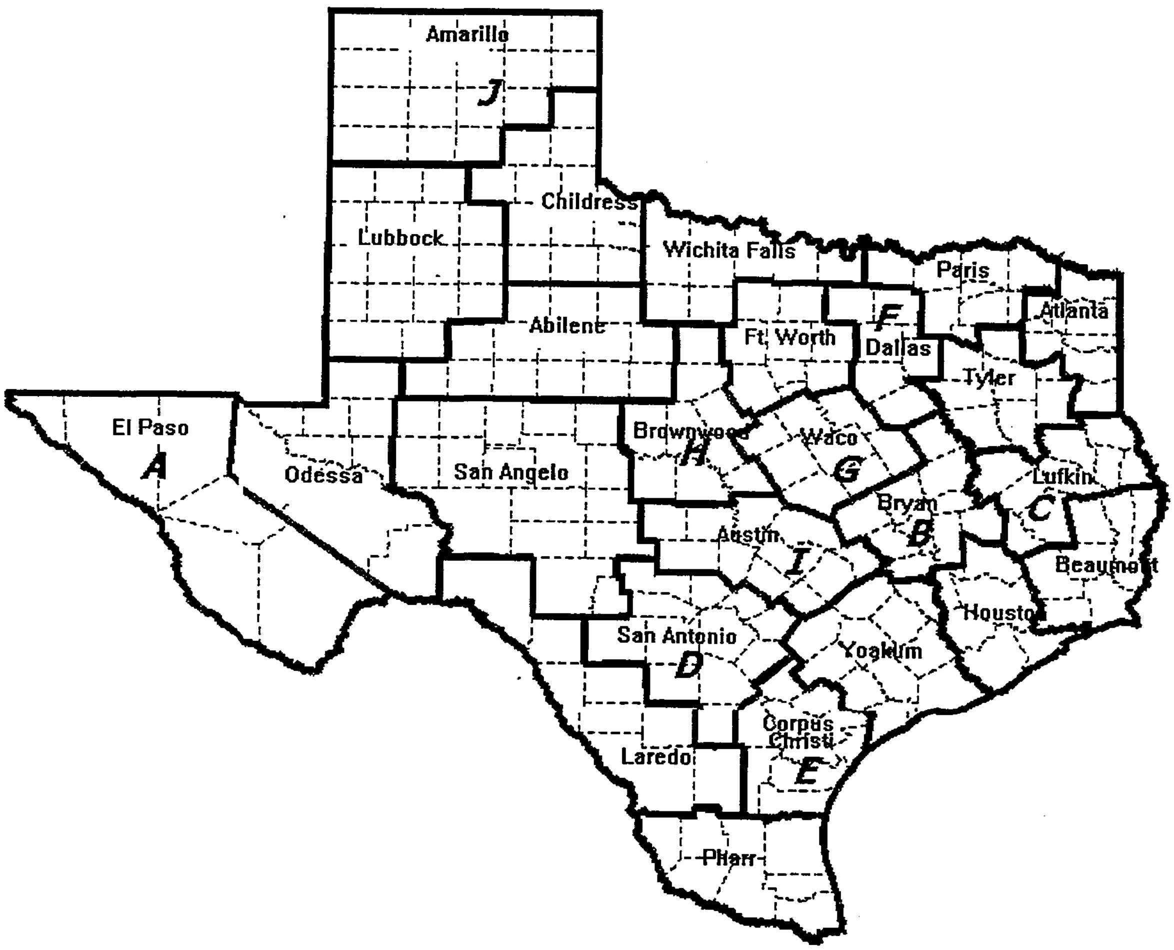

Figure 24. Locations of Field Sampled HMCL Materials.

5.4 SHRP WORKABILITY TEST RESULTS

The SHRP Workability Test, as described in SHRP H-348 (Romine and Wilson, 1993) and also in section 4.5.6 of this report, was performed on all of the field-sampled materials. The results of this test are plotted as a function of stockpile age in Figure 25. All of the materials had workability values well within the acceptable range of values. Any value below a three is considered acceptable workability.

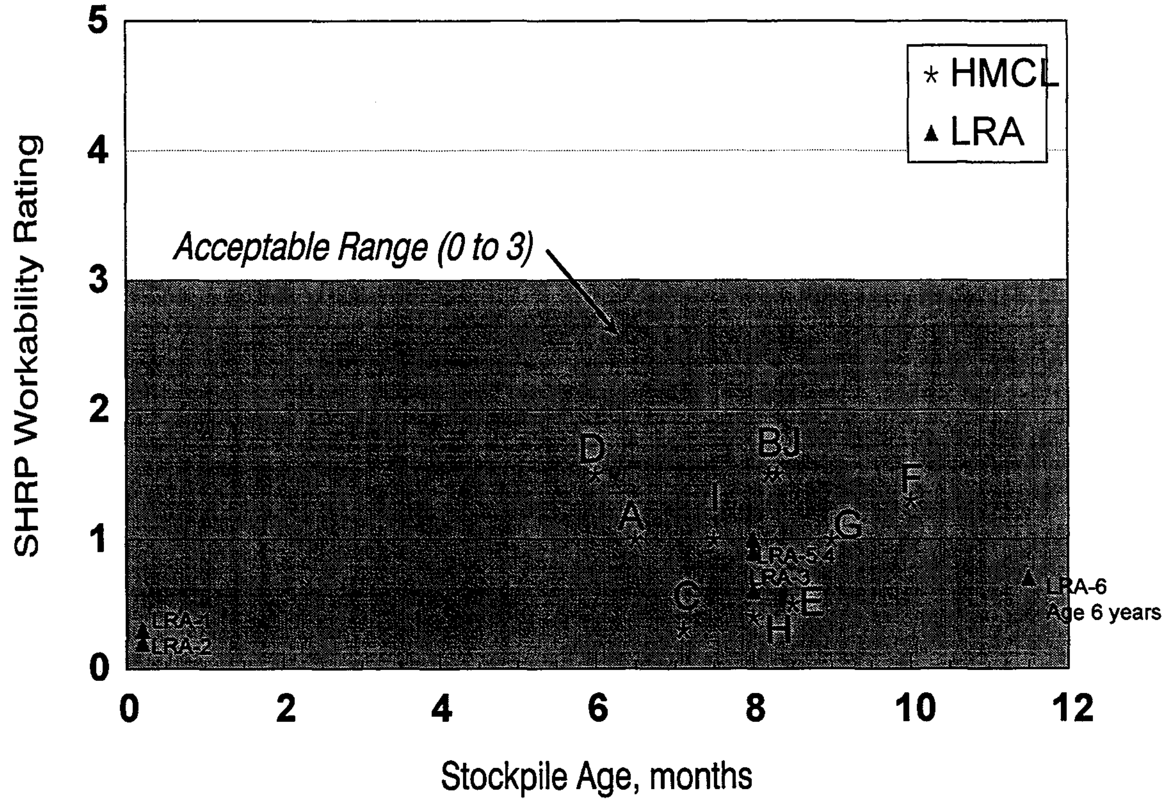

Figure 25. SHRP Workability Measurements of Field-Aged HMCL Mixtures.

5.5 MODIFIED TRIAXIAL TEST RESULTS

In previous research study 0-1377 (Estakhri and Button, 1995), the Texas Triaxial Test was modified slightly to evaluate the workability and cohesion of HMCL maintenance mixtures. This test is typically used by TxDOT to evaluate the strength of a soil defined in terms of the stresses developed at the peak of the stress-strain curve. Data are generated from tests performed at different confining stresses. Mohr circles are drawn to represent the states of stress at the peak points of the stress-strain curve. Then a line is drawn tangent to the Mohr circles. This line is called the Mohr failure envelope. The triaxial test and analysis procedures as performed routinely by TxDOT are described in test method Tex-117-E, *Triaxial Compression Test for Disturbed Soils and Base Materials.* The test as performed on maintenance mixtures is described in Research Report 1377-1F (Estakhri and Button, 1995).

Specimens are compacted at a temperature of 38 °C, using the motorized gyratory soils press. Operation of the press is described in Tex-126-E. Samples were compacted to produce a lightly compacted sample indicative of stockpile consolidation. About 6700 g of mixture were placed in a 152 mm diameter mold in three lifts, rodding once around the outside of the mold using a spatula. The mold was gyrated at a pressure of 345 kPa for one minute, and a leveling load of 1333 N was applied for 30 seconds (Estakhri and Button, 1995). The samples were then cooled for one hour prior to mold extrusion. This produced a sample of about 152 mm in height. More or less material is used as needed to produce a sample at the desired height of 152 mm. Unconfined compression tests were performed at 4 °C using a loading rate of 3.4 mm per minute to failure.

The Mohr failure envelopes for the HMCL samples are shown below in Figure 26. According to these test values, Mixture D would have the *best* workability, and Mixture E would be the least workable.

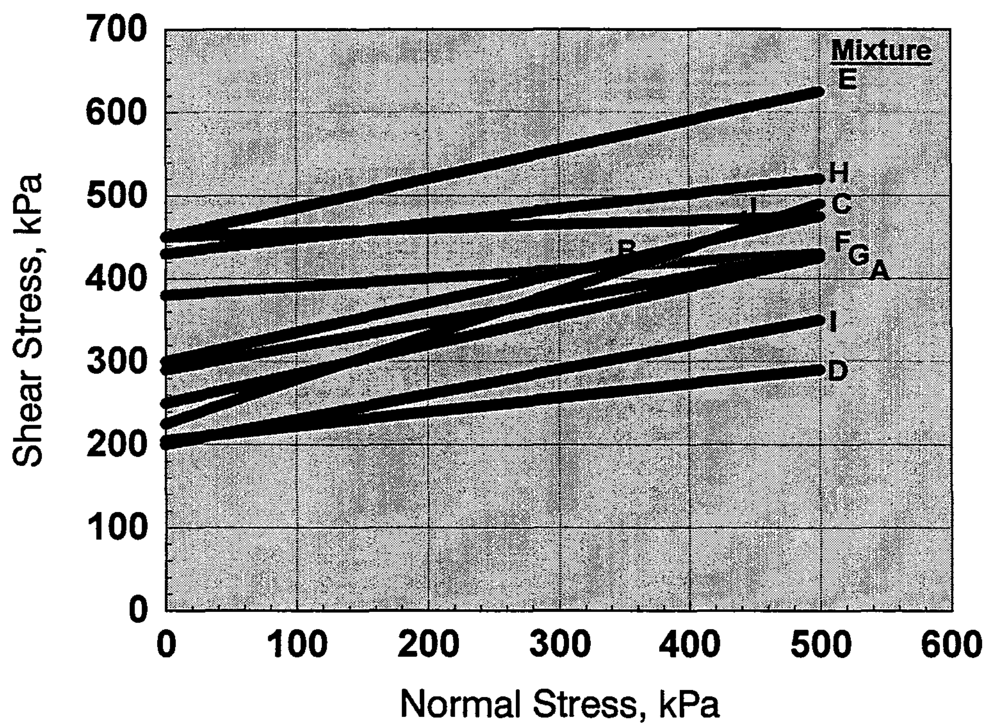

Figure 26. Failure Envelopes from Triaxial Tests on Field-Aged HMCL Samples.

5.6 UNCONFINED COMPRESSION TEST RESULTS

Unconfined compression tests were performed on field-sampled HMCL materials. These results are shown in Figure 27 below as a function of stockpile age. This test was performed on 152 mm diameter by 152 mm high specimens. Samples are molded at 38 °C according to procedures described by Estakhri and Button (1995) using the motorized gyratory soil press. Specimens were cooled to a temperature of 4 °C for a period of 24 hours prior to testing. The data trend indicates an increase in compressive strength with stockpile age.

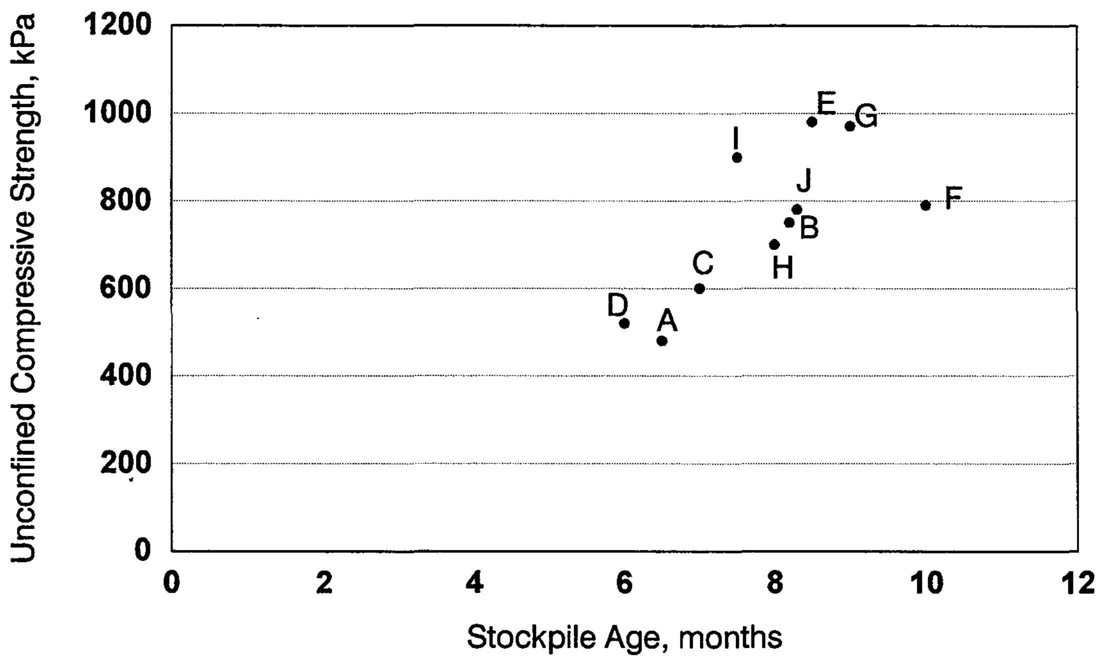

Figure 27. Unconfined Compression Test Results on Field Sampled HMCL Materials.

5.7 SHRP COHESION TEST RESULTS

SHRP cohesion tests were performed on all of the HMCL samples and these results are shown below in Figure 28. The cohesion test, or rolling sieve test, was performed as described in section 4.5.5 of this report. As shown in Figure 28, the fresh mixtures (which were LRAs) had a good cohesion value, while the aged materials had relatively low cohesion. One exception was the mixture designated LRA-5. This mixture, however, had twice the normal binder content, which would probably make it a more cohesive mix even at eight months of age.

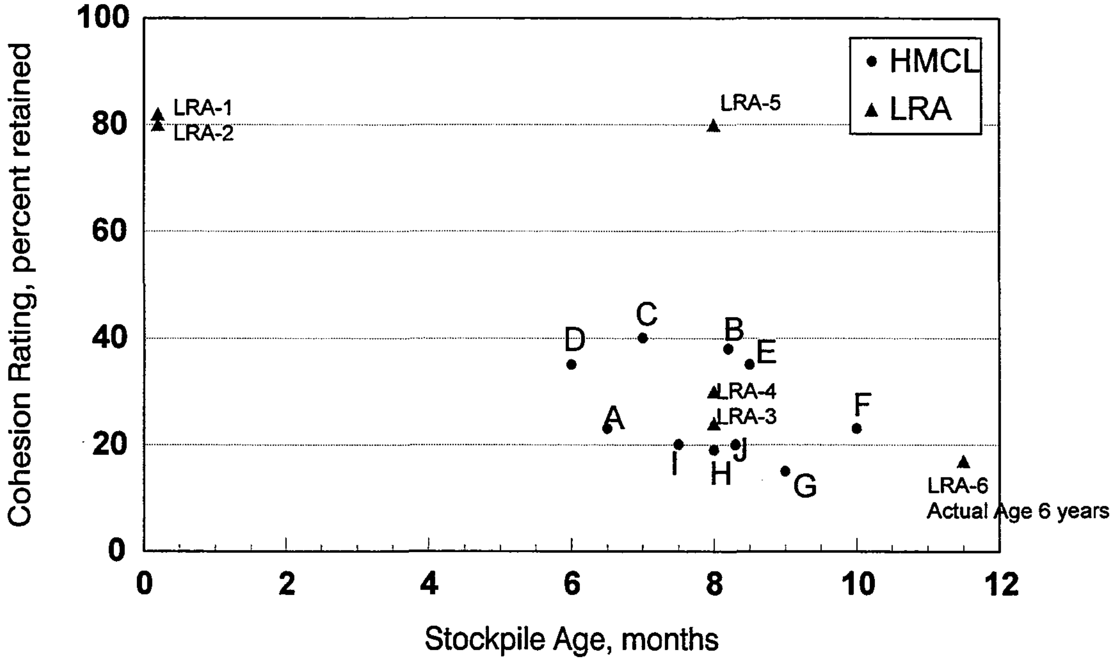

Figure 28. SHRP Cohesion Test Results for HMCL Field Sampled Materials.

CHAPTER 6.0 INVESTIGATION OF PROGRESSIVELY AGED FIELD MIXTURES

6.1 OBJECTIVE OF TASK

The objective of this task was to identify simple but meaningful laboratory tests to be performed on HMCL patching materials which would ensure reasonable stockpile life and field performance. Samples of *new* HMCL patching materials were obtained from several different suppliers around the state, and materials were then resampled from stockpiles an additional two to three times throughout the study as the stockpiles aged. The mixtures were evaluated in the field for workability and patch performance. The following laboratory tests were performed on the field sampled materials:

- Hveem Stability,
- SHRP Cohesion,
- SHRP Workability,
- Blade Penetrometer (workability),
- Unconfined Compressive Strength,
- Marshall Stability,
- Moisture Susceptibility (boiling test, Tex-530-C), and
- Extractions and Gradations.

6.2 FIELD PERFORMANCE AND MIXTURE PROPERTIES

Field materials were sampled when they were new and then again periodically through eight months of age. Field performance of the material was evaluated by maintenance personnel. Between five and 10 blade-on patches were placed when the material was new and the performance evaluation at the end of six to eight months is shown in Table 17. Mixtures are designated as *K* through *V,* as shown in the table and throughout the following charts.

The cold-weather workability of the stockpile was also evaluated during this performance evaluation period. Most of the stockpiles exhibited fair to poor winter workability, as shown in Table 16. In-service patch performance for all of the mixtures was good in the six to eight month time-frame in which they were evaluated, except for a few problems, as noted in Table 17.

Extracted asphalt content and aggregate gradations are also shown in Table 17. In addition, Hveem stabilities of compacted samples are shown in Table 17. Samples were cured to a constant weight at 38 °C prior to molding and testing.

Table 17. Mixture Properties and Performance Information for Field Sampled Mixtures.

Mixture Supplier	Gradation, percent passing sieve size in mm								Extracted Asphalt Content	Hveem Stability	Winter Workability Rating	Overall In-Place Performance at the end of 6 month evaluation period
	12.5	9.5	6.3	4.75	2.00	0.425	0.18	0.075				
K	100	93	-	68	42	23	10	2	4.0	38	Fair	Good, no problems noted
L	100	88	-	64	32	22	12	3	4.0	42	Poor	Excellent
M	100	100	100	-	35	22	12	4	4.0	39	Fair	Good to Excellent (very slight raveling)
N	100	95	-	62	41	26	13	5	4.0	44	Fair	Excellent, no distress noted
O	100	100	88	-	35	18	10	3	4.0	38	Poor	Good to Excellent, very slight flushing
P	100	100	100	-	39	22	13	6	4.0	44	Poor	Fair to Good, some slight raveling and isolated spots of rutting
Q	100	98	-	59	36	20	10	2	3.0	35	Fair	Fair to Good, some slight raveling and isolated spots of rutting
R	100	95	-	62	41	20	9	3	3.0	37	Poor	Good to Excellent, very slight cracking and slight raveling
S	100	92	-	64	39	21	10	5	4.0	42	Poor	Good to Excellent, very slight raveling noted
T	100	90	-	68	39	19	10	5	4.0	40	Poor	Excellent
U	100	95	-	57	33	22	9	4	4.0	40	Fair	Good to Excellent
V	100	92	-	59	34	21	9	4	4.0	35	Fair	Good to Excellent, slight flushing noted

6.3 SHRP COHESION TEST RESULTS (ROLLING SIEVE TEST)

As described previously in section 4.5.5, this test is performed on a lightly compacted specimen at 4 °C. The specimen is placed along the bottom edge of a sieve with 25 mm openings while both the sieve and the sample are standing on end. A cover is placed on the sieve while it is still on end, and the sieve is rolled back and forth 20 times. With the sample still inside, the sieve is laid against the edge of a table for 10 seconds allowing room for sample pieces to fall through the sieve openings. The remaining material is then weighed and reported as the percent retained.

Results of this test are shown in Figure 29. The initial *new* samples were cured to a constant weight prior to testing. The remaining samples were tested in the *as received* condition. Most of the mixtures had excellent retention values, and these values dropped with stockpile age as one would expect. A minimum retention value of 60 percent is recommended, and all of the mixtures had at least this value initially.

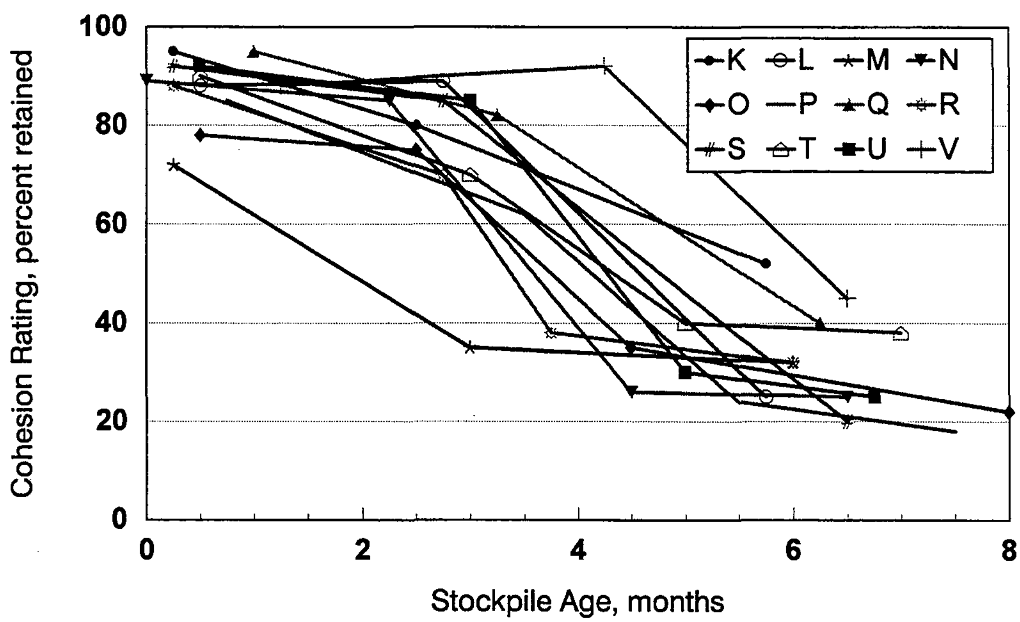

Figure 29. Cohesion Test Data versus Stockpile Age for Field Sampled Mixtures.

6.4 SHRP WORKABILITY TEST RESULTS

This workability test consists of placing the HMCL at 4 °C into a 102 mm square box. A penetrometer (with adapter) is pushed through 10 mm holes in both sides of the box. The maximum resistance is recorded as the workability measurement. This test procedure is described in Section 4.5.6. A workability value under three is considered acceptable. The more *unworkable* a mix, the higher the workability rating.

Results of this test are shown in Figure 30. All of the materials were well within the acceptable range, but there is a general trend indicating an increase in workability rating (or increase in mixture stiffness) as a mixture ages. As mentioned in Chapter 4.0, the SHRP Workability Test was developed for high-performance pothole patching materials and these materials produce higher workability readings than the TxDOT HMCL mixtures. Therefore, acceptable values for this test should be considerably lower for HMCLs. Wilson and Romine (1993b) state that this test should be used for acceptance of a cold mix but that the test does not guarantee success; rather it indicates the potential for poor performance.

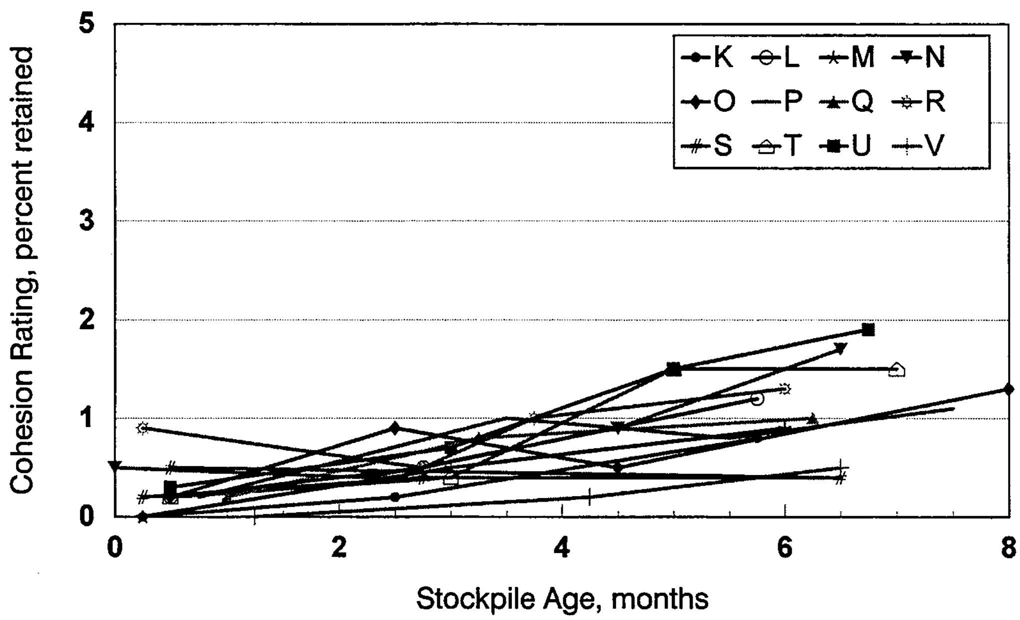

Figure 30. Workability Test Data versus Stockpile Age for Field Sampled Mixtures.

6.5 BLADE PENETROMETER WORKABILITY TEST RESULTS

Previous research on asphalt cold-mix materials has attempted to develop devices to quantify workability. Two of these devices - called penetrometers - were used in this study to test workability in the laboratory. The Pennsylvania Transportation Institute (PTI) developed the workability test described above. The other test, developed as part of a Federal Highway Administration (FHWA) study on the mix design of cold-mixes, used the PTI penetrometer but changed PTI's bullet-shaped attachment to a specially made blade.

This test is performed as described above by simply inserting the penetrometer into the cold mix and recording the maximum resistance encountered. The scale on the penetrometers ranged from 0 to 4.5 tons/ft^2, so the test results ranged from 0 to 4.5 as well.

Test results are shown below in Figure 31. Note that some of the values shown in the chart are plotted as five. This is to indicate that stiffness of the material exceeded the capacity of the penetrometer. These penetrometer values are considerably higher than those shown in Figure 30; however, the trend is similar.

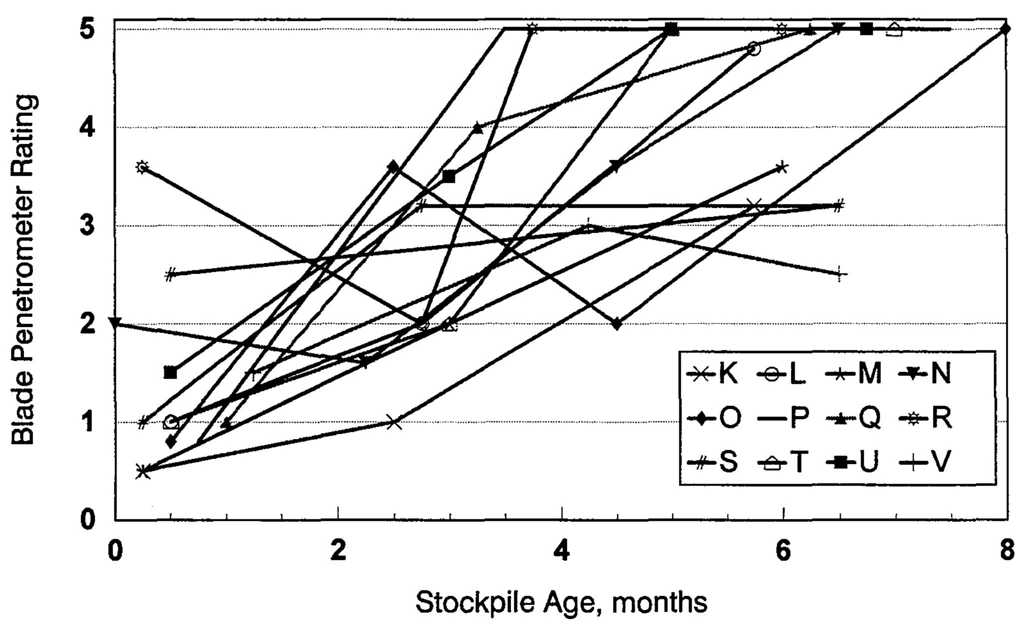

Figure 31. **Blade Penetrometer Test Data versus Stockpile Age for Field Sampled Mixtures.**

6.6 MARSHALL STABILITY TEST RESULTS

Marshall stability tests were performed on all samples according to ASTM D 1559; however, the specimens were not immersed in a water bath prior to testing but were placed in a 60 °C oven for two hours. As in previous tests, the initial samples - or *new* - were cured prior to testing, and the remaining samples were tested in the *as received* condition.

Results of the Marshall stability tests are shown in Figure 32. Stabilities for all mixtures ranged between 800 and 1600 lb. Some mixtures showed an increase in stability with age and a slight drop in stability with additional aging.

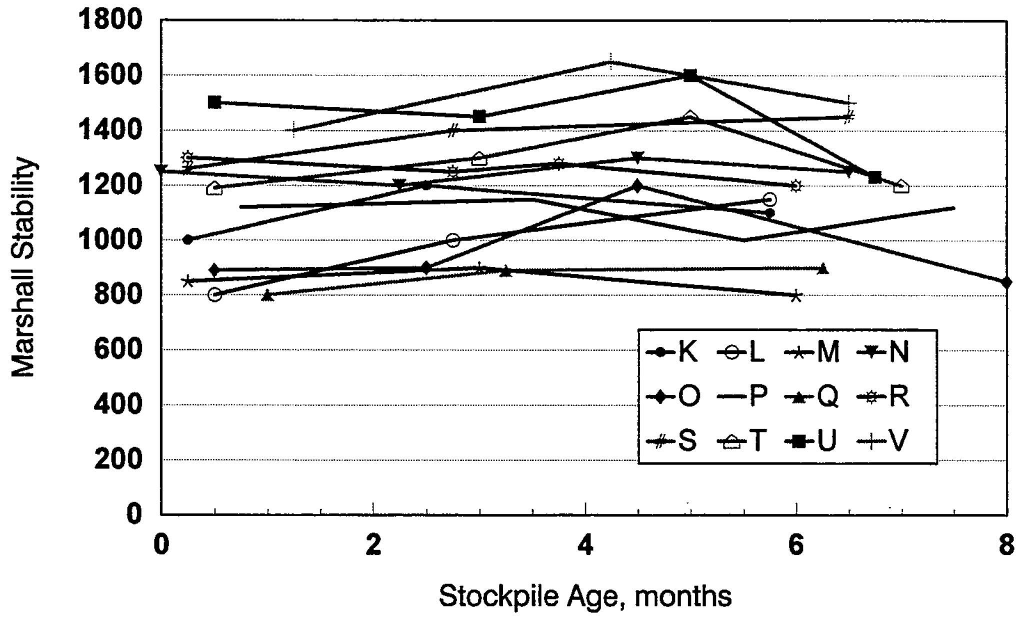

Figure 32. Marshall Stability Test Data versus Stockpile Age for Field Sampled Mixtures.

6.7 UNCONFINED COMPRESSIVE STRENGTH DATA

Unconfined compression tests were performed on field samples of HMCL materials. These results are shown in Figure 33 as a function of stockpile age. This test was performed on 152 mm diameter by 152 mm high specimens. Specimens were molded at 38 °C according to procedures described by Estakhri and Button (1995) using the motorized gyratory soil press. Specimens were cooled to a temperature of 4 °C for a period of 24 hours prior to testing. The data trend indicates an increase in compressive strength with stockpile age. This confirms results presented in Research Study 1377-1F (Estakhri and Button, 1995).

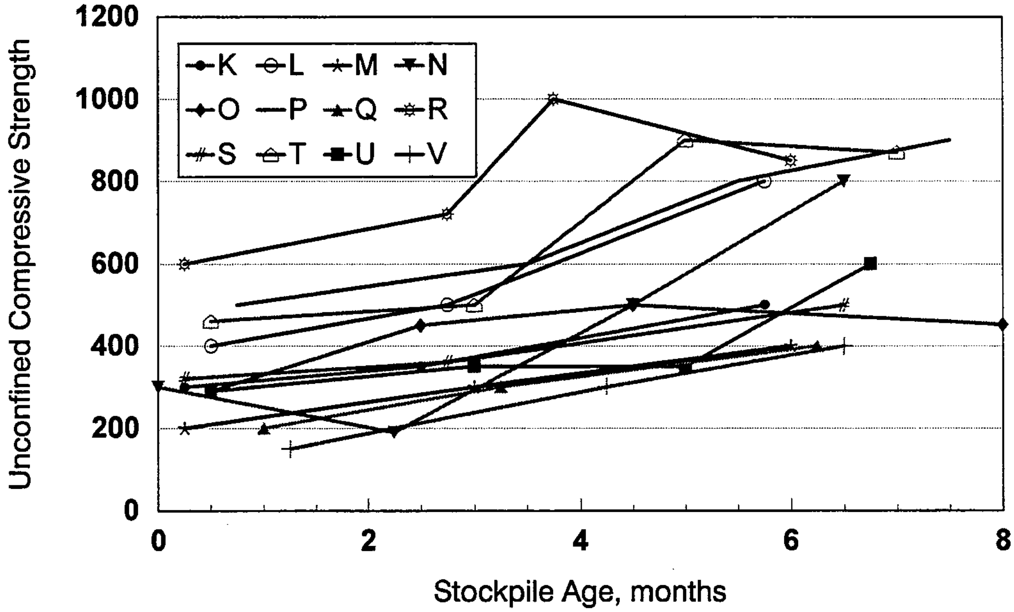

Figure 33. Unconfined Compressive Strength versus Stockpile Age for Field Sampled Mixtures.

6.8 MOISTURE SUSCEPTIBILITY TEST RESULTS

Test Method Tex-530-C, *Effect of Water on Bituminous Paving Mixtures,* evaluated the susceptibility of the mixtures to stripping of the asphalt from the aggregate by water. Samples were tested in two different conditions. The first condition was to test the *new* mixture in its *as received* condition. The second test condition consisted of curing the mix at 88 °C for three hours as described in Tex-530-C. This test was performed to approximate stripping in the stockpile and not necessarily to predict moisture damage.

The test is performed by placing a 200 g sample of mix into boiling water, maintaining the water at medium boil for 10 minutes. Excess asphalt is skimmed from the water surface with a paper towel. Water from the beaker is decanted, and the wet mix is emptied onto a paper towel. The degree of stripping is visually estimated and reported as percent of stripping (after 24 hours of drying).

Test results were compared with field samples taken at six to eight months of stockpile aging, and these results are presented in Table 18. These data indicate that curing of the sample prior to evaluation of its moisture susceptibility approximates field conditions.

Table 18. Laboratory Stripping Test Results Compared to Stockpile-Aged Mixes.

Mixture	Percent Stripped - No Curing	Percent Stripped 3-hr Curing	6-8 Month Field Samples, Percent Stripped (No Boiling Test)
K	20	5	5
L	10	5	0
M	30	10	10
N	50	15	10
O	50	20	30
P	10	10	0
Q	20	10	0
R	20	5	10
S	40	20	20
T	30	10	10
U	10	0	0
V	5	5	0

CHAPTER 7.0 SUMMARY AND CONCLUSIONS

Based on the results presented in Chapters 1 through 6, several conclusions were drawn and are discussed below.

7.1 LITERATURE REVIEW

Most of the available literature on maintenance mixtures is on *pothole* patching materials. The following conclusions were identified from the literature:

- The more expensive, better quality pothole materials last significantly longer than more conventional maintenance mixes. These better quality materials cost as much as four times that of conventional maintenance mixes.
- Since the major cost of pothole repair appears to be labor, equipment, and traffic control, significant savings can be obtained by using more effective materials and methods.
- Several studies indicate that hot-mix makes a better, longer-lasting patch than any other material. New York State found that hot-mix patches last seven to 10 times longer than those made with conventional cold-mix. A cost analysis by the City of Toronto, Ontario, found that conventional cold-mix patching was 70 percent more costly than hot-mix repairs. Agencies who use hot-mix for pothole repair typically have self-contained, mobile units (hot boxes) to keep the mix hot.
- For cold-weather patching, one study recommended heating the stockpile mix.

7.2 DISTRICT SURVEY

At the onset of this study, maintenance engineers in all of the TxDOT districts were contacted to identify their district's experiences and problems with maintenance mixtures. The following conclusions were noted:

- Most of the districts purchase *pothole* materials according to specification CMD 9200.001 and CMD 9200.002. Overall, good performance was reported for this material for cold, wet conditions. These materials are not used for blade-on/level-up repairs, but primarily for potholes.
- Limestone Rock Asphalt (LRA), Item 332, is used by many districts as a blade-on/level-up material, and some districts use this material year-round. Performance is reported as good in most applications.
- Several districts report using hot-mix as a blade-on material in summer months. Performance is noted as more reliable than HMCL (Item 334).
- HMCL (Item 334) is used by many districts as a blade-on/level-up maintenance mix. While many of the districts report good performance of this material, others note that performance is somewhat inconsistent. Some of the problems which were noted include:

- stripping,
- tends to *push* and rut in hot weather, and
- unworkable in winter and too rich in summer;

- Based on results from the district survey, it seems that some of the more inconsistent materials are those where diesel has been added to the binder (sometimes too much diesel is added and material is too soft).
- Maintenance practices are unique to each district and sometimes to each maintenance section within a district. A material which is acceptable and used effectively in one district or section may not be acceptable by another. Some report that HMCL is not useable after being stockpiled through the winter, while others report that it is useable once the weather has warmed up and the workability has returned to the stockpile (beneath the crust which forms on the surface of the stockpile).
- HMCL is generally used as a blade-on/level-up material and not as a pothole repair material (except when necessary). Most districts tend to use this material in the warm months (summer and early fall) prior to the following year's seal coat program (when the repairs will be covered by a seal coat). Most maintenance personnel report that the repair should be in place several months to allow adequate curing prior to sealing with a seal coat.

7.3 EVALUATION OF LABORATORY MIXTURES

Several different HMCL mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregates and three types of binders for a total of six different mixtures. The objectives of this experiment were (1) to evaluate the properties of mixtures designed at different densities and (2) to evaluate the suitability of laboratory tests to differentiate between mixtures with different degrees of workability and cohesion. Based on this laboratory study, the following conclusions were realized:

- A significant amount of time (four or more days) is needed to adequately cure HMCL materials prior to laboratory testing (at 60 °C in a forced-air oven).
- LRA exhibits about five times the weight loss of typical HMCL mixtures.
- There is no significant difference between the rate of weight loss for gravel mixtures versus limestone mixtures, regardless of the binder used.
- Mixtures made with MC-800 seemed to cure faster than the AES-300S or MC-800 with diesel. Some reports from the field indicate that the MC-800 also exhibits poor winter workability.
- Mixtures produced with crushed limestone had a significantly higher Hveem stability than the crushed gravel mixtures. The Hveem stability values were not adversely affected by the lower densities (89 and 92 percent).

- Mixtures produced with crushed limestone also had a significantly higher Marshall stability than the crushed gravel mixtures. Both gravel and limestone mixtures that were made with MC-800 had higher stabilities than those made with the MC-800 with diesel or the AES-300S. This may explain field reports regarding poor winter workability with the MC-800 (stiffer binder).
- For all of the crushed limestone mixtures, there is a definite Marshall stability *peak* at 92 percent density. Stability of the gravel mixtures were relatively unaffected by density.
- Unconfined compressive strength data also showed higher strength for the limestone mixtures. Strength at 92 percent density was greater than the strength at 95 percent density for all of the mixtures.
- The cohesion test is a simple test which adequately measures the cohesiveness of the HMCL materials. This test generally showed that the cohesion decreased as density decreased (and asphalt binder decreased), as would be expected. Mixtures designed at 95 percent density generally had the best cohesion properties (89 to 95 percent retained), while the mixtures designed at 92 percent density saw a loss in cohesion with values ranging from 75 to 88 percent retained. A dramatic loss of cohesion was observed in the mixtures designed at 89 percent density, with values generally ranging from 10 to 39 percent retained.
- No significant trends were observed for any of the mixtures when tested with the SHRP workability test. Values of workability for all of the mixtures were less than one and most of the values were less than 0.5. SHRP criteria states that values under three are acceptable.
- Most of the laboratory data indicate that mixture design density requirements could be lowered to 92 percent (to improve winter workability) without sacrificing mixture properties. In fact, some of the material properties (such as Marshall stability) show improvement at 92 percent density. The primary concern in lowering the density requirement will be the sacrifice in mixture cohesion (mixture might be more prone to raveling); however, the cohesion test did not indicate a problem with these mixes.

7.4 EVALUATION OF FIELD MIXTURES AND LABORATORY TESTS

- Most of the mixtures evaluated in this study exhibited poor winter workability but performed well in service.
- The SHRP Cohesion Test (rolling sieve test) is a very simple test and correlates well with stockpile age. Mixtures exhibited excellent cohesion (70 to 95 percent) initially and dropped to values below 40 percent after six months in the stockpile.
- The SHRP Workability Test is a very simple test procedure developed for high-performance pothole patching materials. Most of the HMCL mixtures evaluated in this study had much lower (better) workability ratings. The data did not indicate a significant correlation between workability rating and stockpile age; however, there was a slight trend of increasing workability rating with stockpile age (as would be expected). The standard criteria for this test states that mixtures with a workability rating below three are acceptable. This criterion should be lowered for TxDOT HMCL mixtures. All of the

HMCL materials tested in this study had workability ratings below two.

- A blade penetrometer test was also used to evaluate mixture workability. This simple test is similar to the SHRP workability test but uses a blade attachment instead of a bullet-shaped attachment. These penetrometer values were considerably higher than those in the SHRP workability test. While the data indicated an increase in workability rating with stockpile age, some of the test values exceeded the capacity of the penetrometer. This test may have some applicability for evaluation of HMCL; however, more field study is needed since this project did not identify acceptable test values.
- Marshall stability tests were performed on all field materials, and the stability values ranged between 800 and 1600 lb. Some of the mixtures showed an increase in stability with age and a slight drop in stability with additional aging.
- Unconfined compression tests were performed on all field materials. These values ranged between 200 and 1000 kPa. The data trend indicated an increase in compressive strength with stockpile age.
- Test Method Tex-530-C, *Effect of Water on Bituminous Paving Mixtures,* was used to evaluate the susceptibility of the mixtures to stripping of the asphalt from the aggregate by water. Samples were tested in both *cured* and *uncured* conditions. These results were compared with field samples taken at six to eight months of stockpile aging. In general, the tests performed on the *cured* mixtures matched the field data better than the *uncured* mixtures.
- Some very simple test procedures (such as SHRP workability and cohesion) were identified in this study which could aid in screening for potential problems with HMCL maintenance mixtures.

Implementation recommendations regarding proposed test procedures, acceptance criteria, and guidelines resulting from this research study are presented in Research Report 1717-S.

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APPENDIX

PennDOT SPECIFICATIONS AND TEST PROCEDURES:

Section 485 Bituminous Stockpile Patching Material from PennDOT Bulletin 27

Specifications for Bituminous Materials from PennDOT Bulletin 25

Specifications and Test Methods for Treated Bituminous Materials from PennDOT Bulletin 25

From PennDOT Bulletin 27

SECTION 485
BITUMINOUS STOCKPILE PATCHING MATERIAL

485.1 DESCRIPTION - The material shall consist of plant mixed stockpile patching bituminous mixture composed of mineral aggregate coated with bituminous material. The material shall be capable of being stocked for at least six months without stripping and shall be workable at all times.

Stocked patching material may be rejected, at any time during the six month period if, in the opinion of the District Materials Engineer, the patching material has stripped (more than 10% uncoated particles) or otherwise become unfit for use.

When the patching material has been delivered directly to a Department stockpile before Department approval, it will be the contractor's responsibility to remove any unacceptable material within two weeks of notification.

Refusal by the contractor to remove unacceptable material from the Department stocking area will be sufficient grounds to suspend the contractor from the Department's bidding list for patching material, until such time as the problem is resolved to the satisfaction of the Department.

This material is intended for patching holes up to 3 inches deep.

485.2 MATERIALS - The material and their use shall meet the applicable requirements of Section 703 and Bulletin 25.

(a) Bituminous Materials. The listed bituminous materials shall be used. For proper mixing, the bituminous materials shall be heated as specified in Section 484.3.

Class of Material	Type of Material
MC-400	Cut-back Petroleum Asphalt
MC-800	Cut-back Petroleum Asphalt
MC-400E	Cut-back Petroleum Asphalt
ME-400	Emulsified Cut-back Asphalt
ME-800	Emulsified Cut-back Asphalt
E-10	Emulsified Asphalt
E-12	Cationic Emulsified Asphalt
RT-4-C	Coal Tar
RT-6-C	Coal Tar

Bituminous Materials MC-400, ME-400 and RT-4-C shall be used between November 1 and March 1. Bituminous Materials MC-800, ME-800 and RT-6-C shall be used between March 1 and October 31. Bituminous Material MC-400E can be used throughout the year.

Bituminous Materials MC-400, MC-800, ME-400 and ME-800 shall be Treated Bituminous Materials meeting the applicable requirements of the supplement attached to Bulletin 25 (Wet Coating Test, Static Immersion Test and Stripping Test) using the job aggregate. Bituminous Materials E-10 and E-12 shall pass the dry and wet stone coating test on the job aggregate.

The contractor shall furnish the sample of the job aggregate each year to the bituminous supplier for the coating and stripping tests specified in Bulletin 25 and obtain a certificate that the bituminous material has been treated to suit the job aggregate. This yearly certificate must be on file and shall be available at the bituminous plant when required by the engineer. A copy shall also be forwarded by the contractor to the District Materials Engineer.

(b) Fine Aggregate. The fine aggregate shall be Type A or B material meeting the quality requirements of Section 703.2.

(c) Coarse Aggregate. The coarse aggregate shall be type A material meeting the quality requirements of Section 703.3.

(d) Composition of Mixtures. The percent of asphalt residue and the percent passing the No. 8 sieve shall be approved by the engineer. The contractor shall furnish the mixed material within the gradation limits (master range) specified in Table A. The percent passing the No. 8 sieve shall not be less than 15 percent in the J.M.F. design.

Acceptance of the mixed material shall be on the averaged test results of a sample of three increments.

To insure uniformity of the mixture the average of the three tests for asphalt residue content shall not exceed ±0.5% and no individual test shall vary more than ±1.0% from the JMF. The average of the three test for percent passing the 200 sieve shall not exceed 2.4% and no individual test shall exceed 3.5%.

TABLE A
Composition of Mixtures
(Total Percent by Weight Passing Square Openings Based on Laboratory Sieve Tests)

Passing Sieve	Percent Passing
3/8"	100
#4	40-100
#8	10-45
#200	0-2

The quantity of bituminous material in the mix shall be such that the minimum requirements on the percent residue specified in Table B are met.

Based on the characteristics of the aggregate and the performance of the mix, the engineer can specify percent asphalt or tar residue higher than the minimum values given in Table B.

The contractor shall furnish the mixed material within the limits specified in Table A and Table B of this section, except, the asphalt residue shall not be deficient by more than 0.5 percent and the No. 8 sieve shall not vary more than ± 5 percent from the JMF values approved by the engineer.

Exceptional cases where the requirements of Table B are difficult to meet, shall be referred to the Chief, Materials and Testing Division, Harrisburg for approval.

TABLE B
Minimum Asphalt or Tar Residue for J.M.F. Design

Aggregate Type	Percent Water Absorption (Coarse Aggregate)	Percent Asphalt or Tar Residue, Min. J.M.F. Design
Stone and Gravel	Less than 1.0	4.5
" "	1.1 to 1.5	5.0
" "	1.6 to 2.0	5.5
" "	2.1 to 2.5	6.0
" "	2.6 to 3.0	6.5
Slag	Less than 4.0	7.0
"	4.1 to 5.0	8.0
"	5.1 to 6.0	9.0
"	6.1 to 7.0	10.0

485.3 CONSTRUCTION REQUIREMENTS

(a) Bituminous Mixing Plant. All plants manufacturing this material shall meet the requirements of Section 401.3.

(b) Preparation of Mixtures. All mineral aggregates and bituminous material shall be proportioned by weight or by volume.

The mixture shall be such that it may be stocked, handled, placed and finished without stripping of the bituminous material from the aggregate. To help prevent stripping, the mixed material shall be stocked no higher than 4 feet for the first 48 hours.

The mineral aggregate shall be clean and surface dry prior to mixing. The temperatures of the bituminous material, aggregate and the resulting mixture shall be maintained as follows:

Type of Bituminous	Temperature Range F		
Material	Aggregate	Bituminous Material	Mixture
MC-400	40-140	150-190	-
MC-800	40-140	165-205	-
MC-400E	40-140	170-205	-
ME-400	40-140	175 max.	-
ME-800	40-140	175 max.	-
E-10 and E-12	Appropriate for specified mix temperature	140-175	190-250
RT-4-C	100-200	130-150	100-190
RT-6-C	100-200	130-175	100-190

When E-10 or E-12 Emulsified Asphalts are used, the temperature requirements on the aggregate and the mixture can be waived by the engineer, if it is demonstrated that the mix can be prepared with unheated aggregate without any coating or stripping problems, during production and stockpiling.

To help prevent drainage of bituminous binder in the stockpile, the mixing temperature shall be held as low as practicable within the ranges specified above.

The following two tests on the mixture, freshly prepared or taken from the stockpile, shall be performed by the contractor in the presence of a Department representative before the samples are sent to the MTD for testing. These results shall be shown on the Form 447 submitted with the mix samples. The mixture shall be rejected if it fails these tests and no samples shall be sent to the MTD.

Water Resistance Test

Place approximately 100 grams of uncured mixture into a clean one quart mason jar. Fill the jar about half full with distilled water and place the lid loosely on top. Place the jar in an oven at 140 ± 5 F for 16 to 18 hours. Remove the jar from oven, tighten lid and shake vigorously for 5 minutes. Decant the water from jar and spread the mixture on an absorbent paper for visual observation of the coating. The aggregate shall be at least 90% coated with a bituminous film.

Workability Test

Approximately five pounds of the mixture shall be cooled to 20 F in the laboratory. After cooling the mixture shall be capable of being broken up readily with a spatula having a blade length of approximately 8 inches. This test shall be performed when the mixture is produced or used between November 1 and March 1. If the mixture is not workable at 20 F, it shall be rejected and proper modification to the composition of the mixture (such as, increase in % bitumen residue or gradation changes) shall be made.

(c) Inspection, Sampling and Approval. Inspection, sampling and approval shall conform to the requirements of Section 483. Failure to comply with these requirements may be cause to suspend plant approval for the production of stockpile patching material.

(d) Delivery of Mixture. When delivered as a hot mixture it shall be hauled to the work site as required in Section 401.3(c) and have satisfactory workability and setting quality at the time of delivery.

485.4 METHOD OF MEASUREMENT - The tonnage will be measured and determined from the actual plant batch reports as recorded by a representative of the Department assigned to the work.

485.5 BASIS OF PAYMENT - The bituminous stockpile patching material will be paid for at the contract unit price per ton, f.o.b. the plant, at the work site or other destination as specified in the proposal.

From PennDOT Bulletin 25

SPECIFICATIONS FOR CUT-BACK ASPHALT
(Medium Curing Type)
MC-400

These specifications cover liquid petroleum products, produced by fluxing an asphalt cement with suitable distillates, to be used for bituminous stockpile patching material.

The material is to be heated, if required, for proper mixing between 150 F and 190 F depending on the viscosity of the material.

The cut-back asphalt shall show no separation or curdling prior to use.

The cut-back asphalt shall conform to the following requirements:

	Minimum	Maximum
Water, percent by weight	-	0.2
Flash point (Tag open cup) degs F	150	-
Viscosity, Kinematic at 140 F, (60C), centistokes	400	800
Distillation:		
Distillate, percentage by volume of total distillate to 680 F (360C)		
0 to 437 F(225C)	-	7
0 to 500 F (260C)	10	45
0 to 600 F (316C)	55	85
Residue from distillation to 680 F (360C), percentage volume by difference	70	-
Tests on residue from distillation:		
Viscosity at 140 F (60 C), 30 cm Hg, poises	300	1200
Ductility at 60 F, (15.5C), 5 cm per min, cm	100	-
Solubility in trichloroethylene, percent by weight	99.0	-

Class MC-400 shall be Treated Bituminous Material meeting requirements of Section 2.0, Appendix to Bulletin 25 attached hereto.

For stockpile mixes these requirements serve as a guide only. When used in stockpile mixes, the job aggregate shall be substituted for the reference aggregate.

NOTE: This material is to be used solely for bituminous stockpile patching material. MC-400 grade shall be used when the patching material is intended to be used between November 1 and March 1.

From PennDOT Bulletin 25

SPECIFICATIONS FOR CUT-BACK ASPHALT
(Medium Curing Type)
AASHTO MC-800

These specifications cover liquid petroleum products, produced by fluxing an asphalt cement with suitable distillates, to be used in bituminous stockpile patching material.

The material is to be heated, when required, for proper mixing between 165 F and 205 F depending on the viscosity of the material.

The cut-back asphalt shall show no separation or curdling prior to use.

The cut-back asphalt shall conform to the following requirements:

	Minimum	Maximum
Water, percent by weight	-	0.2
Flash point (Tag open cup) degs F	150	-
Viscosity, Kinematic at 140 F, (60C), centistokes	800	1200
Distillation:		
Distillate, percentage of volume of total distillate to 680 F (360C)		
0 to 437 F (225C)	-	-
0 to 500 F (260C)	-	35
0 to 600 F (316C)	45	80
Residue from distillation to 680 F (360C), percentage volume by difference	75	-
Tests on residue from distillation		
Viscosity at 140 F (60 C), 30 cm Hg, poises	300	1200
Ductility at 60 F, (15.5C), 5 cm per min, cm	100	-
Solubility in trichloroethylene, percent by weight	99.0	-

Class MC-800 shall be Treated Bituminous Material meeting requirements of Section 2.0, Appendix to Bulletin 25 attached hereto.

For stockpile mixes these requirements serve as a guide only. When used in stockpile mixes, the job aggregates shall be substituted for the reference aggregates.

NOTE: This material is to be used solely for bituminous stockpile patching material. MC-800 grade shall be used when the patching material is intended to be used between March 1 and October 31.

From PennDOT Bulletin 25

SPECIFICATIONS FOR CUT-BACK ASPHALT
(Medium Curing Type)
MC-400 E

These specifications cover liquid petroleum products, produced by fluxing an asphalt cement with suitable distillates, to be used for bituminous premixed stockpile patching mixtures only.

The material is to be heated, if required, for proper mixing between 170 F and 205 F depending on the viscosity of the material.

The cut-back asphalt shall show no separation or curdling prior to use. The cut-back asphalt shall conform to the following requirements:

	Minimum	Maximum
Water, percent by weight	-	0.2
Flash point (Tag open cut) degs F	200	-
*Viscosity, Kinematic at 140 F (60 C) centistokes	400	1500
Distillation:		
Distillate, percentage by volume of total distillate to 680 F (360C)		
0 to 437 F (225 C)	-	0
0 to 500 F (260 C)	-	20
0 to 600 F (316 C)	35	70
Residue from distillation to 680 F (360 C), percentage volume by difference	78	-
Tests on residue from distillation:		
Penetration at 77 F (25 C), 100 g, 5 sec	200	-
Ductility at 39.2 F (4 C), 1 cm/min, cm	150	-
Solubility in trichloroethylene, percent by weight	99.0	

Class MC-400 E shall be Treated Bituminous Material meeting requirements of Section 2.0, Appendix to Bulletin 25 using the job aggregate.

* The kinematic viscosity at 140 F (60 C) of this material shall be based on the intended time period when the patching material will be used and shall be as follows:

Between November 1 and March 1-----400 to 1000 centistokes
Between March 1 and October 31-----1000 to 1500 centistokes

NOTE: This material is to be used solely for bituminous stockpile patching material.

From PennDOT Bulletin 25

SPECIFICATIONS FOR EMULSIFIED CUT-BACK ASPHALT, ME-400

These specifications cover emulsified cut-back asphalt of the medium curing type for use in bituminous stockpile patching.

The material shall be heated, if required, for proper use but not in excess of 175 F.

This material shall be prepared by compounding MC-400 cut-back asphalt with suitable agents and water to produce a water in oil emulsion.

The emulsified cut-back asphalt shall not be miscible with water in any proportions, shall remain homogeneous after 15 hours at zero degress F, and shall meet the following requirements:

	Minimum	Maximum
Viscosity, Kinematic at 140 F (60C)	400	800
Settlement, 7 days, numerical difference between top and bottom residues	-	1
Stripping test, percent retained coating	98	-
Static immersion, percent retained coating	98	-
Distillation, AASHTO T-78 (Modified) See Appendix, Section 6-0		
Asphalt, percent by weight	66	-
Water, percent by weight	3	12
Naphtha, (by difference) percent by weight	14	-
Tests on residue from distillation		
Viscosity at 140 F (60 C), 30 cm Hg, poises	300	1200
Ductility at 60 F, (15.5C), 5 cm per min, cm	100	-
Solubility in trichloroethylene, percent by weight	98	-

See Appendix Sec. 6.0 to Bulletin 25 for testing procedures.

When used in stockpile mixes job aggregates shall be substituted for reference aggregates.

NOTE: This material is to be used solely for bituminous stockpile patching material. ME-400 grade shall be used when the patching material is intended to be used between November 1 and March 1.

4.1.2 Static-Immersion Test - The coated aggregate, as prepared in 4.1.1, shall remain immersed in the beaker of distilled water (70-90 F) for 24 hours. At the end of this period, visually determine the percent of retained coating while the sample remains immersed in water.

4.1.3 Stripping Test - Weigh 200 g of dry reference aggregate in a shallow pan (8-inch x 10-inch x 1-inch) add cut-back asphalt equivalent to 10.0 g of asphaltic residue and thoroughly mix with a stiff spatula until the aggregate is completely coated. Cure the sample in air (70-90 F) for 48 hours. At the end of the curing period, weigh 25 g of the cured mixture in a Florence flask (100 ml) add 75 ml of distilled water (140 F), stopper and place the flask in the rotating flask holder. Fill the rotating machine bath with water (140 F) and insert the rotating flask holder. Rotate the contents at 60 RPM for 15 minutes. Remove the flask, drain the water, transfer the contents into a beaker of distilled water (70-90 F) and immediately determine the percent of retained coating visually.

4.2 Asphalt Cement:

4.2.1 Stripping Test - Weigh 200 g of dry (290-310 F) reference aggregate in a shallow pan and add 10.0 g of asphalt cement (290-310 F). Mix with a stiff spatula until completely coated. Cool and without curing, proceed as in the stripping test for asphalt cut-back.

5.0 EMULSIFIED ASPHALT TESTS

5.1 General Requirements:

5.1.1 The requirements of specifications as noted in Bulletin No. 25 shall be determined in accordance with Methods of Test for Asphalt Emulsions, AASHTO Designation T 59, except the following:

5.2 Residue by Evaporation at 163 C, AASHTO Designation T 59 except that determination of residue shall be the average of three 50 g samples, heated for three hours in a 600 ml metal or glass beaker.

5.3 Stone Coating Test:

When specified Job aggregate shall be used instead of the reference aggregate in the following procedures:

5.3.1 Dry Reference Aggregate: Weigh 465 g of the reference aggregate into a metal kitchen saucepan approximately eight inches in diameter by three inches deep. Add 35 g of the emulsion into the pan and mix vigorously with a spoon for two minutes. Set the mixture aside to cure in the pan for 30 minutes at room temperature. After curing and without remixing, drench the mixture in the pan with cold tap water (two feet below tap) until the overflow water runs clear. Drain off the excess water and place the mixture on absorbent paper for evaluation.

5.3.1.1 Estimate visually the percent of total retained coating.

5.3.2 Wet Reference Aggregate Test: Weigh 465 g of dry reference aggregate into a saucepan, add 10 ml of distilled water and thoroughly mix. Complete test following the same procedure as in dry reference aggregate test.

From PennDOT Bulletin 25

SPECIFICATIONS FOR EMULSIFIED CUT-BACK ASPHALT, ME-800

These specifications cover emulsified cut-back asphalt of the medium curing type for use in bituminous stockpile patching.

The material shall be heated, if required, for proper use but not in excess of 175 F.

This material shall be prepared by compounding MC-800 cut-back asphalt with suitable agents and water to produce a water in oil emulsion.

The emulsified cut-back asphalt shall not be miscible with water in any proportions, shall remain homogeneous after 15 hours at zero degrees F and shall meet the following requirements:

	Minimum	Maximum
Viscosity, Kinematic at 140 F (60C)	800	1200
Settlement, 7 days, numerical difference between top and bottom residues	-	1
Stripping test, percent retained coating	98	-
Static immersion, percent retained coating	98	-
Distillation, AASHTO T-78 (Modified) See Appendix, Section 6.0		
Asphalt, percent by weight	67	-
Water, percent by weight	3	12
Naphtha, (by difference) percent by weight	12	-
Tests on residue from distillation		
Viscosity at 140 F (60 C), 30 cm Hg, poises	300	1200
Ductility at 60 F, (15.5C), 5 cm per min, cm	100	-
Solubility in trichloroethylene, percent by weight	98	-

See Appendix Sec. 6.0, to Bulletin 25 for testing procedures.

When used in stockpile mixes job aggregates shall be substituted for reference aggregates.

NOTE: This material is to be used solely for bituminous stockpile patching material. ME-800 grade shall be used when the patching material is intended to be used between March 1 and October 31.

From PennDOT Bulletin 25

SPECIFICATIONS FOR EMULSIFIED ASPHALT, E-10

These specifications cover emulsified asphalt of the medium setting type for use in hot plant mix stock pile patching material.

This material is to be heated, if required, for proper mixing between 140 F and 175 F.

The emulsified asphalt shall be homogeneous, shall be miscible with water in all proportions and shall show no separation after thorough mixing within 30 days after delivery, provided separation has not been caused by freezing or contamination.

Emulsified asphalts held in storage tanks or drums for periods longer than 30 days shall be inspected visually to determine if separation occurred during storage. If no separation is noted, the emulsified asphalt shall be agitated, sampled and retested to determine its compliance with specification requirements.

The specific gravity of the emulsified asphalt shall be reported for each shipment and shall also meet the following requirements:

	Minimum	Maximum
Viscosity, Saybolt Furol at 122 F, (50C), sec	50	1500
Storage Stability test, 1 day	-	1.0
Stone coating test, proposed aggregate		
Percent retained on dry aggregate	80	-
Percent retained on wet aggregate	60	-
Distillation: ASTM D 244		
Residue, percent by weight	65	-
Oil distillate, percent by volume of total emulsion	2	7
Tests on residue from distillation		
Float test, at 140 F, (60C), sec	1200	-
Solubility in trichloroethylene, percent	96.0	-

All samples shall be shipped and stored in clean air-tight sealed widemouth jars or bottles made of plastic.

See Bulletin 25 appendix, section 5.3 for coating test procedures.

From PennDOT Bulletin 25

SPECIFICATIONS FOR EMULSIFIED ASPHALT E-12

These specifications cover cationic emulsified asphalt of the medium setting type for use in hot plant mix stockpile patching material.

This material is to be heated, if required, for proper mixing between 140 and 175 F.

The emulsified asphalt shall be homogeneous, shall be miscible with water in all proportions and shall show no separation after thorough mixing within 30 days after delivery, provided separation has not been caused by freezing or contamination.

Emulsified asphalts held in storage tanks or drums for periods longer than 30 days shall be inspected visually to determine if separation occurred during storage. If no separation is noted, the emulsified asphalt shall be agitated, sampled and retested to determine its compliance with specification requirements.

The specific gravity of the emulsified asphalt shall be reported for each shipment. The emulsified asphalt shall meet the following requirements:

	Minimum	Maximum
Particle charge	Positive	
Viscosity, Saybolt Furol at 122F (50C), sec	50	1500
Storage Stability test, 1 day	-	1.0
Stone coating test, proposed aggregate		
Percent retained on dry aggregate	80	-
Percent retained on wet aggregate	60	-
Distillation: ASTM D 244		
Residue, percent by weight	62	-
Oil distillate, percent by volume of total emulsion	2	8
Tests on residue from distillation:		
Penetration at 77F (25C), 100 g, 5 sec	200	-
Solubility in trichloroethylene, percent	96.0	-

All samples shall be shipped and stored in clean air-tight sealed widemouth jars or bottles made of plastic.

See Bulletin 25 Appendix, Section 5.3 for coating test procedures.

From PennDOT Bulletin 25

SPECIFICATIONS FOR TREATED BITUMINOUS MATERIALS

REVISED JANUARY, 1986

Bituminous material treated with a prepared additive to meet the requirements hereinafter described shall be classified as treated bituminous material.

1.0 GENERAL REQUIREMENTS

1.1 When required in the contract, all asphaltic material shall be treated bituminous materials.

1.2 A sufficient quantity of an additive, shall be homogeneously incorporated in the bituminous material at the point of manufacture to meet the requirements hereinafter specified.

1.3 The Pennsylvania Department of Transportation reserves the right to sample and test the asphalt cement, naphtha and cut-back prior to and after the addition of the additive.

1.4 The additive shall not be injurious to road equipment and accessories and shall not alter the normal mixing and setting qualities of the bituminous material.

1.5 The additive shall not detrimentally affect the bituminous material which when treated shall conform to the specification requirements of the untreated bituminous material as specified in Bulletin 25.

1.6 The treated bituminous material shall be homogeneous and shall withstand normal storage at manufacturing or maximum application temperatures.

2.0 TEST REQUIREMENTS

The treated bituminous material shall be tested in accordance with the hereinafter prescribed procedures and shall meet the following specified requirements.

Minimum Percent Retained Coating on Unovened and on Ovened Samples

	Asphalt Cut-back	Asphalt Cement
Wet Coating 15 Minutes, 70-90 F	98	—
Static Immersion 24 Hours, 70-90 F	98	—
Stripping @ 140 F	98	98

3.0 PROCEDURE

3.1 Materials:

3.1.1 Aggregate - The gradation of the reference aggregates (Massachusetts Rhyolite) used shall be 100 percent passing the 3/8 inch sieve and retained on the 1/4 inch sieve. The aggregate shall be washed and oven-dried at 200 F. Reference aggregate can be obtained from Rowe Contracting Co., 1500 Salem St., Malden, Mass. 02148 (Phone 617-324-0460).

If specified, the job aggregate shall be used in lieu of the reference aggregate using the above gradation. However, some mixtures might have a finer gradation. In such cases, one of the following gradations (coarser one preferred, if possible) shall be used:

(1) 100% passing 3/8" sieve and retained on #4 sieve.
(2) 100% passing #4 sieve and retained on #8 sieve.

3.1.2 Distilled Water - The pH of the distilled water shall be between 6.0 and 7.0. No electrolyte of any kind shall be used for pH correction.

3.1.3 Bituminous Materials - The treated bituminous materials shall be ovened at the specified temperature for 96 hours prior to testing.

The specified temperature for ovening and mixing each class is as follows:

Class	Temperature degrees F Ovening	Mixing
Asphalt Cut-back	175	See Viscosity Curve
Asphalt Cement	325	290-310

3.2 Ovening:

Weigh 250 g of the treated bituminous material in a tared triple seal pint can, cover and place in a quart can. Cover the quart can and punch a 1/8 inch hole in the lid to serve as a safety vent. Place in an oven maintained at the specified temperature for the particular class of bituminous material being ovened. At the end of the 96-hour period, remove, cool and weigh. Replace any loss of volatile solvent in cut-back.

3.3 Bath Temperatures:

Refer to the viscosity chart and read the temperature at the intersection of the 2500 cSt line and the drawn parallel curve representing the shipment. Use this temperature as the rotating bath temperature in conducting the Wet Coating Test.

Note - The rotating bath equipment can be obtained from Becker Brothers, 1213 W. Princess St., York, Pennsylvania.

4.0 TESTING METHODS

4.1 Cut-back Asphalt:

4.1.1 Wet Coating Test

4.1.1.1 Washed Stone and Rotating Machine - Fill rotating machine bath to approximately half mark with water and bring to the determined temperature Heat aggregate, cut-back asphalt and distilled water to 100 F in a suitable oven. Weigh 50 g of aggregate into a 100 ml extraction (Florence type) Flask and add 1.5 ml of distilled water. Agitate the contents for ten seconds or until the aggregate is wet. Add cut-back asphalt equivalent to 2.5 g of asphaltic residue and place in rotating machine. Maintain the determined temperature of the bath throughout the two minute rotating period. At the end of the rotating period, remove the flask and transfer the contents into a 250 ml beaker containing 100 ml of distilled water (70-90 F). Let stand for 15 minutes and visually determine the percent of retained coating.

The MTD will continue to run the wet coating test using the rotating machine and the reference aggregate (Massachussets Rhyolite) as specified above to insure a certain minimum level of additives. However, when testing the job aggregate for the wet coating test, the producer shall be permitted to use the following test procedures in lieu of the above procedure:

4.1.1.2 Washed Stone and Hand Mixing - Heat the washed job aggregate, cut-back asphalt and distilled water to 100 F in a suitable oven. Weigh 100 g of dry aggregate into a suitable mixing container (such as seamless tin cans, 16 oz. capacity). Add 3 ml of distilled water. Mix thoroughly with a spatula until the aggregate particles are uniformly wetted. Add cut-back asphalt equivalent to 5.0 $\pm$ 0.2 g of asphaltic residue. Mix vigorously with the spatula until all aggregate is coated, but for not more than 5 minutes. Transfer the contents into a 400 ml beaker containing 150 ml of distilled water (70-90 F). Let stand for 15 minutes and visually determine the percent of retained coating.

4.1.1.3 Unwashed Stone and Rotating Machine or Hand Mixing

If the job aggregate is heated in a dryer before pugmill mixing with hot cut-back asphalt to produce stockpile patching mixtures, the rotating machine procedure (Section 4.1.1.1) or the above alternate hand mixing procedure (Section 4.1.1.2) can be modified (if desired) to represent actual field conditions as follows:

(a) Unwashed job aggregate shall be used.

(b) The job aggregate can be heated to a temperature being obtained at the bituminous mix plant but not exceeding 125 F. The distilled water should also be heated to equal the aggregate temperature.

(c) The cut-back asphalt can be heated to a temperature being used at the bituminous mix plant but not exceeding 160 F for MC-250, 175 F for MC-400, and 185 F for MC-800.