PHASE II REPORT

Slurry Seal / Micro-Surface Mix Design Procedure
Contract 65A0151

FOR
CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS)
MATERIALS/INFRASTRUCTURE SECTION

PREPARED BY
FUGRO CONSULTANTS, INC.
8613 CROSS PARK DRIVE
AUSTIN, TEXAS 78754

AND
MACTEC
CONSOLIDATED ENGINEERING LABS
APTECH

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1.0 CHAPTER 1 EXECUTIVE SUMMARY

This report summarizes the work conducted by Fugro Consultants, Inc., Applied Pavement Technologies, MACTEC Engineering and Consultants and CEL laboratories for a study entitled "Slurry Seal/Micro–Surface Mix Design Procedure". This study was initiated in response to a request for proposals (RFP) issued by the California Department of Transportation (Caltrans) in the fall of 2002 to conduct a fourteen state pooled fund study. The objective of the study was to develop a rational mix design method for Slurry Seal and Microsurfacing.

Historically, design procedures for these mixtures have been based on empirical procedures that have little or no relationship to field performance. The current procedures are the result of extensive work done by Mr. Ben Benedict in the 1960's and 1970's with materials readily available to him in Southwestern Ohio and this work resulted in the mix design procedures contained in the International Slurry Surfacing Association (ISSA) Technical Bulletins, Performance Guidelines A-105 and A-143 and ASTM International Practices D-3910 and D-6372.

After proposal review and contractual matters were concluded, a kick-off meeting took place in July of 2003. The project was designed to have three phases: Phase I consisting of a Literature review of current practices worldwide and a survey of industry and agencies using these systems; Phase II consisting of an evaluation of existing and potential new test methods, the development of a rational design procedure, and ruggedness evaluation of any new test methods developed; Phase III was intended to develop guidelines and specifications, a training program, and the construction of pilot projects to validate the recommended design procedures and guidelines.

Phase I of the project was completed in March 2004 and a report was submitted to Caltrans documenting the literature review and survey information along with a work plan for Phase II. Approval to commence work on Phase II was granted in June 2004.

The premise for the Phase II work was to measure mixing, spreading, and curing characteristics for either existing test methods or ones developed during the study. Each of the existing methods used to measure these characteristics were determined to be highly dependent on operator (technician) training and competency. For this reason the team agreed that, where possible, the test methods should be automated to reduce operator bias.

For the Phase II work, the research team selected two commonly used aggregates and two emulsified asphalts as “Standards” upon which to characterize the mixes using the current ISSA design procedures. Using the information from the literature search and industry survey, the project team selected a German automated mixing procedure to replace ISSA TB-113 and the French Wet Track Abrasion test to replace ISSA TB-100. The team developed a prototype schematic for an automated cohesion test and then working with an equipment vendor, Temple Systems Laboratory in Dayton, Ohio, jointly developed a “first article device which was used in the study. The materials used for the current ISSA Procedures were then evaluated using the three automated devices.

Chapters 2 and 3 of this report discuss the proposed Slurry Systems Mix Design Method and the operating characteristics of the three test methods evaluated. It should be noted that several existing ISSA test procedures, TB-109 and TB-113, will continue to be used in the recommended mix design. Ruggedness evaluation for the automated mixing test (AMT) and the cohesion-abrasion test (CAT) are noted in Chapter 5. Chapter 6 contains a “Strawman” specification for slurry surfacing systems. The researchers agreed that the same tests should be conducted on the systems regardless if they were to be subjected to early traffic. The test parameters are modified to accommodate both types of conditions, and as a result the specification is named Slurry Surfacing Systems (SSS or 3S)

The appendices contain the proposed laboratory test methods for the AMT and CAT, results for ruggedness tests on two mixes using the AMT and CAT, and all the laboratory test results completed during the study.

The project was delayed several times during the course of the work because of personnel changes and testing and equipment issues. Fugro requested and was granted a one year no-cost extension to the project which was originally scheduled to end in December 2007. Fugro requested another extension in October 2008, which was denied by the Contracts unit of Caltrans. This cancellation resulted in approximately $75,000 of unspent contract funds and several areas of work not completed.

We were not able to complete the ruggedness testing on three of the five ‘standard’ mixes, the ruggedness testing of the automated cohesion tests (ACT), the proposed test method for the ACT, nor any of the Phase III work including validation of the new test methods and the construction or test sections.

For purposes of those who may wish to complete the study, Appendix F contains the updated work plan for Phase III and the details regarding the construction of pilot projects.

The results of the research conducted in this study indicate that the automated test procedures appear to be less variable than the current test methods and should be further analyzed for acceptance by the industry. In addition, performing the tests under several temperature and humidity conditions better approximates the conditions that will be encountered in the field when constructing these systems. Unfortunately, as noted above we were not able to verify and validate the design procedure in the field. It is highly recommended that field sections be constructed in order to accomplish this validation.

2.0 CHAPTER 2 INTRODUCTION

2.1 BACKGROUND

Slurry seals were developed and used for the first time in Germany in the late 1920's.[1] At that time, the product consisted of a mixture of very fine aggregates, asphalt binder, and water, and was mixed by introducing the components into a tank outfitted with an agitator. It proved to be a novel approach, a new and promising technique for maintaining road surfaces, and marked the beginning of slurry seal development. However, it was not until the 1960's, with the introduction of improved emulsifiers and continuous flow machines, that real interest was shown in the use of slurry seal as a maintenance treatment for a wide variety of applications: from residential driveways to public roads, highways, airport runways, parking lots, and a multitude of other paved surfaces.[2]

Micro-surfacing was pioneered also in Germany in the late 1960's and early 1970's.[1] European scientists were looking for a way to use conventional slurry in thicker applications that could be applied in narrow courses to fill wheel ruts, and not destroy the expensive road striping lines on the autobahns. Micro-surfacing was the result of combining highly selected aggregates and bitumen, and then incorporating special polymers and emulsifiers that allowed the product to remain stable even when applied in multi-stone thicknesses. Micro-surfacing was introduced in the United States in 1980 as a cost-effective way to treat the surface wheel-rutting problem and a variety of other road surface problems.[1]

Despite the widespread use of slurry seals and micro-surfacing in the recent years, current tests and design methods are primarily empirical and are not related to field performance. The current International Slurry Seal Association (ISSA) procedures for Slurry Seal Mix Design A-105 and Micro-surfacing A-143 and the corresponding American Society for Testing and Materials (ASTM) Standards D-3910 and D-6372 have their origin in the 1980's before the widespread use of micro-surfacing and the use of polymer modified emulsions in slurry seals.[3-6]

Recognizing the need for more rational design methods for slurry seal and micro-surfacing, the Federal Highway Administration (FHWA) enlisted the California Department of Transportation (Caltrans) to form a pooled fund study with the overall objective of developing a rational mix design method for slurry seal and microsurfacing. The improved mix design procedures, guidelines, and specifications will address the performance needs of the owners and users, the design and application needs of the suppliers, and improve the reproducibility of the test methods used for the mix designs. While differences exist between slurry seal and micro-surfacing applications (i.e., traffic volume, application thickness, and curing mechanisms), the similarities of the tests currently used indicate that the two systems must be studied together.

The States that contributed to the pooled fund study are: California, Delaware, Georgia, Illinois, Kansas, Maine, Michigan, Minnesota, Missouri, New Hampshire, New York, North Dakota, Texas, and Vermont.

2.2 OBJECTIVES OF THE POOLED FUND STUDY

The overall goal of the pooled fund study is to improve the performance of slurry seal and micro-surfacing systems through the development of a rational mix design procedure, guidelines, and specifications.

Phase I of the project had two major components; the first consisted of a literature review and a survey of industry and agencies using slurry and micro-surfacing systems; the second part of Phase I dealt with the development of a detailed work plan for Phases II and III. The Phase I effort is complete and all findings were summarized in the Phase I Report.

In Phase II, the project team evaluated existing and potential new test methods, proposed a rational mix design procedure, conducted ruggedness tests on recommended equipment and procedures, and prepared the subject report that summarizes all the activities undertaken in Phase II.

In Phase III, the project team will develop guidelines and specifications, a training program, and provide expertise and oversight in the construction of pilot projects intended to validate the recommended design procedures and guidelines.

2.3 PURPOSE OF THE PHASE II REPORT

The purpose of this report is to summarize the findings and recommendations of the Phase II effort. The report provides the following:

1.0 The development of a preliminary mix design procedure.

2.0 The evaluation of new and improved tests for understanding the short term and long term properties of slurry systems.

3.0 Findings from the ruggedness testing program.

4.0 The development and evaluation of field test methods for evaluating the quality of slurry systems.

5.0 Updated plan for Phase III.

2.4 REFERENCES

1. International Slurry Surfacing Association, Web Page: www.slurry.org.
2. Benedict, R.C., New Trends in Slurry Seal Design Methods, Proceedings of the 23rd Annual Convention of the International Slurry Seal Association, Orlando, FL, February 3-7, 1985.
3. ISSA Technical Bulletin A-105 (Revised) February 2010, recommended Performance Guidelines for Emulsified Asphalt Slurry Seal, International Slurry Surfacing Association, Annapolis, MD, Web Page: www.slurry.org.
4. ISSA Technical Bulletin A-143 (Revised) February 2010, Recommended Performance Guidelines for Micro-Surfacing, International Slurry Surfacing Association, Annapolis, MD, Web Page: www.slurry.org.
5. ASTM Designation D-3910, Standard Practice for Design, Testing, and Construction of Slurry Seal, ASTM Book of Standards 1998, American Society for Testing and Materials, West Conshohocken, PA.
6. ASTM Designation D-6372, Standard Practice for Design, Testing, and Construction of Micro-Surfacing, ASTM Book of Standards 1999, American Society for Testing and Materials, West Conshohocken, PA.
7. TTI 1289-1, The Evaluation of Micro-Surfacing Mixture Design Procedures and Effects of Material Variation on the Test Responses, Research Report, Texas Transportation Institute, Texas A&M University, College Station, TX, Revised April 1995.

3.0 CHAPTER 3 DEVELOPMENT OF A RATIONAL MIX DESIGN FOR SLURRY SYSTEMS

3.1 GENERAL

This chapter presents the work plan to develop an improved mix design procedure based on performance and constructability parameters. The framework for the mix design procedure is first presented, followed by a discussion of the proposed tests to be evaluated and discussion of the plan for evaluating the ruggedness of the tests.

Please note that this Chapter does not exactly follow the Phase II outline contained in the original proposal. Upon commencement of the actual work, the project team considered the proposal outline to be in need of modification. As a result of the literature review and the surveys, the project team concurred that it was necessary to cover the essential elements in a logical fashion. For example, the proposal work plan identified a separate item for evaluating constructability parameters. However, instead of treating all matters related to construction in one place, the different aspects of construction are discussed in various sections of the report as they relate to that section.

3.2 TECHNICAL APPROACH

The ultimate purpose of a mix design procedure is to recommend the right “combination” of emulsion, aggregate, water, and additives to produce a mix that will perform under specific short-term and long-term conditions. For example, a different mix design may be needed when a quick set slurry mix is placed under high temperature-low humidity conditions versus a slow setting mix placed in low-temperature high-humidity conditions. Estimated future traffic and environmental conditions should also influence the choice of a certain mix design.

However, rather than specifying the materials to be used and proportions of these in the mix, a mix design procedure specifies laboratory tests for the mix components and for the mix itself. When the results of the laboratory tests meet certain criteria, the mix design is accepted. Therefore, the designer goes through an iterative process, adjusting materials and quantities until the desired mix properties are obtained. The process is schematically illustrated in the flowchart presented in Figure 3.1.

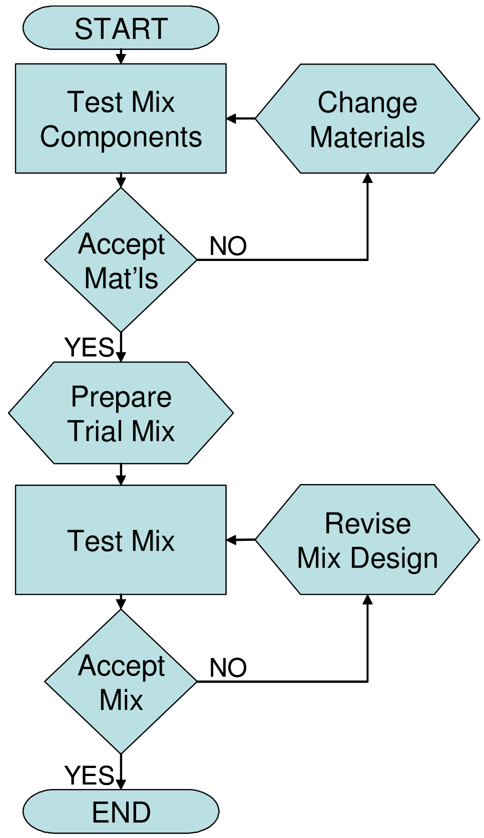


Figure 3.1: Schematic of Typical Mix Design Process

3.3 DESIRABLE FEATURES FOR A NEW MIX DESIGN METHOD

The current ISSA and ASTM procedures for the design of slurry seal and micro surfacing have their origins in the 1980's, before the wide-spread use of micro-surfacing and the use of polymer modified emulsions in slurry seals. As mentioned in the Phase I Report, the current recommended laboratory test methods have, in general, poor repeatability, limited ability to relate to field performance and do not characterize the material over the range of temperature and humidity conditions that may occur in the field. It is well known that humidity and temperature may dramatically influence the short term and long term performance of slurry seal or microsurfacing. Therefore, an effort was made by the research team to improve the current test methods or propose new test methods to address these issues. Ideally, the proposed test methods should be:

- Repeatable
- Relate to field performance

- Cover the range of temperature/humidity conditions that may occur during placement and long term performance in the field

Overall, the following desirable characteristics of the mix should be covered in the mix design:

- Mixable: The emulsified asphalt, aggregate, mineral filler, water, and control additives can be mixed, coated and applied through the machine in a continuous fashion
- Workable: The applied mixture sets to a rain-safe condition quickly without segregation, raveling, displacement, or flushing. In addition, the mix cures within a reasonably defined time period to allow return of traffic
- Performance: The mixture maintains good friction resistance, does not ravel, de-bond, bleed, exhibit moisture damage, or lose cohesiveness over the life of the treatment

Other features taken into account in evaluating new and existing test methods for the proposed mix design included:

- Ease of use
- Cost (as much as possible simple equipment and or adaptations of existing methods)
- Ease of implementation by users

3.4 SLURRY SEAL VERSUS MICROSURFACING

The research team discussed the possibility of having separate mix design procedures for slurry seal and microsurfacing. The differences between slurry seal and microsurfacing can be defined in terms of both chemical and performance characteristics. For the purposes of mix design, however, differences in the chemistry of the system are not relevant. In terms of field performance, the degree to which each system meets the performance requirements for traffic and environment (or fails to meet them) is the main differentiator. In terms of constructability, issues are similar for both slurry and microsurfacing (e.g., mixing, placing, finishing).

The mix design must attempt to quantify performance requirements and allow the selection of slurry or micro-surfacing systems to meet these requirements. This will not only allow for the development of appropriate specifications for a specific application to achieve the desired performance, but also should promote innovation with material suppliers to enhance or extend material performance.

For all the above considerations, the project team decided to use a single mix design procedure for both slurry seal and microsurfacing. Further, the term "slurry surfacing systems" was adopted and will be used to refer to both slurry seal and microsurfacing in the new mix design procedure. The proposed specification was named "S3" from Slurry Surfacing Systems.

3.5 LABORATORY TESTS FOR INDIVIDUAL COMPONENTS

As illustrated in Figure 2.1, in the initial phases of the mix design, the components of the mix are tested individually to ensure that each component has the desired quality and properties. The basic materials making up a slurry system are:

- Aggregate
- Mineral Filler
- Emulsified Asphalt
- Control Additives
- Water

The selection of materials, the first step of the mix design process, is an optimization process. Mixing is a function of the individual material properties and their compatibility with one another. Therefore, the performance characteristics of the mix during and after construction are affected by the individual material properties which are discussed in more detail in the following paragraphs.

3.5.1 Aggregates

The aggregate test methods used for slurry seal and micro-surfacing appear to be functional and were adopted with minimal changes for the new design procedure. Table 3.1 summarizes the requirements of the proposed S3 specification in comparison with the existing ISSA specification guidelines for slurry seal and microsurfacing.

Table 3.1: Comparison of ISSA and S3 Aggregate Requirements

Item	Test/Requirement	Method	ISSA Slurry Seal	ISSA Microsurfacing	S3
Aggregate	Sand Equivalent	T176/D2419	45 minimum	65 minimum	65 min for all traffic applications
	Soundness	T104/C88	15% (Na2SO4) OR 25% (MgSO4) Maximum	15% (Na2SO4) OR 25% (MgSO4) Maximum	20% (MgSO4) Maximum
	Abrasion resistance	T96/C131	35% maximum	30% maximum	30% max for high traffic applications 35% max for low traffic applications
	Percent Crushed	N/A	100%	100%	100%
	Micro-Deval	T327	N/A	N/A	Report
Type I	Percent Passing 3/8 (9.5 mm)	T27/C136 and T11/C117	100	100	100
	Percent Passing #4 (4.75 mm)		70 - 90	70 - 90	70 - 90
	Percent Passing #8 (2.36 mm)		45 - 70	45 - 70	45 - 70
	Percent Passing #16 (1.18 mm)		28 - 50	28 - 50	28 - 50
	Percent Passing #30 (0.600 mm)		19 - 34	19 - 34	19 - 34
	Percent Passing #50 (0.330 mm)		12 - 25	12 - 25	12 - 25
	Percent Passing #100 (0.150 mm)		7 - 18	7 - 18	
	Percent Passing #200 (0.075 mm)		5 - 15	5 - 15	5 - 15
Type II	Percent Passing 3/8 (9.5 mm)	T27/C136 and T11/C117	100	100	100
	Percent Passing #4 (4.75 mm)		90 - 100	90 - 100	94 - 100
	Percent Passing #8 (2.36 mm)		65 - 90	65 - 90	65 - 90
	Percent Passing #16 (1.18 mm)		45 - 70	45 - 70	40 - 70
	Percent Passing #30 (0.600 mm)		30 - 50	30 - 50	25 - 50
	Percent Passing #50 (0.330 mm)		18 - 30	18 - 30	18 - 30
	Percent Passing #100 (0.150 mm)		10 - 21	10 - 21	
	Percent Passing #200 (0.075 mm)		5 - 15	5 - 15	5 - 15
Type III	Percent Passing 3/8 (9.5 mm)	T27/C136 and T11/C117	100	-	100
	Percent Passing #4 (4.75 mm)		100	-	100
	Percent Passing #8 (2.36 mm)		90 - 100	-	90 - 100
	Percent Passing #16 (1.18 mm)		65 - 90	-	65 - 90
	Percent Passing #30 (0.600 mm)		40 - 65	-	40 - 65
	Percent Passing #50 (0.330 mm)		25 - 42	-	25 - 42
	Percent Passing #100 (0.150 mm)		15 - 30	-	
	Percent Passing #200 (0.075 mm)		10 - 20	-	10 - 20

Note: "C" or D references an ASTM International
"CT" References a Caltrans Test Method
"T" References an AASHTO Test Method
For lower traffic applications, the abrasion loss values are less stringent.

Type A, B, and C Slurrys are generally used as follows:

Type I – parking lots, urban streets, and runways

Type II – urban streets and runways

Type III – primary and interstate routes

Type I is the finest gradation and type II is the coarsest.

Type II and III microsurfacings are generally used as follows:

Type II urban streets, runways, scratch and leveling courses

Type III primary and interstate routes, wheel ruts, scratch and leveling courses.

Type II is finer than Type III.

The proposed specification requires a sand equivalent minimum of 65, a maximum of 20% magnesium sulfate soundness and allows for a maximum 30% abrasion loss for higher traffic applications.

The recommended gradations are similar to the ones specified by the ISSA with minor changes to the percent passing the No. 4, 16 and 30 sieves for Type II aggregates. This was done to produce a denser grading and smoother gradation curve. In addition, the requirement for the No. 100 sieve was removed from aggregate Types I, II, and III.

Two other tests were considered for the characterization of the aggregates in the new mix design method: the Methylene Blue test and the Micro-Deval test. Table 3.2 summarizes the existing and proposed tests for the evaluation of aggregates to be used in slurry systems.

Table 3.2: Summary of Laboratory Tests for Aggregates

Test Name	Test Method	Comment
Sieve Analysis	AASHTO T27 ASTM C136 CAL 202	The team considered adding requirements on fines grading less than 0.075 mm and further evaluating the aggregate size proportions.
LA Abrasion	AASHTO T96 ASTM C131 CAL 211	Aggregate hardness quality
Sulfate Soundness	AASHTO T104 ASTM C88 CAL 214	Aggregate freeze-thaw resistance
Sand Equivalent	AASHTO T176 ASTM D2419 CAL 217	Aggregate fine particle quality
Durability	AASHTO T210 ASTM D3744 CAL 229	Hardness quality of aggregates in a wet condition
Methylene-Blue	ISSA TB-145	Indicator of both clay content and reactivity
Micro-Deval	ASTM D6928	Abrasion resistance

The Methylene-Blue value, standardized against the fraction passing the No. 200 sieve, has been shown by some to be a good indicator of aggregate acceptability. The effect of filler types and the percentage addition can be monitored in this way. The evaluation of the Methylene-Blue test was carried out as part of the study. The project team agreed there was enough literature to include it in the laboratory tests and the S3 specification. The limited nature of the aggregates used meant that reactivity was essentially fixed at a range. A further study to correlate this with field performance would be necessary with a much wider range of aggregates.

In addition, a more detailed evaluation for the Micro-Deval test methods for aggregate characterization was carried out. The test is included in the proposed S3 specification as Report Only. This was thought to be useful as wear factors in the aggregate are an important failure mechanism.

3.5.2 Mineral Filler

Mineral Filler Specifications

No changes in the current specifications were considered necessary; the mineral fillers should meet the requirements of AASHTO M-17 (ASTM D-242) for mineral filler and AASHTO M-85 (ASTM C-150) for Portland cement. Any reactivity or performance issues are addressed in other parts of the test regime for the mix itself.

3.5.3 Emulsified Asphalt and Asphalt Residue

In contrast with the ISSA guidelines, the proposed specification requires more elaborate testing requirements for emulsified asphalt and the asphalt residue, as illustrated in Table 3.3.

Table 3.3: Emulsified Asphalt and Asphalt Residue Requirements for S3 Systems

Item	Test/Requirement	Method	ISSA Slurry Seal	ISSA Microsurfacing	S3
Emulsified asphalt	Emulsion type	M208/D2397		CSS-1h, quick traffic, polymer modified	CSS-1h, quick traffic, polymer modified
	Residue after distillation	T59/D244	60% minimum	62% minimum	60% minimum
	Viscosity, Saybolt Furol @ 77 F (25°C)	T59/D244			20 – 100sec
	Storage stability, one day	T59/D245			1% maximum
	Particle charge	T59/D246			Positive
	Sieve test	T59/D247			0.1% maximum
Emulsion residue	Penetration @70°F (25°C)	T49/C2397	40 - 90	40 - 90	55 - 90
	Softening point	T53/D36		135°F (57°C) minimum	135°F (57°C) minimum
	Ductility @70°F (25°C)	T51			27.5 in (700 mm) minimum
	Solubility in trichlorethylene	T44			97.5% minimum

Note: "C" and "D" refer to ASTM International test methods.

“M” Refers to an ASSHTO Standard Method.

“T” Refers to an AASHTO Test Method

The amount of asphalt in the emulsion is obtained by one of the residue recovery tests. The recovery can be done by distillation, evaporation or forced air evaporation. Ideally, a method of residue recovery that does not destroy polymer characteristics is desired.

Table 3.4 summarizes other tests methods that could be used for asphalt residue characterization. However, since it was beyond the scope of this project, it was not possible to evaluate these methods in more detail.

Table 3.4: Potential Laboratory Tests for Asphalt Residue of S3 Systems

Test Name	Test Method	Comment
Penetration	AASHTO T49 ASTM D5	Standard & low temperature parameters; Performed at 59°F (15°C) and 77°F (25°C)
Ring & Ball Softening Point	AASHTO T53 ASTM D36	Index of residue flow
Dynamic Shear Rheometer (DSR)	AASHTO TP5	Stiffness parameters, G* and sin(delta)
Bending Beam Rheometer (BBR)	AASHTO TP1	Low temperature stiffness
Direct Tension Test	AASHTO TP3	Low temperature stiffness
Pressure Aging Vessel	AASHTO PP1	Aging characteristics of binder/residue

Testing of residual binders is limited by the ability to recover materials characteristics of the in-field materials. This is because all the binders in use have polymer modification and the binder morphology is changed by the extraction procedures. This has been an ongoing issue in emulsion specification and is still under study. Base binders used in the emulsion and overall mechanical properties of the microsurfacing mixes should be determined as part of the emulsion selection.

3.5.4 Control Additives

The control additives used in S3 mixes are proprietary systems and the designer can only control the proportion of additive in the mix. No tests or requirements are specified at this time for control additives. This does not preclude the designers from using a range of additives based on an understanding of the chemistry of the system.

3.5.5 Water

The water used in the design and construction of S3 mixes should be potable. No changes from the current specifications are considered necessary.

3.6 LABORATORY TESTS FOR THE SLURRY MIXTURE

Laboratory tests, ideally, relate to known performance criteria. For the design of S3 mixes, the following issues are of special interest:

1. **Will the materials mix?**

   This addresses the issues of constructability, i.e. compatibility, coating, and adhesion:

   Compatibility: The chemical and physical properties of the emulsified asphalt and the aggregate influence the ability of the emulsified asphalt to bond to the aggregate and create a long-lasting slurry system. A test for “compatibility” is described in ISSA TB-115 Determination of Slurry Seal Compatibility.

   Coating and Adhesion: Coating and adhesion can be evaluated using ISSA TB-114: Wet Stripping Test for Cured Slurry Seal Systems.

2. **Will the mixture spread?**

   This covers the issues of rheology, consistency, viscosity, and break of the mixture:

   Consistency: The ability of the mix to maintain consistency; in other words the elements of the mix (emulsified asphalt, aggregate, mineral filler, water, and additives) do not separate but maintain the same proportions throughout the mix. Consistency is measured using ISSA TB-106: Measurement of Slurry Seal Consistency. Consistency is important because the lack of it will cause the mix to segregate during mixing and spreading which will lead to the application of a non-uniform, poor quality material.

   Break: The moment in time when, following mixing, the slurry system transitions from a fluid state to a solid state. After break, the mix can no longer be spread or finished. The time available for mixing and spreading can be measured using ISSA TB-113: Mix Time.

Viscosity: A property of the mix that can be measured while the slurry system is in a liquid state. Viscosity changes with time during mixing and spreading. When viscosity reaches a certain maximum, the mix is too stiff to be workable. The time at which this limit viscosity is reached can be used as an estimate of the available "spreading time" for the slurry system. Mixing is also a function of viscosity and a "mixing time" can be estimated based on the increase in viscosity with time. Note that viscosity can only be measured as long as the mix is still in a fluid state.

3. **Will the mixture set?**

   This addresses the issue of time to cure to achieve a strength that will allow traffic flow without surface damage. **Cohesion** is an indirect measure of the stiffness of the mix. Unlike viscosity however, cohesion can be measured when the mix is in a solid state. Cohesion also changes with time immediately after placement. Measuring this change in cohesion with time allows the designer to estimate the amount of time needed for the mix to cure before allowing traffic loading on the project.

4. **Will the mixture last?**

   The long-term properties of slurry surfacing systems are dependent on their mechanical properties and the ability to maintain these properties over time and under service conditions. In this respect, slurry systems are similar to other thin aggregate/binder mixtures such as thin and ultra-thin hot mix overlays. When the material is placed in thicker layers up to 4 inches (100 mm), permanent deformation performance (rutting) becomes important and should be evaluated in the design process. The main properties of interest for long-term performance include:

   - Abrasion resistance (raveling)
   - Water resistance (stripping)
   - Deformation resistance
   - Crack resistance

3.6.1 Tests for Mixing, Spreading and Setting Properties

Table 3.5 summarizes existing and proposed tests to characterize the slurry surfacing material in the mixing and spreading stages.

Table 3.5: Tests for Mixing, Spreading, and Setting Properties of S3 Systems

Combined Materials/Mix Property	Current/New Methods	Measured Property
Mixing Time	ISSA TB-113	Available fluid mixing time of all components; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
Mix-ability Tests	European Cohesion Test	Initial slope of mixing torque versus time curve; mixability index
Workability Tests	European Cohesion Test New: Torque Viscosity	Slope of mixing torque versus time curve after initial mixing; Relates to construction parameters; Increase flow resistance; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
Consistency	ISSA TB-106	Ability of fluid material to flow properly in an un-augured application box; Consistency of mixture in the spreader box stage; Motorized cohesion test or simple cup flow test; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
Spreadability Test	New: Torque Viscosity	Slope of torque curve vs. time defined as exiting from mixing box (shear modulus)
Curing Time	ISSA TB-139	Identification of curing time for earliest traffic ability; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
	HILT Bend Test French Test	Identify internal cohesion at traffic time; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
	European Cohesion Test	Identify the build up in cohesion over time; Varying temperatures: 50°F (10°C), 77°F (25°C), 122°F (50°C)
Traffic-ability Test	Oven-cured specimens	Relate cure time test by comparison of oven-cured specimens
	New	Compaction test to determine how long it will take for mix to reach final in-place voids
	New	Permeability of specimens for determining compaction ability
Additive Effectiveness	Above test methods	Determining the effects of different additives and varying quantities; Varying temperatures 50°F (10°C), 77°F (25°C), 122°F (50°C)

Of the many tests listed in Table 3.5, the project team saw a great potential in the European Mixing Test. Also, it became apparent that ISSA TB-139 could be automated/computer controlled to minimize operator-induced variability. The two tests are described in more detail in the following paragraphs.

3.6.2 The European Mixing Test

Based on the test evaluation criteria presented in Section 3.2 of the report (Technical Approach), ISSA TB-113 was proposed for use as a basis to determine the mixing time. The test can be used as a very good indicator of compatibility of the mix components as well as to estimate the available mixing time for the slurry system. However, the test is highly variable, largely because:

- stirring (mixing) is carried out by hand and will vary to one operator to another
- the assessment of the viscosity of the mix is also subjective and will be different from one test operator to another

As an alternative, a more rational, automated test procedure was needed. The project team considered the European mixing test, which was later called the Automated Mixing Test or AMT. In this test, the slurry system components are mixed in a cup similar to the one used in TB-113. However, mixing is carried out with an automated motor. The device measures changes in viscosity (torque) with time, during the mixing process, and is shown in Figure 3.2. In Figure 3.3, a schematic of the device and its components are shown.

The test can be used to determine a mixability parameter (cohesion limit where coating occurs to >95 percent) and a workability parameter (a cohesion value where the mix will still flow). These can be defined by observing the consistency and be quantified by the cohesion value and shape of the mixing curve. An example of this curve is provided in Figure 3.4. These parameters could be measured over a range of shear values, temperatures, and other parameters.

The mixing test uses a torque transducer to measure stiffness of a mix and it is similar to TB-106. However, the test method is computerized and standardized and has been under development in Europe for a decade.

Figure 3.2: European Mixing Test

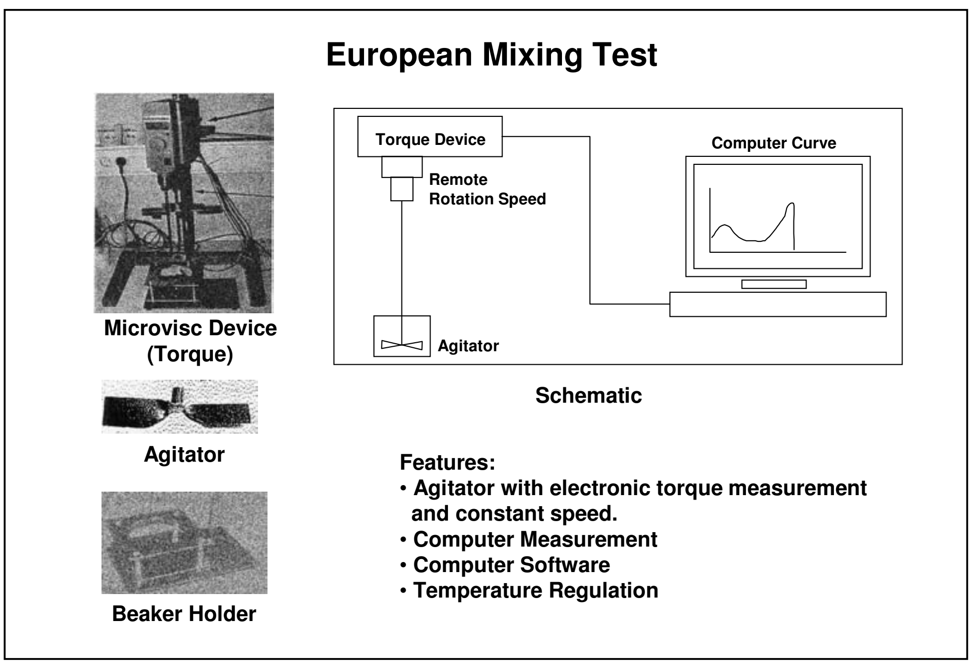


Figure 3.3: European Mixing Test Schematic

The intent of the automated test procedure is to remove operator variability and be easy to run at the same time.

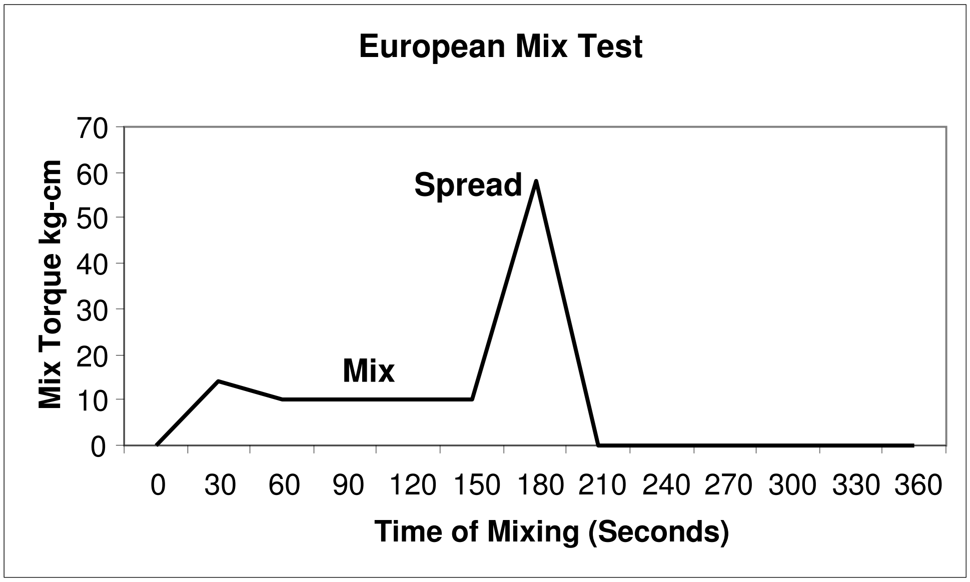


Figure 3.4: European Mixing Test Cohesion Parameters Versus Time

The test data would be evaluated by observing the mix parameters noted above as compared to results from TB-113. In addition, the coating of the aggregate would be evaluated visually as is currently done. This test would determine the preliminary range of mix proportions.

Starting from the European mixing test, the team purchased the equipment and carried out series of tests to optimize the test for use in slurry seal design. The development and evaluation of this test method is discussed in detail in Chapter 4.

3.6.3 The Automated Cohesion Test (ACT)

The next step in the mix design process is to determine the traffic time. This is a constructability parameter, or a measure of the cohesion the mix must reach in order to accept traffic. This level should be the same for any traffic type, but it may require different times at other application conditions (e.g., temperature, time of day, anticipated rainfall).

The cohesion measurement is thus very important to ensure the mix will perform under traffic. This property will be based on TB-139 to determine the mix and set traffic cohesion as well as a 24-hour cohesion. This may be measured under a range of conditions of humidity, temperature, and ambient light to determine the suitability of mixtures for specific application conditions.

Figure 3.5 is a schematic indicating the intended output from the test. The test determines the minimum requirement for cohesion based on TB-139 and acceptable mixtures at standard conditions. It also determines the cohesion requirements at a nominal traffic time of 60 minutes. The 24-hour cohesion can be based on project specific cure conditions. A fully cured value may also be established using oven-cured samples. The test provides three specification points for cohesion: mixing, spreading, and traffic. Figure 3.6 is a schematic drawing of the equipment.

As mentioned earlier in this report, the test method is subject to operator variability. To reduce this unwanted effect, the project team developed an automated cohesion tester. Further details are given in Chapter 4.

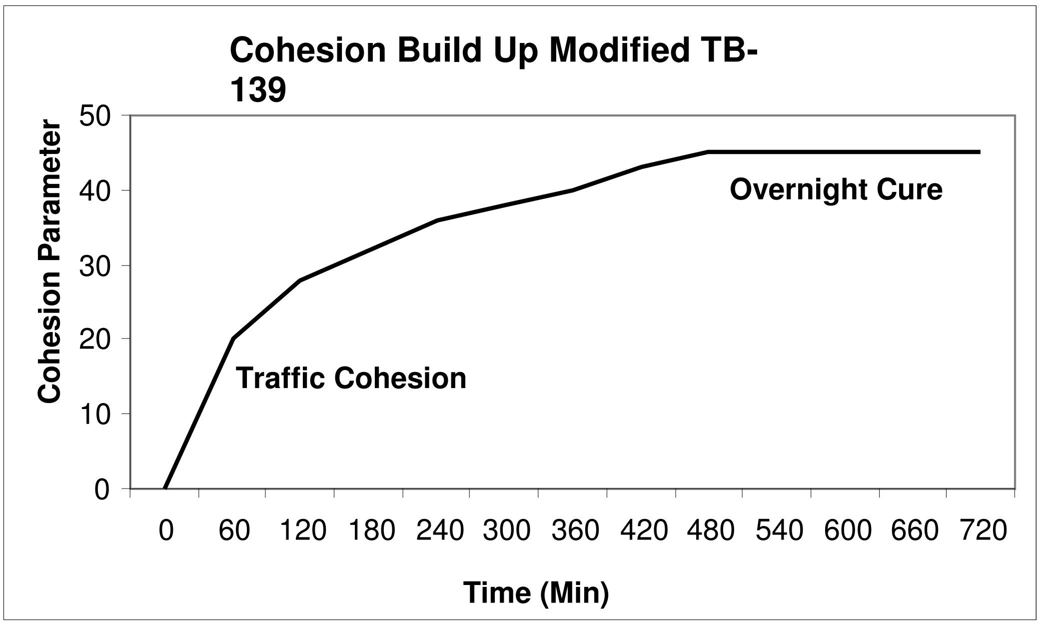


Figure 3.5: Modified TB-139 Cohesion Parameters Versus Time

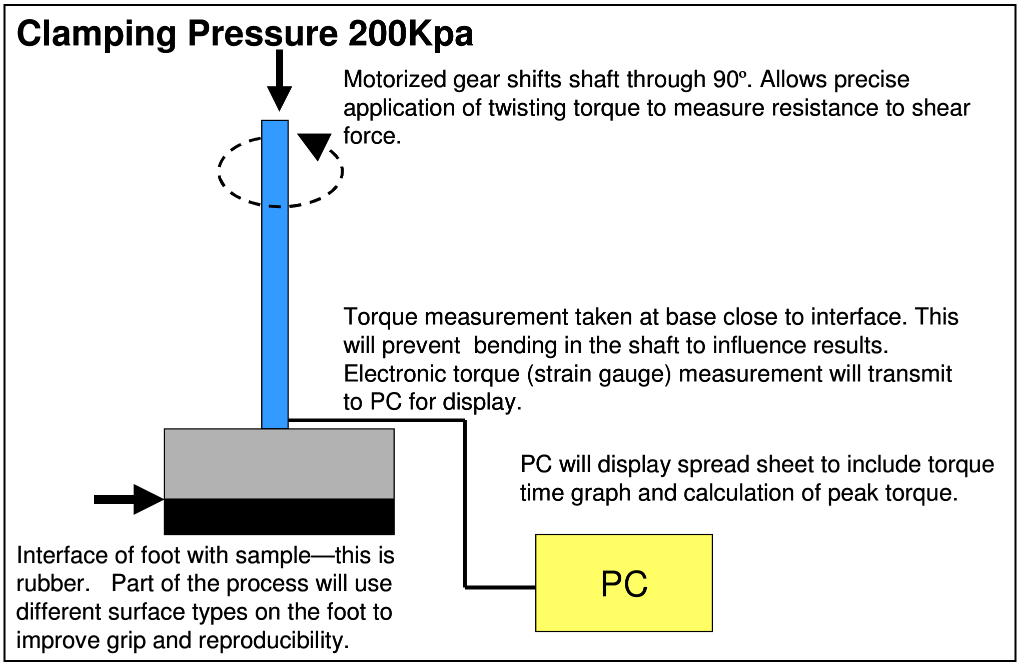


Figure 3.6: Schematic of the Initial Automatic Cohesion Test Method

The Hilt test was also considered for measuring cohesion, but was rejected for the mix design due to reported repeatability issues.

3.6.4 The Cohesion-Abrasion Test (CAT)

Another test that was investigated in more detail by the team is a modified version of the Wet Track Abrasion Test (WTAT), ISSA TB-100. Although not listed in Table 3.5, the modified WTAT can be used on test samples similar to those for the wet cohesion test to evaluate the increase in strength of a slurry system in the period after placement and before opening to traffic. The CAT test is the modification to the WTAT. They are two separate tests and we are recommending the CAT. He named it CAT since it is significantly different from the WTAT.

As shown in Figure 3.7, the modification consists in the use of a set of wheels instead of the standard abrasion head. Abrasion loss and short-term stone retention may be measured in this test. The test may be performed under different cure conditions to determine the effect of early water intrusion due to rain. Development of this test method is described in detail in Chapter 4.

Results from this test can be used to establish a limit for stone retention with respect to cure at time and conditions. Samples should be cured under the following three laboratory conditions:

- Laboratory “standard” conditions 77°F (25°C), 50 percent relative humidity).
- Oven at 140°F (60°C).

- Humidity and temperature bath 50°F (10°C), 90 percent relative humidity; 104°F (40°C), 90 percent relative humidity).

Figure 3.8 shows a simple conditioning system for humidity/night-time curing of samples that has been used in an actual field project. The space at the bottom may contain water with ice for low temperature-high humidity, or hot water for higher humidity. A cooler or heater and a thermostat control the water temperature.

3.6.5 The Loaded Wheel Test (LWT)

The LWT may be used to establish the upper limit of bitumen content by determining the amount of sand adhesion in accordance with TB-109. Determining the upper bitumen limit is important to prevent bleeding of mixes in service and this test should be modified to include different conditions. The test will be used as is, but conditioning of samples will be carried out at 59°F (15°C), 77°F (25°C), and 95°F (35°C) to allow for the effects of high shear or high temperature. Deformation in early life is evaluated using cohesion testing.

Figure 3.7: CAT Test

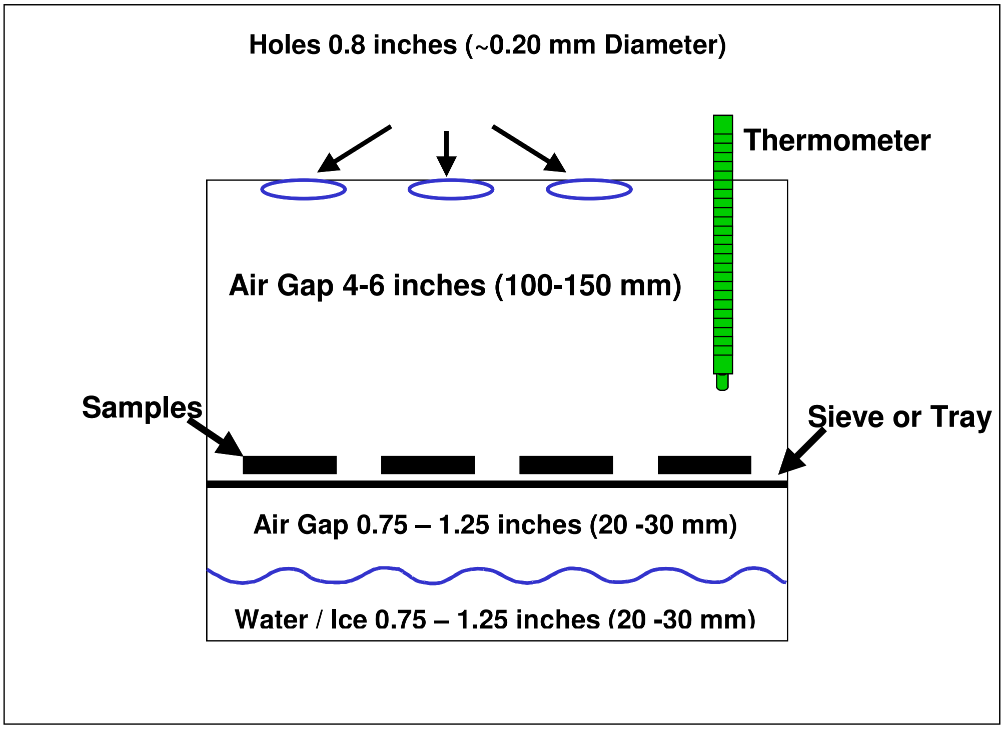


Figure 3.8: Proposed Curing/Conditioning System

3.6.6 Long Term Performance Tests

The long-term properties of S3 mixes are dependent on their mechanical properties and their ability to maintain these properties over time and under service conditions. This makes them no different from any other thin aggregate/binder mixtures such as thin and ultra-thin hot mix overlays. For high traffic or rut filling applications, when the material is placed in thicker layers up to 4 inches (100 mm), performance becomes important and must be evaluated in the design process. Table 3.6 provides a list of candidate tests that were identified in the original proposal.

Table 3.6: Candidate Long Term Performance Tests

Combined Materials	Current/New Methods	Defined Property
Initial Target Residual Asphalt Content		Film thickness determinations based on surface area and sieve analysis
Coatability	ASTM D-244	Coating characteristics
Wet Stripping	ISSA TB-114 ASTM D-3625	Boiling water adhesion
Durability/Aging/Stripping	ISSA TB-114 ASTM D-3625	Testing compacted mix samples after PAV curing; Stripping test by boiling of aged and un-aged specimens
Stripping Resistance	AASHTO T-283	Moisture sensitivity of compacted specimens
Wet Track Abrasion	ISSA TB-100 Modified with French Wheel Method	Minimum asphalt requirements under wet abrasive conditions; One hour soak; Varying soaking conditions of time and temperature
Abrasion Test for cured specimens	ISSA TB-100 Modified with French Wheel Method	Effect of wear on pavement surface over the life. Aging indication on PAV-based or oven-based specimens
Water Sensitivity under wheel load	Modified Hamburg Test	Deformation resistance and water resistance utilizing various testing conditions on the Hamburg test equipment
Water Sensitivity Test	ISSA TB-100	Minimum asphalt requirement under wet abrasion conditions; Six day soak; Varying soaking conditions of time and temperature
Volumetric Criteria	Voids determination before and after compaction New method	Optimize asphalt content based on volumetrics; Determine voids-in-place requirements which would give a mechanical set of properties at allowable residual binder levels
Permeability	NCAT procedure	Determine voids permeability at varying asphalt contents
Excess Asphalt	ISSA TB-109	Maximum asphalt content requirement by measurement of hot sand
Crack Resistance Fatigue Testing	Bruge Bending Test-Modified Reflection Cracking JIG Fatigue Thin Slice	Cracking resistance using fatigue testing or flexural testing
Fuel Resistance	ASTM D	Fuel resistance determinations; Varying residual asphalt contents
Pick up	Modified Hamburg Test	Determining optimum asphalt content which would give acceptable pick up per Hamburg test at varying laboratory environmental conditions
Modulus Loss	Indirect Tensile Test	Modulus test on briquette using an Indirect Tensile test
Lateral Displacement	ISSA TB-147	Measurement of lateral deformation under Loaded Wheel Tester
Deformation Resistance	ISSA TB-147 Hamburg/Creep/Modulus	Deformation of multi-layered system

The main properties of interest for long-term performance include:

- Abrasion resistance (raveling)
- Water resistance (stripping)
- Deformation resistance (rutting)

The test methods that are recommended for inclusion in this study are included in Table 3.7. The project team considers that the criteria in Section 3.3 is met by these tests. A summary of the long term performance tests are as follows:

- Abrasion: CAT. This test may be conducted on fully (oven cured) samples under water and with various conditioning methods including soaking at different temperatures and times, and different curing cycles.
- Water Resistance: The CAT will be carried out for extended times on fully cured samples under elevated temperature under water. This will be expressed as a ratio of 1-hour soak to 6-day soak and a limit set for acceptable mixes of retained abrasion resistance.
- Deformation Resistance: The existing TB-109, Loaded Wheel Test, will be used to evaluate deformation characteristics.

Table 3.7: Long Term Performance Tests included in S3 Specifications

Long Term Performance Tests	Test Method	Defined Property
Abrasion Resistance	CAT	Raveling
Water Resistance	CAT	Resistance to moisture damage
Permanent Deformation	ISSA TB-109	Deformation characteristics

3.6.7 The Asphalt Pavement Analyzer Test (APA)

Due to budget limitations, the APA test was not evaluated in this study. However, the team recommends that future research be conducted regarding the use of the APA as an alternative to the Loaded Wheel Tests (LWT) to evaluate the permanent deformation properties of slurry systems used for rut-filling applications.

3.7 PROPOSED S3 SLURRY SYSTEMS MIX DESIGN METHOD

The proposed mix design procedure is shown in Figure 3.9. The design procedure addresses the shortcomings of the existing procedures by examining mix properties that relate to field performance issues. The steps in the proposed mix design procedure are described below.

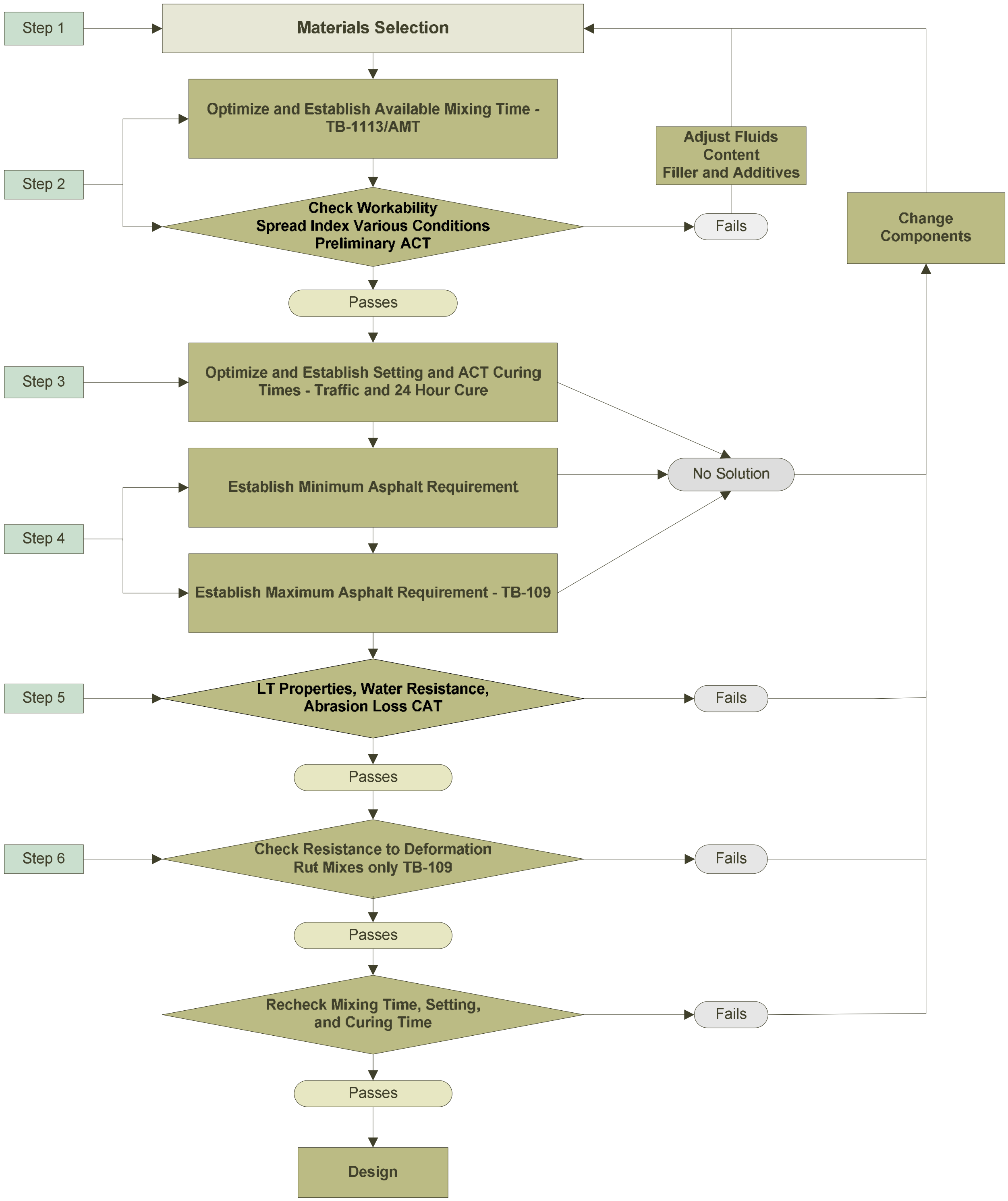


Figure 3.9: Proposed S3 Mix Design Procedure

3.7.1 Step 1: Materials Selection

To begin the mix design, the current ISSA recommendations will be used. Step 1 is subdivided into the following steps, in the order given:

- Selection of aggregate: The first step is to choose the aggregate grading based on the existing ISSA specifications. In addition, the selected aggregate must meet the minimum requirements for mechanical and chemical properties in the specifications prepared as a result of this study.
- Selection of the emulsion and binder: This will be largely a matter of the climatic conditions where it will be applied, and available supply. These parameters are included in the project's specifications.
- Selection of a locally available potable water source.
- Selection of a mineral filler, Portland cement, or hydrated lime, which meets the specification requirements.
- Selection of a liquid retardant such as Aluminum Sulfate when necessary.
- Include a set control additive at the addition rate recommended by the emulsion supplier if necessary.

3.7.2 Step 2: Create a Mix Matrix and Determine Mix Constructability

After the materials have been selected, it will be necessary to determine the proportions of aggregate, water, emulsion, and additives to create a mix matrix. This step will involve the use of the AMT test to determine the mix and spread indices. With the results of the AMT, the conditions at which the materials can be mixed safely and placed in a timely fashion can be determined. These tests will be performed at standard laboratory conditions and repeated for selected mixes for a range of anticipated application conditions.

This process should be repeated with different filler types (if necessary) to optimize the mixture for constructability and performance criteria. This will lead to a recommended filler type and additives levels to be used.

3.7.3 Step 3: Allowable Field Adjustment

This step consists of taking the acceptable mixes and conducting cohesion testing using the ACT. The cohesion test is performed at 60 minutes and after 24-hours of cure. This testing would be repeated for specified application conditions of the project. If the results do not meet the standards, then the mixes and materials would be modified as required. In all cases, it is important to ensure that the mix time and spreadability are acceptable. Spreadability is a measure of the ability of the mix to be placed and finished on the pavement surface.

After the proportions have been selected, the ACT test should be performed and repeated for anticipated curing conditions to evaluate the short-term abrasion properties.

The mix proportions can then be modified if necessary and a check performed to confirm that the cohesion at 60 minutes provides an acceptable traffic time and the cohesion at the 24-hour cure period is also acceptable.

The results of step 3 are used to establish a target optimum for the next step in the design, and to evaluate the short-term abrasion properties of the selected mix.

3.7.4 Step 4: Determine the Optimum Binder Content

This involves preparing selected samples for the specific application conditions and varying the emulsion content ±2% from the target optimum. The additive and filler proportions will remain as determined from the targets developed in step 3.

Under this step the WTAT will be performed at 1-hour and 6-day soak periods followed by tests using the LWT to determine the excess asphalt at the temperature that corresponds to the proposed traffic conditions, i.e., heavy at 95°F (35°C), moderate at 77°F (25°C), and low at 59°F (15°C).

The recommended optimum binder content will be selected by evaluating the abrasion loss in the WTAT test and the binder content versus sand adhesion from the Loaded Wheel Tester (LWT).

NOTE: The specification minimums established by this study will be used for abrasion loss and the maximum for sand pick up from the LWT.

3.7.5 Step 5: Evaluate the Cohesion Properties at Various Curing Conditions

The selected curing conditions should be representative of the project's estimated humidity and temperature conditions at the time of construction. CAT test is then performed at 30 minutes, 1 hour, and 3 hours.

3.7.6 Step 6: Evaluate the Long Term Properties of the Mixture

This step consists of evaluating the following:

- Abrasion: Using the CAT
- Water Resistance: Using the CAT
- Deformation (rut-filling mixes only): TB-109

Finally, any necessary adjustments and recheck of the mixing indices (spreadability, traffic, and 24 hour cohesion) will be made.

After selecting the best mix from the short-term test methods noted above, the mix will be tested for the following long-term performance properties:

- Abrasion resistance
- Water resistance
- Deformation

3.7.6.1 Abrasion Resistance

This property will be measured using the CAT test using fully cured specimens, soaked for 6 days, under project specific environmental conditions.

3.7.6.2 Water Resistance

The CAT abrasion test will be run on the final mix design after being soaked for 6 days at a temperature of 77℉ (25℃) and comparing the loss to that of a 1-hour soak and express this as a ratio. This information will be compared to the results of an existing mixture in order to determine the appropriate specification limits. The test will then be checked with a mix of known standard properties using other materials with which the team and advisory group have experience.

3.7.6.3 Deformation

This property will be measured using TB-109 “Excess Asphalt by LWT Sand Adhesion”.

4.0 CHAPTER 4 LABORATORY EVALUATION OF PROPOSED TEST METHODS

4.1 EXPERIMENTAL MATRIX

Two aggregates and two asphalt emulsions were initially used in the laboratory test program. Four slurry systems (mixes) were created using all possible combinations of aggregate and emulsion:

Aggregates:

A1 George Reed, Inc. Table Mountain, Sonora, CA (ISSA Type III)

A2 Lopke Gravel Products, Lounsberry Pit, Nichols, NY Products (ISSA Type III)

Emulsions:

E1 Sem Materials (Koch), Tulsa, OK, Ralumac

E2 VSS Emultech, Polymer Modified LMCQS-1h, W. Sacramento, CA

A third aggregate and emulsion were acquired during the third quarter of 2006. The aggregate (A3) is a Sandstone from Delta Materials in Marble Falls, TX, and the emulsion is from Ergon Asphalt and Emulsions, Inc., (E3) from their Waco, TX, plant. The aggregate and emulsion were used to design the “unknown” mix, denoted M5:

Aggregate:

A3 Delta Materials, Marble Falls, TX

Emulsion:

E3 Ergon Asphalt & Materials, Waco, TX

The experimental mixes and combinations are noted in Table 4.1.

Table 4.1: Experimental Matrix

System	Aggregate + Emulsion Combination
M1	A1+E1
M2	A1+E2
M3	A2+E1
M4	A2+E2
M5	A3+E3

4.2 LABORATORY TEST METHODS DEVELOPMENT

4.2.1 Development of the Automated Mixing Test (AMT)

In the development and verification of the AMT, the decision was made to begin with the existing trial mix procedure included in ISSA TB-113. This would provide the basis for comparing the results of an accepted and widely used procedure to the new process. In addition to TB-113, a consistency description is included in the new test method.

Mixing Test (TB-113)

The mixing test, TB-113, was run on the five systems noted above and a matrix of aggregate and emulsion proportions were determined based on past experience with these mix types.

Results for the mixes M1 through M5 using the current TB-113 procedure with the inclusion of the consistency description are contained in the following tables. Additional data for these mixes is contained in Appendix E.

Table 4.2.1: TB-113 Results for Mix M1 (A1+E1)

Formulation	Parts by dry weight of aggregate, g					Mix time, sec	Blot Test, 30 sec	Coating Visual/boiling	Consistency Description
	agg, g	cement	water	additive*	emulsion				
1	100	1.0	9.0	0.50	13.0	>120	CW	100/98	St
2	100	1.0	8.0	0.50	14.0	>120	CW	100/98	LV
3	100	1.0	8.0	0.50	15.0	>120	CW	100/98	S
4	100	1.5	8.0	0.50	14.0	>120	CW	100/98	LV
5	100	1.5	8.0	0.50	14.0	>120	CW	100/98	MV
6	100	1.0	8.0	0.50	14.0	>120	CW	100/98	MV
7	100	1.0	8.0	0.50	13.0	>120	CW	100/98	LV
8	100	1.0	8.0	0.25	14.0	>120	CW	100/98	LV
9	100	1.5	8.0	0.25	14.0	>180	CW	100/98	LV

* 5% emulsifier solution

Consistency	Blot Test
S = Soupy (Brown free liquid, segregating sample)	A = Aggregate and clear water
LV = Low Viscosity (Non segregating easy to mix)	BT= Brown transfer
MV = Moderate Viscosity (Non segregating, moderate resistance to mix)	CW= clear water
St = Stiff (Hard to mix but workable)	
B = Broken (Lumps, non consistent)	

Based on the data contained in Table 4.2.1, the mixture components selected for the AMT for Mix M1 are as follows:

- 100 grams of Aggregate

- 1 gram of cement
- 8 grams of water (Based on the weight of dry aggregate)
- 14 grams of emulsion
- 0.5 grams of additive

The resulting mix had the following characteristics:

- Mix displays a narrow range of consistencies
- At lower mix viscosities, the consistency is soupy with a tendency for the aggregate to segregate and the emulsion to darken in color
- Proceeded to clear water very quickly

In addition to the “base mixture” noted above for M1, components were varied to produce additional mixtures with the following consistencies for further testing:

- Soupy
- Low Viscosity
- Medium Viscosity
- Stiff

The purpose of testing different consistencies is simply to select the best target mixture for further evaluation.

Table 4.2.2: TB-113 Results for Mix M2 (A1+E2)

Formulation	Parts by dry weight of aggregate, g					Mix time, sec	Blot Test, 30 sec	Coating Visual/boiling	Consistency Description
	agg, g	cement	water	additive*	emulsion				
1	100	0.0	8.0	0.00	11.0	>180	BT	100/95	foam ,LV
2	100	1.0	8.0	0.00	12.0	>180	CW	100/98	MV
3	100	1.5	8.0	0.00	12.0	>180	CW	100/98	MV
4	100	1.5	8.0	0.25	12.0	>180	CW	100/98	MV
5	100	1.5	8.0	0.25	13.0	>180	CW	100/98	MV
6	100	1.5	8.0	0.25	14.0	>180	CW	100/98	MV
7	100	1.5	8.0	0.50	12.0	>180	CW	100/98	MV
8	100	1.5	8.0	0.50	13.0	>180	CW	100/98	MV
9	100	1.5	8.0	0.50	14.0	>180	CW	100/98	MV
10	100	2.0	9.0	0.00	14.0	>180	CW	100/98	MV
11	100	2.0	8.0	0.50	14.0	>180	CW	100/98	MV
12	100	2.0	9.0	0.50	15.0	>180	CW	100/98	LV

* 5% emulsifier solution

Consistency	Blot Test
S = Soupy (Brown free liquid, segregating sample)	A = Aggregate and clear water
LV = Low Viscosity (Non segregating easy to mix)	BT= Brown transfer
MV = Moderate Viscosity (Non segregating, moderate resistance to mix)	CW= clear water
St = Stiff (Hard to mix but workable)	
B = Broken (Lumps, non consistent)	

Based on the data contained in Table 4.2.2, the mixture components selected for the AMT for Mix M2 were as follows:

- 100 grams of aggregate
- 1.5 grams of cement
- 8 grams of water (Based on the weight of dry aggregate)
- 13 grams of emulsion
- 0.25 grams of additive

The resulting mix had the following characteristics:

- Very stable and displayed a wide range of compositions
- Very quick set
- Proceeded to clear water and exhibited cohesive form

In addition to the “base mixture” noted above for M2, components were varied to produce mixtures with the following consistencies for further testing:

- Soupy

- Low Viscosity
- Medium Viscosity
- Stiff

Table 4.2.3: TB-113 Results for Mix M3 (A2+E1)

Formulation	Parts by dry weight of aggregate, g					Mix time, sec	Blot Test, 30 sec	Coating Visual/boiling	Consistency Description
	agg, g	cement	water	additive*	emulsion				
1	100.0	1.0	9.0	0.50	13.0	60	-	-	B
2	100.0	1.0	9.0	0.25	12.0	90	-	-	B
3	100.0	1.0	10.0	0.25	13.0	120	-	-	B
4	100.0	1.0	10.0	0.25	14.0	>120	A	90/85	LV
5	100.0	1.0	10.0	0.50	16.0	>120	A	90/85	MV
6	100.0	1.0	9.0	0.50	14.0	>120	-	90/85	St
7	100.0	1.0	9.0	0.50	14.0	100	-	95/85	B

* 5% emulsifier solution

Consistency	Blot Test
S = Soupy (Brown free liquid, segregating sample)	A = Aggregate and clear water
LV = Low Viscosity (Non segregating easy to mix)	BT= Brown transfer
MV = Moderate Viscosity (Non segregating, moderate resistance to mix)	CW= clear water
St = Stiff (Hard to mix but workable)	
B = Broken (Lumps, non consistent)	

Based on the data contained in Table 4.2.3, the mixture components selected for the AMT for Mix M3 are as follows:

- 100 grams of aggregate
- 1 gram of cement
- 10 grams of Water (Based on the weight of dry aggregate)
- 16 grams of emulsion
- 0.5 grams of additive

The resulting mix had the following characteristics:

- Mix displays a narrow range of consistencies
- At higher viscosities, the mix is moderate to stiff with a tendency for the mix to have a slower break reaction
- Proceeded to aggregate and clear water for blot evaluations

In addition to the “base mixture” noted above for M3, components were varied to produce mixtures with the following consistencies for further testing:

- Soupy
- Low Viscosity
- Medium Viscosity
- Stiff

Table 4.2.4: TB-113 Results for Mix M4 (A2+E2)

Formulation	Parts by dry weight of aggregate, g					Mix time, sec	Blot Test, 30 sec	Coating Visual/boiling	Consistency Description
	agg, g	cement	water	additive*	emulsion				
1	100	0.0	8.0	0.00	10.5	10	-	-	B
2	100	1.0	8.0	0.25	12.0	70	-	-	B
3	100	1.0	9.0	0.25	13.0	>180	A	98/95	S
4	100	1.0	9.0	0.25	14.0	>180	A	98/95	S
5	100	1.0	9.0	0.50	16.0	>180	CW	95/85	MV
6	100	1.5	9.0	0.50	14.0	100	-	-	B
7	100	1.0	10.0	0.50	14.0	>180	CW	95/85	S
8	100	0.5	10.0	0.50	15.0	>180	CW	95/85	MV
9	100	0.5	12.0	0.50	15.0	>180	CW	85/75	LV
10	100	0.5	15.0	0.75	15.0	>180	CW	75/70	S

* Aluminum Sulfate

Consistency	Blot Test
S = Soupy (Brown free liquid, segregating sample)	A = Aggregate and clear water
LV = Low Viscosity (Non segregating easy to mix)	BT= Brown transfer
MV = Moderate Viscosity (Non segregating, moderate resistance to mix)	CW= clear water
St = Stiff (Hard to mix but workable)	
B = Broken (Lumps, non consistent)	

Based on the data contained in Table 4.2.4, the mixture components selected for the AMT for Mix M4 are as follows:

- 100 grams of aggregate
- 1 gram of cement
- 9 grams of Water (Based on the weight of dry aggregate)
- 16 grams of emulsion
- 0.5 grams of additive

The resulting mix had the following characteristics:

- Very stable and displayed a wide range of compositions.
- Very quick set.

- Proceeded to clear water and exhibited cohesive form.
- With this emulsion, A2 was not easy to mix and showed poor coating and poor rheology, it also indicated some potential for moisture damage.

In addition to the "base mixture" noted above for M4, components were varied to produce mixtures with the following consistencies for further testing:

- Soupy
- Low Viscosity
- Medium Viscosity
- Stiff

Table 4.2.5: TB-113 Results for Mix M5 (A3+E3)

Formulation	Parts by dry weight of aggregate, g					Mix time, sec	Blot Test, 30 sec	Coating Visual/boiling	Consistency Description
	agg, g	cement	water	additive*	emulsion				
1	100	0.0	10.0	0.0	14.0	>120	A	100	LV
2	100	0.0	10.0	0.0	12.0	>120	A	100	LV-MV
3	100	0.0	10.0	0.0	10.0	>120	CW	100	MV
4	100	0.0	8.0	0.0	10.0	>120	CW	100/100	MV
5	100	0.5	10.0	0.0	14.0	>120	A	100	LV-MV
6	100	0.5	10.0	0.0	12.0	>120	CW	100	MV
7	100	0.5	8.0	0.0	10.0	>120	CW	100/100	MV-St

* Aluminum Sulfate

Consistency	Blot Test
S = Soupy (Brown free liquid, segregating sample)	A = Aggregate and clear water
LV = Low Viscosity (Non segregating easy to mix)	BT= Brown transfer
MV = Moderate Viscosity (Non segregating, moderate resistance to mix)	CW= clear water
St = Stiff (Hard to mix but workable)	
B = Broken (Lumps, non consistent)	

Based on the data contained in Table 4.2.5, the mixture components selected for the AMT for the Mix M5 are as follows:

- 100 grams of aggregate
- 0.5 gram of cement
- 10 grams of Water (Based on the weight of dry aggregate)
- 12 grams of emulsion
- 0 grams of additive

The resulting mix had the following characteristics:

- Very stable and displayed a wide range of compositions
- Proceeded to clear water and exhibited a very cohesive form

Automated Mixing Test (AMT)

As described in Chapter 3, the automated mixing test is used to measure the increase in viscosity with time, by means of a computer-controlled stirrer. From the observed time-viscosity plot, two values of interest are identified: the mix and spreadability indices. The measured mixing times from TB-113 were used as the first cut for initial mixing. Mixing to coating is the mix index and the spreadability is the time for stiffening just prior to setting (see Figure 3.4).

The cohesion values that are reported are the mix and spread indices. Mix components, using different levels of additives and fillers to establish a range of values for control purposes, were evaluated.

This test was repeated for four levels of environmental conditions:

- High temperature 95°F (35°C) low humidity (<50 percent)
- High temperature 95°F (35°C) high humidity (90 percent)
- Low temperature 50°F (10°C) low humidity (<50 percent)
- Low temperature 50°F (10°C), high humidity (90 percent)

The specification values may be adjusted and the mixes repeated with both TB-113 and the proposed AMT.

The acceptance criteria will be based on mixes with which the project team has experience and has identified for both TB-113 and the AMT. The test will then be checked with a mix of known performance histories using other materials with which the team and advisory group have significant experience.

The AMT setup considered the following variables:

- Stirrer type
- Mixing container type and size
- Procedure for combination of components

- Stirrer speed
- Mix consistency and type

Initial analysis was based on the observation of mixing of the material compared to observations in TB-113 such as, problems with aggregate particles catching in the gap between the bowl and the stirrer, consistency of the mixture and the produced trace. In other words, how the mixtures behaved in the AMT compared to known behavior from the TB-113.

During the beginning phases of the evaluation of the AMT, it was important that the proper configurations of the stirring apparatus (blade and shaft) be determined since several are available. The following types were evaluated:

Stirrer type:

The following stirrers were tested in combination with bowl size and type.

- **Small Anchor** 1.8 inches, (45 mm) diameter
  - Vendor-IKA Works, Wilmington, NC
  - Catalog/Code Number-R1330 #2022300

- **Large Anchor** 3.5 inches, (90 mm) diameter)
  - Vendor-Velp Scientifica
  - Catalog/Code Number-A00001311

These stirrers are noted in Figure 4.1.

Figure 4.1: Large and Small Anchor Stirrers

Features: Produces a tangential flow with high shearing at the outer parts. The produced flow limits the deposition of solids on the sides of vessel.

Uses: Homogenization at low to medium speed of high solids in liquids of mean to high viscosity.

- **Standard Propeller**
  - Vendor - Velp Scientifica
  - Catalog/Code Number-A00001307

This stirrer is noted in Figure 4.2.

Features: Standard stirring shaft produces an axial flow in the vessel from bottom to top with local shearing.

Uses: Stirring at medium to high speed of high solids, flocculation, mixing of thickening agents, sludges, etc.

Figure 4.2: Standard Propeller Stirrer

- **Paddle Stirrer**
  - Vendor - Velp Scientifica.
  - Catalog/Code Number-A00001308

This stirrer is noted in Figure 4.3.

Features: Produces a tangential flow with a limited turbulence and a gentle mixing.

Uses: Stirring at low to medium speed when a good heat exchange among the mixed products is required.

Figure 4.3: Standard Paddle Stirrer

- **Turbine**
  - Vendor - Velp Scientifica.
  - Catalog/Code Number-A00001309

This stirrer is noted in Figure 4.4.

Features: Produces a radial flow with a movement of products from top and from bottom with a strong turbulence and shearing.

Uses: Use at medium to high speed for dissolving products or breaking particles.

Figure 4.4: Standard Turbine Stirrer

Mixing Containers type and size:

a. Beakers

- 1 Liter Glass with flat base
- 1 Liter Plastic with concave base

b. Stainless Steel Bowls

- 7.9 inches, (200 mm) diameter by 6.9 inches, (17.50 mm) high Large stainless steel Hobart Bowl from N50 mixer
- 2.75 inches, (70 mm) diameter by 3.9 inches, (100 mm) high Large stainless steel with round bottom
- 1.5 Quarts SS Bowl, #1044 supplied by Norpro, Everett, WA
- 2.75 inches (70 mm) tall with a 1.96 inches, (50 mm) radius and round bottom Small stainless steel Bowl, # 99637 supplied by Vollrath.

These bowls are noted in Figure 4.5.

Figure 4.5: Stainless Steel Bowls

Other

Other containers were evaluated including pitcher type and flat- bottomed pans. These quickly were abandoned, as they were not acceptable because their particular shape did not allow the material to achieve a homogeneous state while mixing. It was noted that containers with semi-rounded bottom edges allowed the material to "fold" better.

Procedure for Combination of Components:

The components were combined in various ways in an attempt to obtain an optimum system. The methodology in the AMT is to determine the amount of each of component materials using TB-113, placing them in the mixing bowl, and using the AMT to pre-blend them.

Stirrer Speed:

Stirrer speeds were varied to create mixing that did not seclude material on the sides of the bowl. TB-113 consistency criteria were used to make this determination.

A series of speeds were varied to arrive at the most effective to combine the ingredients without "splashing" them out of the bowls. The speeds were 50, 60, 200, 500, and 1000 revolutions per minute (rpm). The mixing speed recommended for the proposed test method was 50 rpm.

Mix Consistency and Type:

Mixes that were classified as Moderate Viscosity (MV), Stiff (St), and Low Viscosity (LV) were tested to evaluate mixing torque and combinations of consistencies to ascertain if the mixing torque range could be used as a rheological classification. The results indicated clearly that the mixing torque was dependant on the rate of cohesion build up and presumably the reaction rate between the aggregate and the emulsion type. That is, microsurfacing systems and slurry quick set systems could be differentiated by mixing torque and its change with time.

AMT Results

A) Preliminary Container/Stirrer/Speed Combination:

A single mix, mix M2, was selected to determine the best container/stirrer combination as it was determined to be the most stable mix from TB-113. In addition, M2 exhibited good consistency (MV) and an acceptable mixing time between 3 to 5 minutes. The stirrer type was matched with the container size to provide some separation between the sides of the stirrer and the walls of the container. The purpose of this was to accommodate the largest stone in the mix. This was checked and assessed by observing the mix and its consistency. The mix speed was varied and the mix characteristics were noted. The selection of the container, stirrer, and speed was based on the results that are contained in Table 4.3. The proposed AMT configuration is shown in Figure 4.6. The results showed that the best combination for the AMT setup is as follows:

- Small stainless steel bowl
- Standard propeller stirrer

- 50 rpm mixing speed

This configuration generated a mix that was complete with little to no hang up material on the sides of the cup rated as "Good Mixing" (GM). An even mixing trace for the configuration is shown in Figure 4.7. The sudden spikes in the graph are due to aggregate caught in the gap between the bowl and the stirrer. The torque is noted on the vertical axis and time in the horizontal axis. In this case, an increase in torque from 8kg-cm to 10kg-cm was observed.

Figure 4.6: AMT Configuration of Standard Propeller and Small Stainless Steel Bowl.

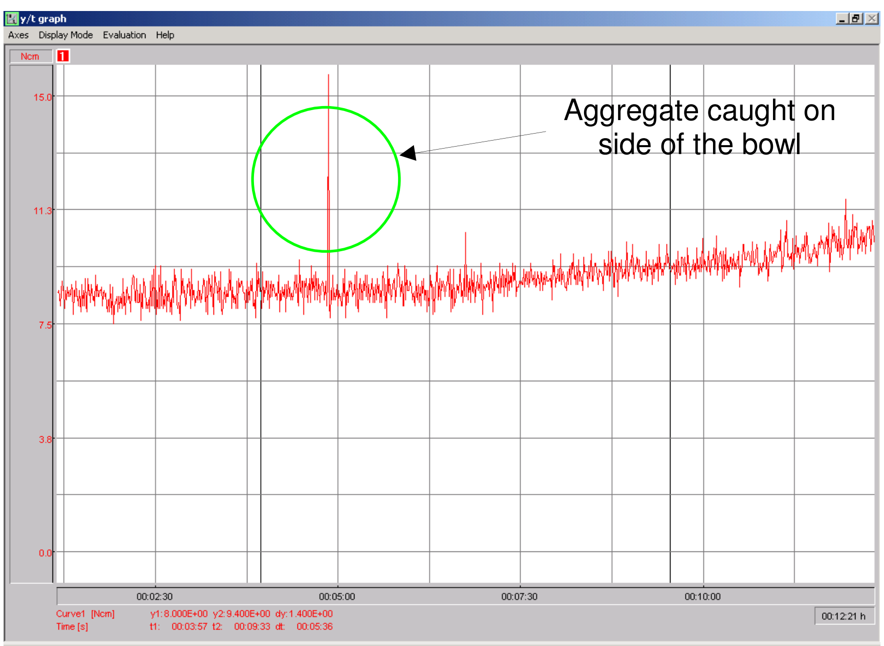


Figure 4.7: Screen Shot of AMT Using Small Stainless Steel Bowl and Standard Propeller Configuration at 50 rpm for M2

Table 4.3: Combinations of Stirrers and Containers for mix M2

Stirrer	Cup Type	Speed rpm	Mixing Result
Small Anchor	400ml Beaker Glass	50	Poor Mixing (PM)
Small Anchor	400ml Beaker Glass	60	Poor Mixing (PM)
Small Anchor	400ml Beaker Glass	200	Poor Mixing (PM)
Small Anchor	400ml Beaker Glass	500	Broken
Small Anchor	400ml Beaker Glass	1000	Broken
Large Anchor	1 L Glass	50	Adequate Mixing (AM)
Large Anchor	1 L Glass	60	Adequate Mixing (AM)
Large Anchor	1 L Glass	200	Adequate Mixing (AM)
Large Anchor	1 L Glass	500	Broken
Large Anchor	1 L Glass	1000	Broken
Large Anchor	1 L Plastic	50	Poor Mixing (PM)
Large Anchor	1 L Plastic	60	Poor Mixing (PM)
Large Anchor	1 L Plastic	200	Poor Mixing (PM)
Large Anchor	1 L Plastic	500	Broken
Large Anchor	1 L Plastic	1000	Broken
Large Anchor	Hobart Bowl	50	Poor Mixing (PM)
Large Anchor	Hobart Bowl	60	Poor Mixing (PM)
Large Anchor	Hobart Bowl	200	Poor Mixing (PM)
Large Anchor	Hobart Bowl	500	Adequate Mixing (AM)
Large Anchor	Hobart Bowl	1000	Broken
Large Anchor	Large SS Bowl	50	Good Mixing (GM)
Large Anchor	Large SS Bowl	60	Good Mixing (GM)
Large Anchor	Large SS Bowl	200	Adequate Mixing (AM)
Large Anchor	Large SS Bowl	500	Adequate Mixing (AM)
Large Anchor	Large SS Bowl	1000	Adequate Mixing (AM)
Large Anchor	Other	50	Poor Mixing (PM)
Large Anchor	Other	60	Poor Mixing (PM)
Large Anchor	Other	200	Poor Mixing (PM)
Large Anchor	Other	500	Broken
Large Anchor	Other	1000	Broken
Standard Propeller	Small SS Bowl	50	Good Mixing (GM)
Standard Propeller	Small SS Bowl	60	Good Mixing (GM)
Standard Propeller	Small SS Bowl	200	Good Mixing (GM)
Standard Propeller	Small SS Bowl	500	Broken
Standard Propeller	Small SS Bowl	1000	Broken
Paddle	Large SS Bowl	50	Poor Mixing (PM)
Paddle	Large SS Bowl	60	Poor Mixing (PM)
Paddle	Large SS Bowl	200	Poor Mixing (PM)PM
Paddle	Large SS Bowl	500	Broken
Paddle	Large SS Bowl	1000	Broken
Turbine	Small SS Bowl	50	Poor Mixing (PM)
Turbine	Small SS Bowl	60	Poor Mixing (PM)
Turbine	Small SS Bowl	200	Poor Mixing (PM)
Turbine	Small SS Bowl	500	Broken
Turbine	Small SS Bowl	1000	Broken
Large Anchor	Other	50	Poor Mixing (PM)
Large Anchor	Other	60	Poor Mixing (PM)
Large Anchor	Other	200	Poor Mixing (PM)
Large Anchor	Other	500	Broken
Large Anchor	Other	1000	Broken

The shape of the traces for different configurations of mix container and stirrer did vary. In addition, for some configurations, differences in torque were observed. Some configurations produced poor mixing and hang up on the sides of the mixing containers. As a result, the mix tends to break and the mixer had less material to turn. The endpoint of the mixing was characterized by a decrease in torque (torque fall off) due to the mixer effectively turning in the liquid left after the mixture broke. These tests were rejected and classified as poor mixing. The best results were obtained with the combination of the small stainless steel bowl and the standard propeller. Part of this testing was repeated with mix M4 and the results were consistent with the previous findings and are noted in Table 4.4. An interesting observation was that the mixes that contained the emulsion E2, continued to mix in excess of 10 minutes but broke as soon as the mixer was turned off. This is a phenomenon often observed in the field and is a function of the film formation process created by aggregate/emulsifier interaction. The mechanical action appears to prevent coalescence by disrupting film formation; when the mixer was turned off, coalescence proceeded swiftly, and the cohesion increased as a result. In CQS type systems, the films form during agitation and cohesion build up is more gradual. As this is a function of interaction of two materials it depends on both. As it is a function of reactivity, it is also dependent on the conditions of temperature and as water will interfere with coalescence and film formation, it is dependant on humidity and total water content.

The two configurations that produced best mixing results were: the standard propeller with the small stainless steel bowl, and the large anchor stirrer with the large stainless steel bowl.

Table 4.4: Mix M4 Stirrers and Mixing Containers Combinations and Results

Stirrer	Cup Type	Speed rpm	Mixing Result
Large Anchor	Large SS Bowl	50	Adequate Mixing (AM)
Large Anchor	Large SS Bowl	60	Adequate Mixing (AM)
Standard Propeller	Small SS Bowl	50	Good Mixing (GM)
Standard Propeller	Small SS Bowl	60	Good Mixing (GM)

The characteristic mixing trace of the large stainless steel bowl and large anchor configuration is shown in Figure 4.8. This trace indicates that the system did not mix well, and as the material broke, the segregation was of liquid to the center of the bowl. This trace was not indicative of mix M4 actual behavior.

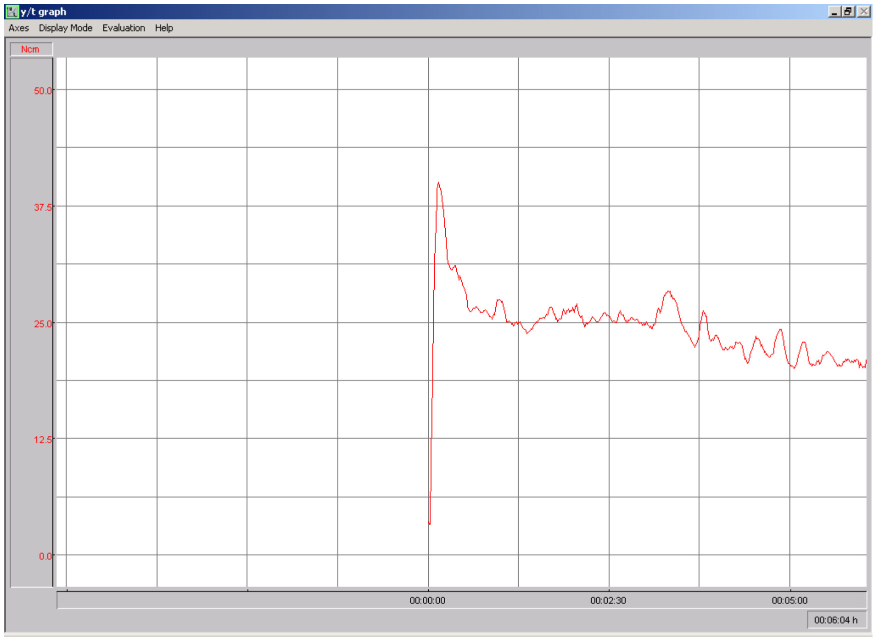


Figure 4.8: Mix M4 with Large Anchor Stirrer and Large Stainless Steel Bowl

For the standard propeller and small stainless steel bowl configuration, and using a stirrer speed of 50 rpm, the mixing was improved. A close-up of the standard propeller and small stainless steel bowl is shown in Figure 4.9. A homogeneous state was achieved for the mix. An increase in torque with time was also the result of the configuration and is shown in Figure 4.10.

Figure 4.9: AMT Standard Propeller and Small Stainless Steel Bowl Close Up

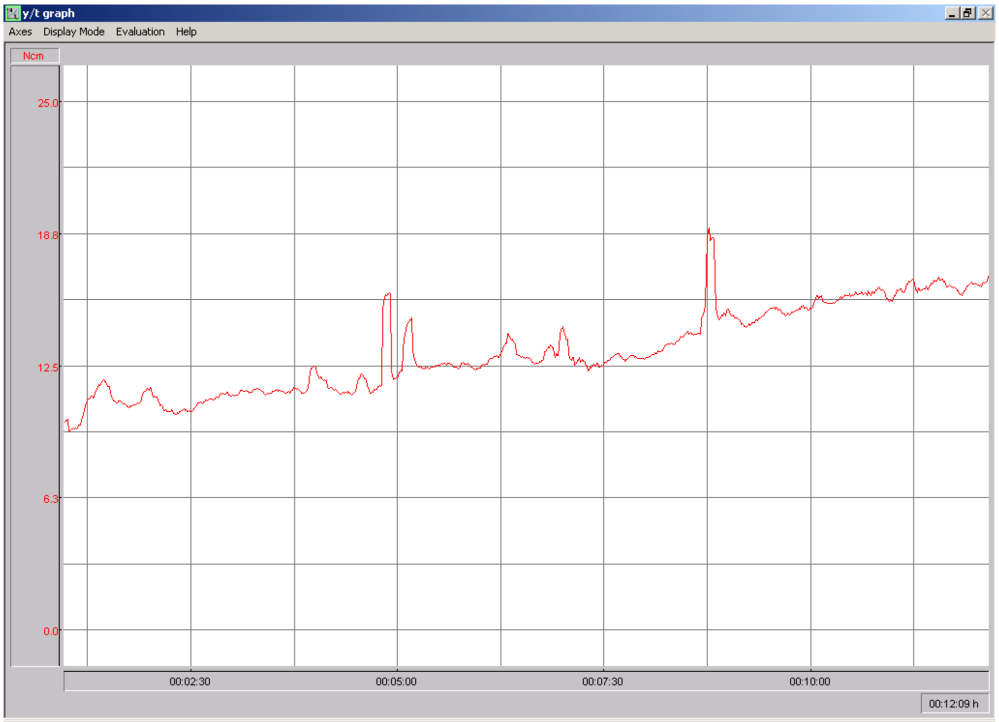


Figure 4.10: Mix M4 Trace with Standard Propeller and Small Stainless Steel Bowl at 50 rpm

B) Effect of Mixing Procedure:

The first mixing procedure attempted was combining the dry aggregate, cement, additives, and water in the mixing bowl. The emulsion was added last. At this point, the AMT was started. This procedure caused a significant increase in "noise" in the AMT traces and almost no increase in torque. This noise was a result of the materials initial resistance to mix. The trace for this mixing procedure is shown in Figure 4.11.

The second mixing procedure consisted in "pre-mixing" the ingredients in the bowl; emulsion last. The results indicated less initial mixing resistance and an increase in torque with time. Figure 4.12 shows the trace of the pre-mixed materials. Based on these observations, the mixing procedure steps were determined.

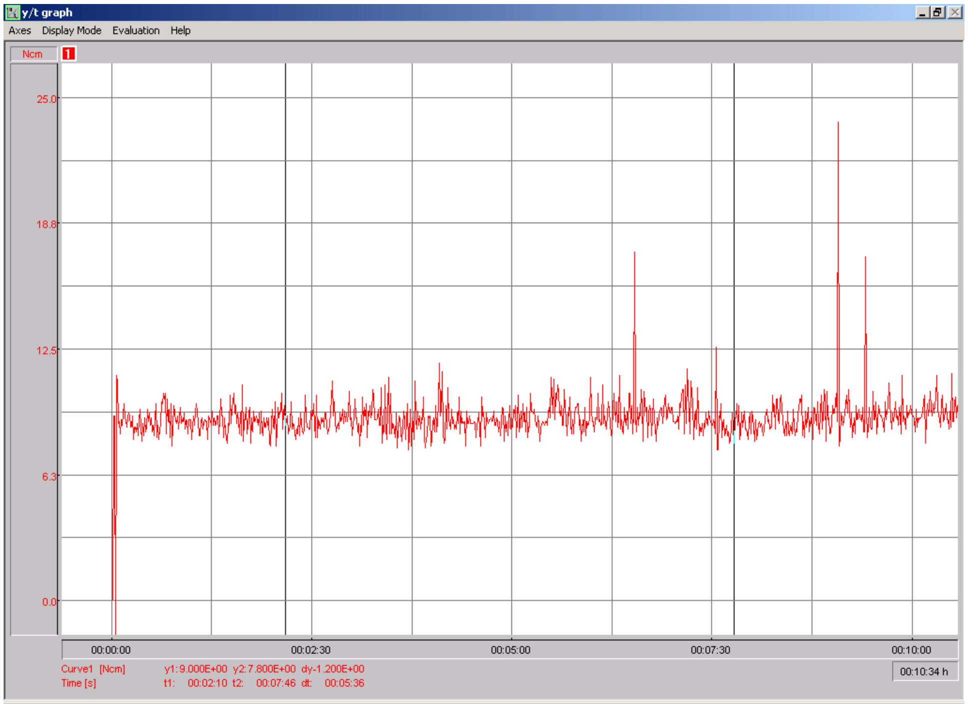


Figure 4.11: AMT All Ingredients Combined in the Mixing Bowl

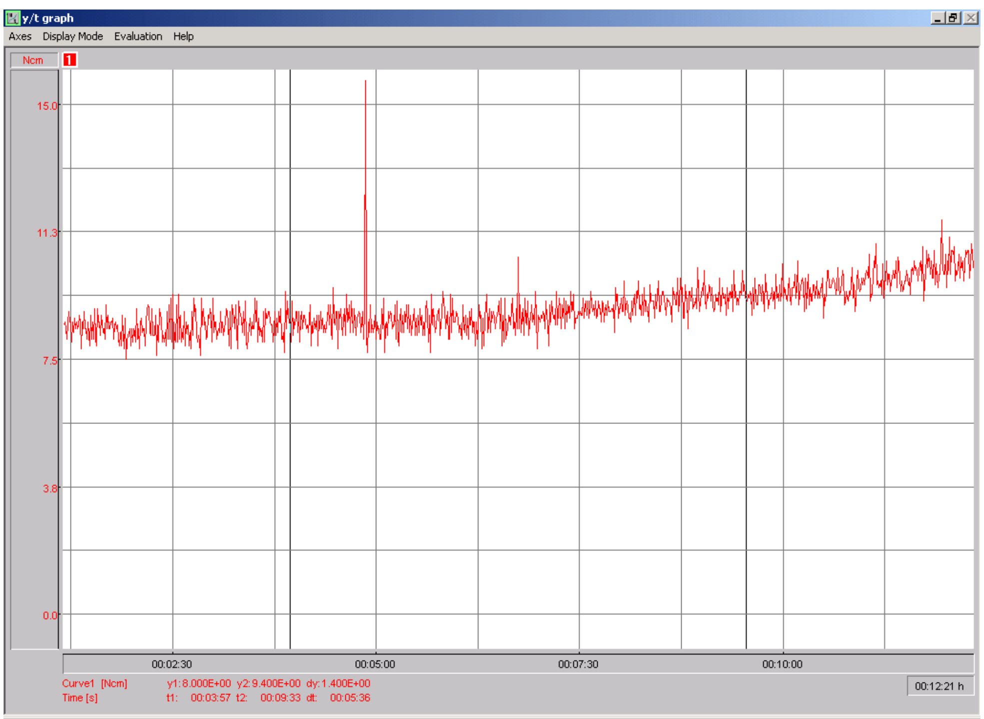


Figure 4.12: AMT Pre-Mixed Ingredients in the Mixing Bowl

The recommended mixing procedure for the AMT is the following:

1. Choose mix components from existing information or TB-113 and determine the percentage of each component based on the weight of dry aggregate.
2. Weigh 300g of dry aggregate into the small stainless steel bowl.
3. Add cement or other dry additive and mix thoroughly.
4. Add water and mix thoroughly.
5. Add liquid additive and mix thoroughly.
6. Add emulsion and mix quickly for 5 to10 seconds.
7. Immediately after mixing the emulsion, place the bowl in the AMT machine, clamp, and lower stirrer to within 0.40 - 0.78 inches (1-2 mm) from the bottom of the bowl and assure that the stirrer is centered.
8. Turn on AMT unit and mix 5 seconds.
9. Set test speed to 50 rpm.
10. Measure trace for 10 minutes.
11. Record steady state torque as the <u>Mix Index</u>, record time where steady increase of torque begins as the <u>Mix Time</u>.
12. Record time where torque reaches (12 N-cm) as the <u>Spread Time</u>.
13. Record time when mix is broken by observation.

C) Effect of System Type:

To evaluate the effectiveness of the recommended AMT procedure, systems with E1 and E2 emulsion were measured. Systems with three different consistencies, Soupy (S) or Low Viscosity (LV), Stiff (St), and Moderate Viscosity (MV) were evaluated and observations noted.

Mix M4 was chosen as the system with Soupy consistency. In Figure 4.13, the mixing Torque was observed to be (6 to 7 N-cm). It was also noted that the mix M4 did not break until after the AMT was stopped.

For the stiff system, Mix M1, the mixing torque was recorded to be (9 to10 N-cm) and the mix time about 3.5 minutes. At this point in time, the torque was noticeably beginning to increase. The trace is shown in Figure 4.14.

For the system M2 previously identified as a good mixing system, with Moderate (MV) consistency, the mixing torque was (8 to 9 N-cm). The mix time was close to 7 minutes. However, mix M2 never reached the maximum spread torque of (12 N-cm) before 14 minutes. The system stiffened only after mixing ceased. The trace of mix M2 is shown in Figure 4.15.

Table 4.5 shows the summary of the ranges in torque for the three different systems with Soupy, Stiff, and Moderate consistencies.

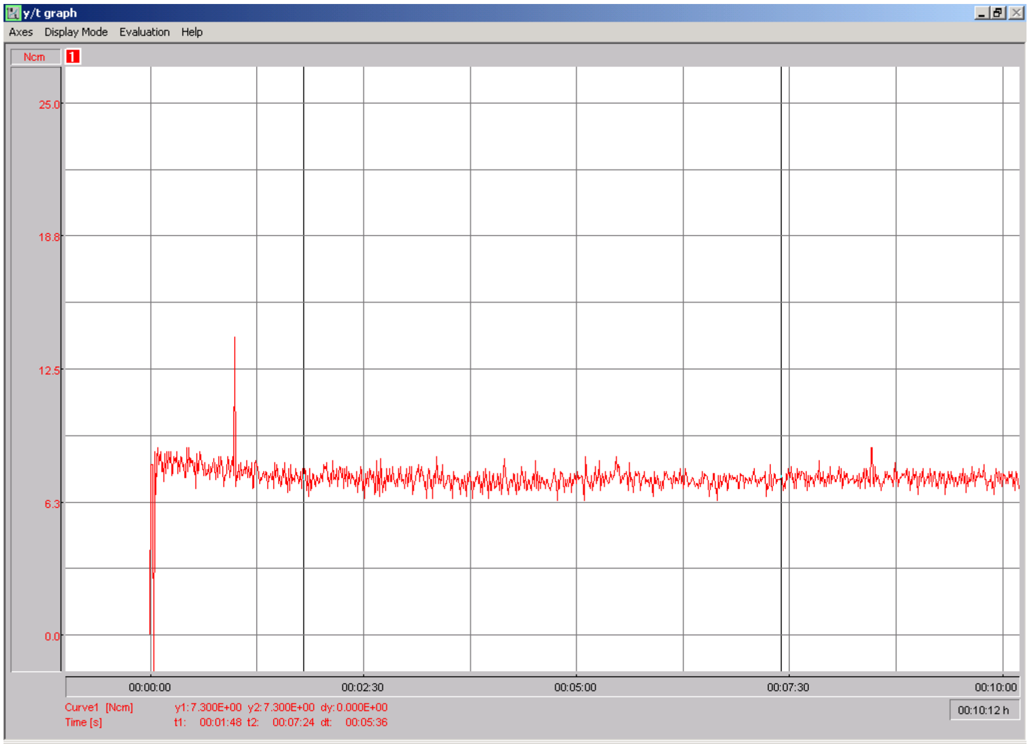


Figure 4.13: AMT Trace for Mix M4, Soupy (S)/LV System

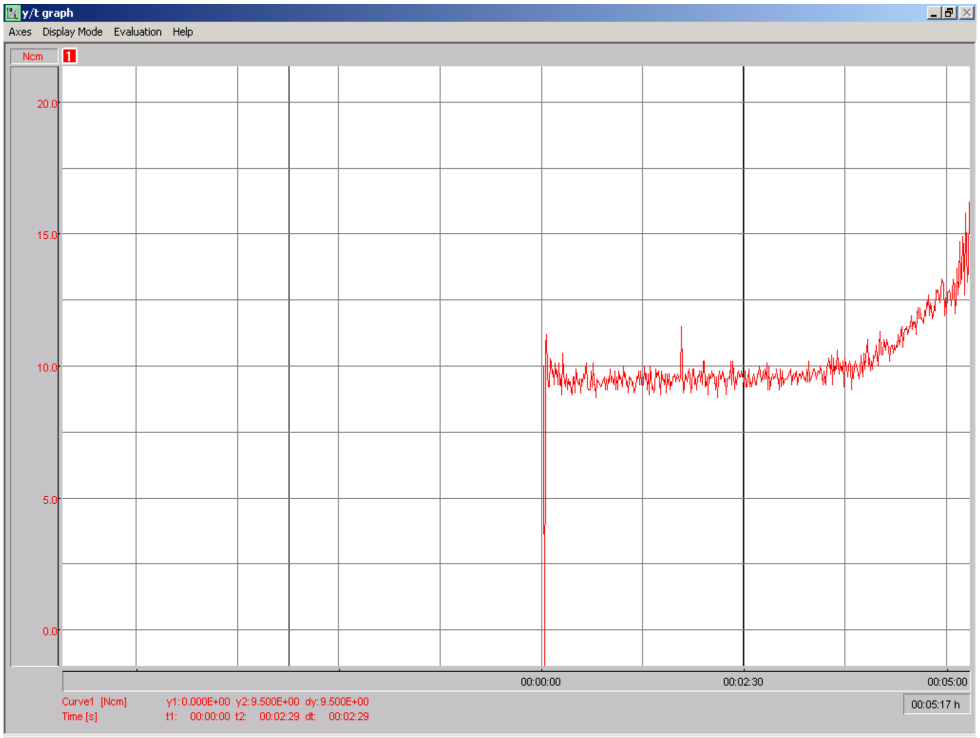


Figure 4.14: AMT Trace for Mix M1, Stiff (St) System

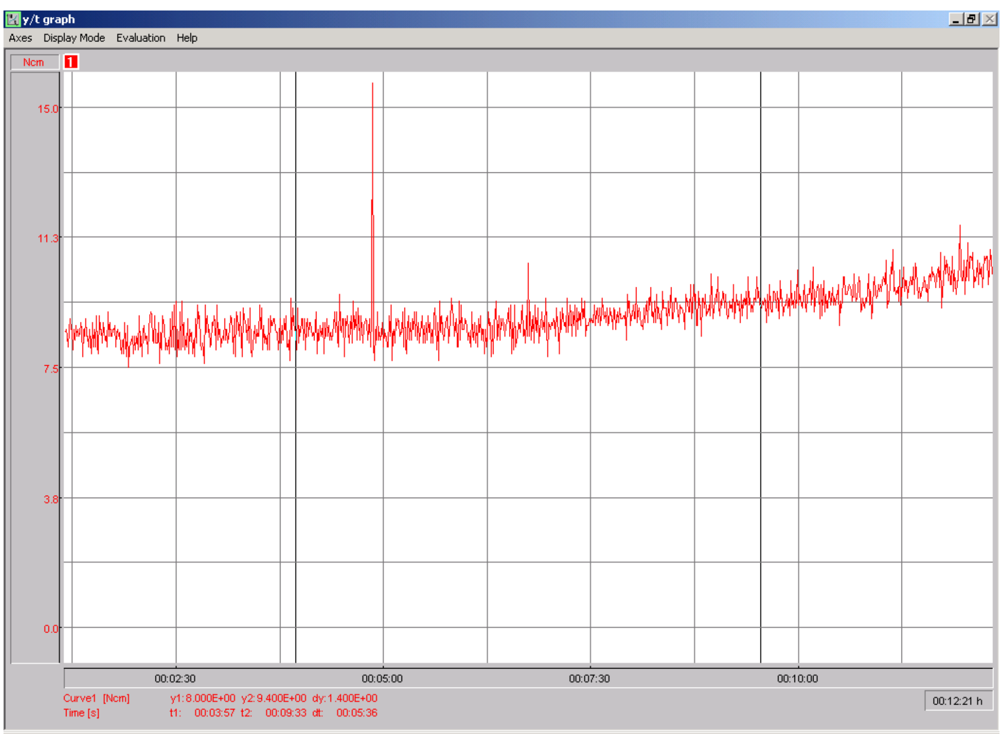


Figure 4.15: AMT Trace for Mix M2, Moderate (MV) System

Table 4.5: Preliminary Evaluation of Consistency and Mixing Torque

System	Consistency	Mixing Torque, N-cm	Mixing Time, min	Spread Time, min
M1	Stiff (St)	9 – 10	3.5	4.9
M2	Moderate (MV)	8 – 9	7	>10
M3	Soupy (S)/LV	6 – 7	>10	>10

Conclusions:

The mix procedure can distinguish between very fast and fast setting systems. The procedure can show the differences in mixing and spread time for different systems. It also shows mixing torque correlation with the mix characteristics of TB-113.

4.2.2 Development of the Automated Cohesion Test (ACT)

The existing ISSA test method for cohesion, TB-139, uses a hand held torque wrench to apply a load to a test specimen 0.23 inches (6mm) or 0.39 inches (10mm) in diameter depending on the top size of the aggregate. Torque measurements are made at intervals of 30, 60, 90, 150, 210, and 270 minutes after casting the specimens.

The major difficulty with this procedure is that the application of torque is very operator dependent. To overcome this problem, the project team contracted with Temple Systems, Inc. of Dayton, Ohio to develop an automated device to perform this test. The device is connected to a computer and is controlled by software that lowers a pressure foot on the test specimen. The operator specifies the amount of rotation of the foot at the time intervals specified. The rotation can be set from 45 to 360 degrees. During rotation, the device transmits torque values to the computer. When complete, the torque measurements are graphically displayed.

The "first article" design of the Automated Cohesion Test device has been developed by Temple Systems Lab of Dayton, Ohio and it is shown in Figure 4.16. Testing on sandpaper was completed to assure that the device functioned properly. The device was then sent to MACTEC's laboratory in Phoenix, Arizona, to complete the testing matrix.

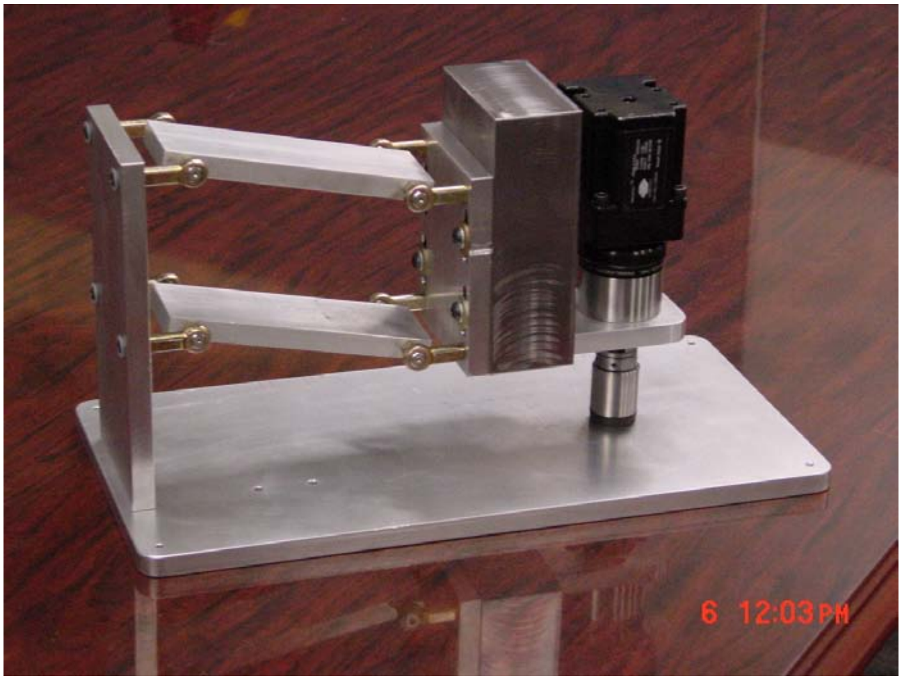


Figure 4.16: Automated Cohesion Test – Under Development

Limited comparison testing with both the automated and the conventional cohesion testers was carried out by Temple Systems and MACTEC. The results are presented in Figures 4.17 and 4.18.

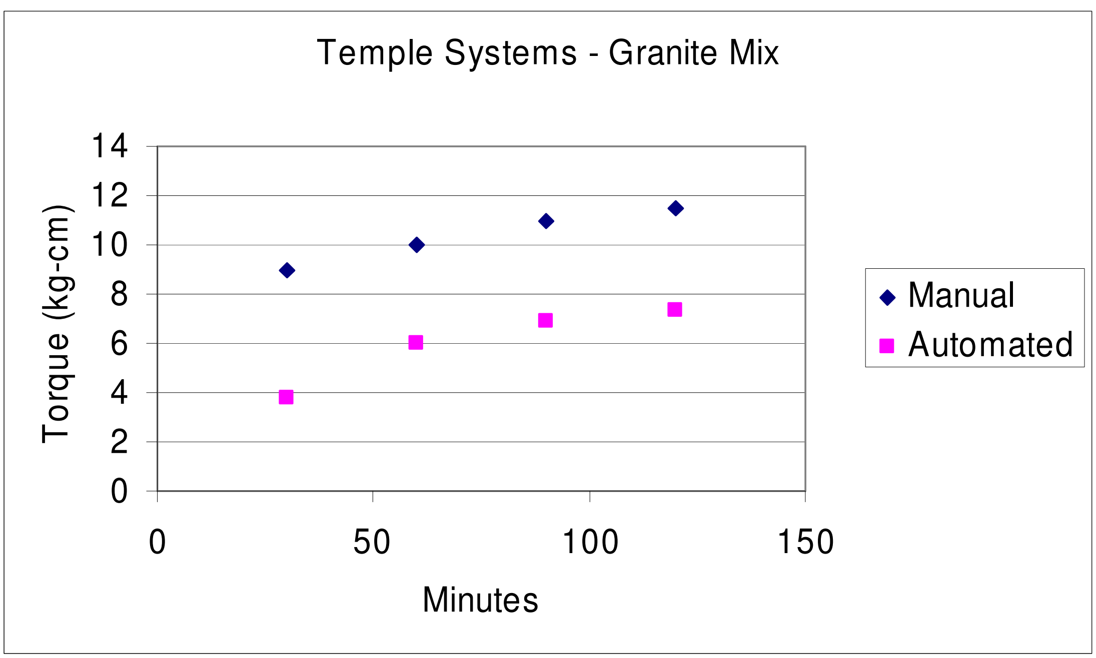


Figure 4.17: Cohesion Testing Results from Temple Systems – Granite Mix

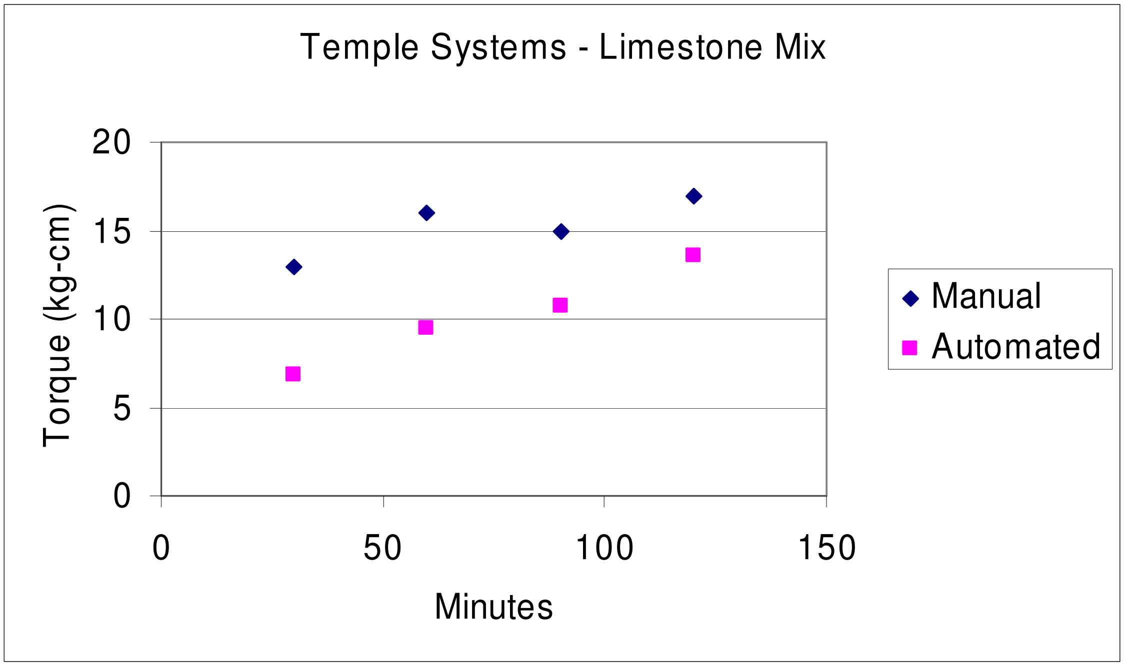


Figure 4.18: Cohesion Testing Results from Temple Systems – Limestone Mix

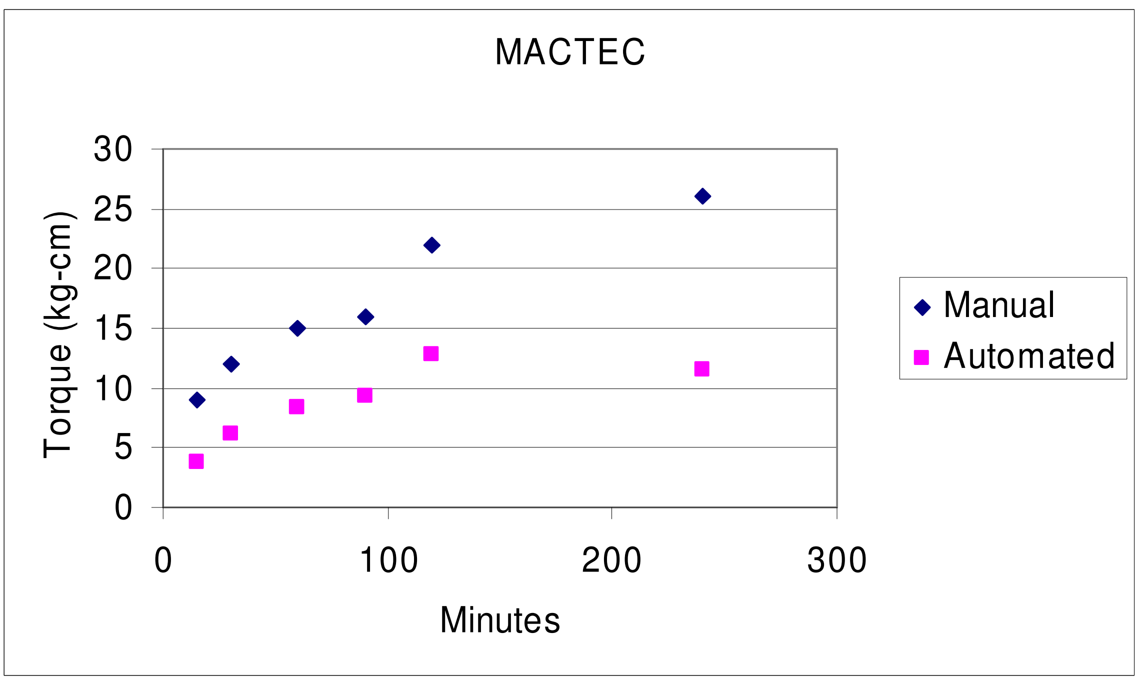


Figure 4.19: Testing Results from MACTEC

As illustrated in Figures 4.17 and 4.18, the ACT results are consistently lower than the conventional (manual) wet cohesion results. The possibility of correcting the ACT results by a correction factor or model was then investigated. This was done by pooling the data from Temple Systems and MACTEC into a single data set and plotting “automated” versus “manual” results, as illustrated in Figure 4.19.

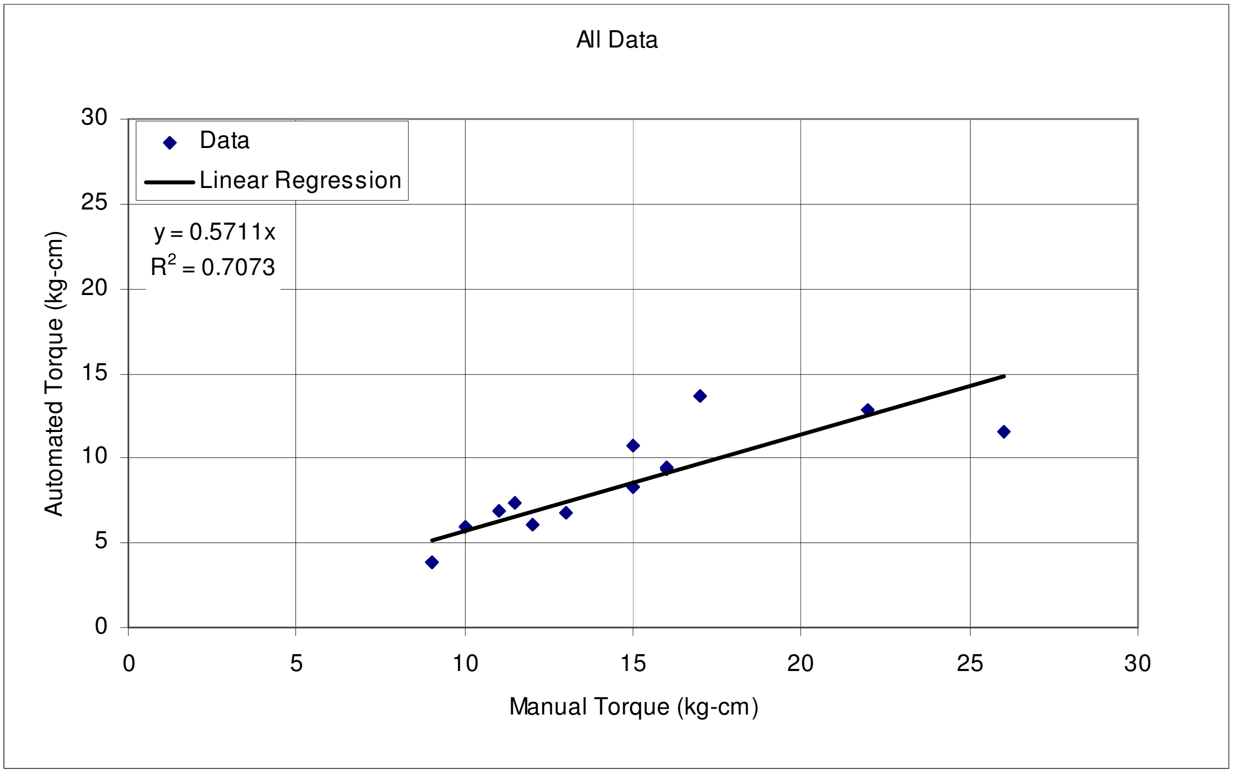


Figure 4.20: Correlation of Test Results from ACT (Automated Torque) and the Conventional Wet Cohesion Tester (Manual Torque)

As illustrated in Figure 4.20, there is a good correlation between the two tests (R^2 = 0.7). A correction factor of 1.75 (=1/0.5711) can be used to bring the Automated values within the range of values obtained from the conventional wet cohesion test. A plot of corrected values versus the conventional ones is shown in Figure 4.21.

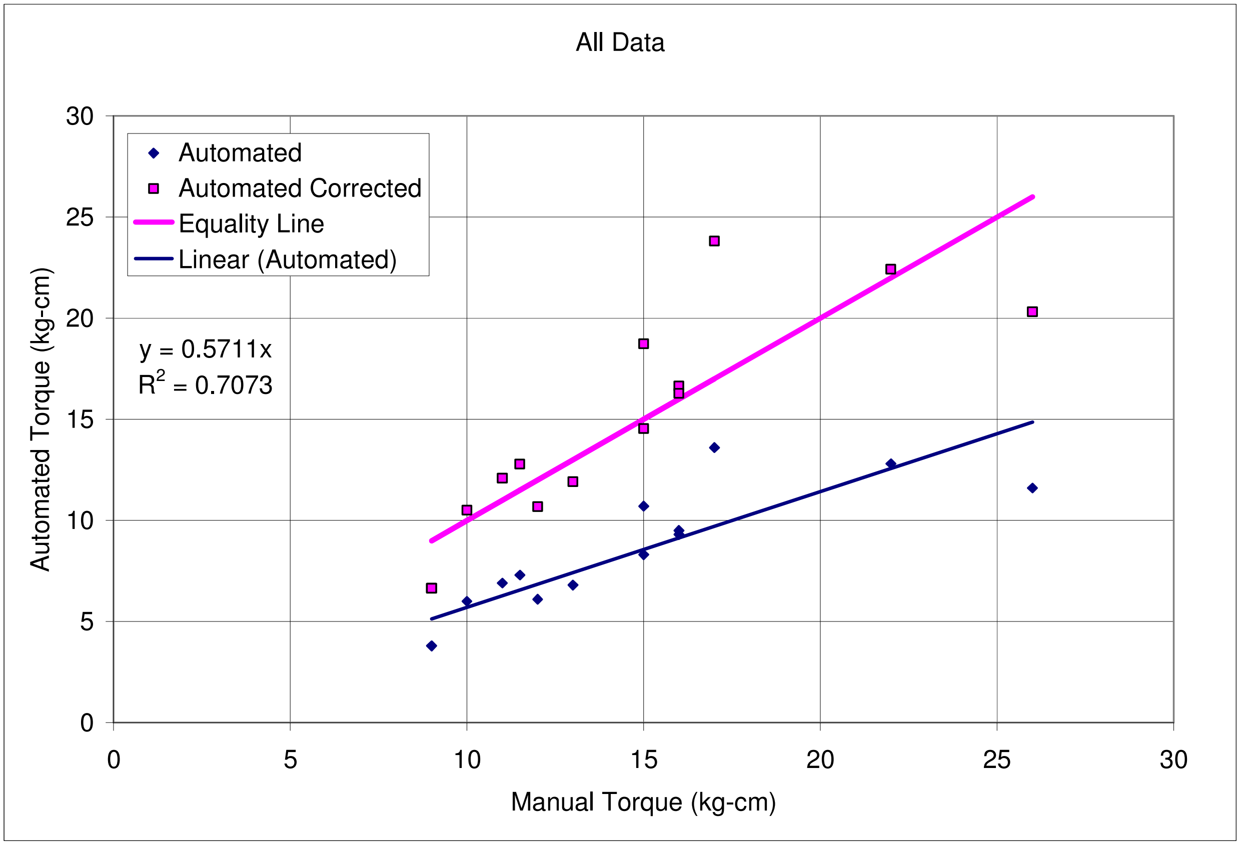


Figure 4.21: Correction of Test Results from ACT.

As illustrated in Figure 4.21, the 1.75 correction factor can be used to bring the ACT results within the range of values normally measured with the conventional wet cohesion test.

Another experiment run at the MACTEC laboratory in Phoenix consisted of calibration tests with the two devices on 220 grit sand paper. A number of 10 measurements were taken with each device. The average and standard deviation of the test results are given in Table 4.6

Table 4.6: Results of Calibration Tests on 220 Grit Sand Paper

Statistic	Conventional Wet Cohesion Torque (kg-cm)	Automated Cohesion Torque (kg-cm)
Average	19.90	11.22
Standard Deviation	0.99	1.14

Note that the ratio of the two averages (i.e. 19.9/11.22) equals 1.77, which is very close to the correction factor of 1.75 obtained from the tests on slurry systems.

4.2.3 Development of the Cohesion-Abrasion Test (CAT)

The Cohesion-Abrasion Test is a modified version of the Wet Track Abrasion Test (WTAT), ISSA TB-100. A two-wheel fixture is used instead of the standard abrasion head. As a result of this modification, the abrasive action is less severe and the test can be used to evaluate system cohesion buildup during curing and before opening to traffic as well as abrasion resistance after opening to traffic or on oven cured specimens. The test can be performed on test samples similar to those for the wet cohesion test as developed by the French. It is a better replication of traffic than the hose.

It was also hoped that the test could be used to differentiate between slurry quick set, microsurfacing, and slow set slurry. For specification purposes, ranges of loss would be more appropriate than minimum or maximum losses alone.

The first modification made to the standard Wet Track Abrasion Test (TB-100) setup was the use of a N50 Hobart unit with the wheel attachment; this has a smaller abrasion area so the loss levels needed to be reestablished when compared to the existing TB-100 test. Figure 4.22 shows the CAT with the wheel attachment during testing.

The following variables were identified and evaluated during the development phase:

1. Effect of test specimen base support type (Roofing Felt/Steel/Aluminum)
2. Effect of assessment method for aggregate loss (Wet Loss/Aggregate Loss Recovery/Dry Loss)
3. Effect of tack coat
4. Effect of soaking samples in relation to cure time
5. Stripping effects in aggregates at different test conditions
6. Effect of system on aggregate and emulsion behavior
7. Compaction by hand surface consolidation (Hand Roller)

Figure 4.22: Cohesion Abrasion Test Apparatus (CAT)

1. Effect of Test Specimen Base Support

Three base supports were evaluated: the first one was a 30 lb (13.6 kg) roofing felt, the second was a stainless steel plate 8 inches (203 mm) thick, and the third was an aluminum plate 8 inches (203 mm). The effect that these support bases had on the test results was examined for two mixes, M2 and M4. Results and recommendations are discussed together with the assessment method for aggregate loss.

2. Effect of Assessment Method for Aggregate Loss

The assessment of material loss after abrasion was done as follows:

- Wet Loss Method – The initial weight of the specimen and support base were recorded before abrasion. After the abrasion test, specimen and plate were patted dry with paper towels. This resulting weight was the final weight and the difference was recorded as the loss.
- Aggregate Loss Recovery Method - The initial weight of the specimen and support base were recorded before abrasion. During and after abrasion, all loose aggregate was recovered. The weight of the recovered aggregate was subtracted from the initial weight of the specimen and support base to obtain the final weight.

- Dry Loss Method – Two identical specimens were prepared. One specimen and support base was abraded and the loose material was removed. The second specimen and support base were not subjected to the abrasion test. Both specimens were then oven-dried over night. The loss was determined as a percentage between the abraded specimen and the un-tested specimen.

The general results for the support bases and the assessment method were noted as follows:

The felt support base absorbs water and is difficult to handle and to pat-dry with paper towels. It tends to loose more material as it flexes, therefore, it produces a wider scatter of results. The aluminum and steel support bases were easy to use and handle. The results using these metal bases were observed to be more repeatable.

The Dry Loss Method and the Wet Loss Method gave the most reproducible results. The Aggregate Loss Recovery Method proved very difficult to do and larger variations of the results were observed.

In order to evaluate the effects that the base support and the assessment method have, mix M2 was used. The formulation of mix M2 was previously studied and consisted of the following proportions:

Mix M2

- 100 grams of aggregate
- 1.5 grams of cement
- 8 grams of water (Based on the weight of dry aggregate)
- 0.25 gram of additive
- 13 grams of emulsion

The test specimens were cured for 30, 60, and 180 minutes before testing. Duplicate tests were performed for each of the assessment methods and base supports, except for the aluminum base, for which only one test was performed. The results are summarized in Table 4.7. The decrease in abrasion loss with time is illustrated in Figures 4.23 and 4.24.

Table 4.7: Test Specimen Bases and Assessment Methods for Mix M2

Curing Time, (min)	Support Base	Wet Loss Method (g)	Aggregate Loss Recovery Method (g)	Loss on dry basis* (%)
30	Felt	290/320	265/280	29/31
30	Steel	248/225	210/195	24.5/23.5
30	Aluminum	235	195	23
60	Felt	162/220	199/175	16.4/17.5
60	Steel	94/85	85/75	9.5/10.1
60	Aluminum	87	80	8.9
180	Felt	25/35	19/28	2.9/3.5
180	Steel	23/19	23/18	2.4/2.1
180	Aluminum	25	21	2.5

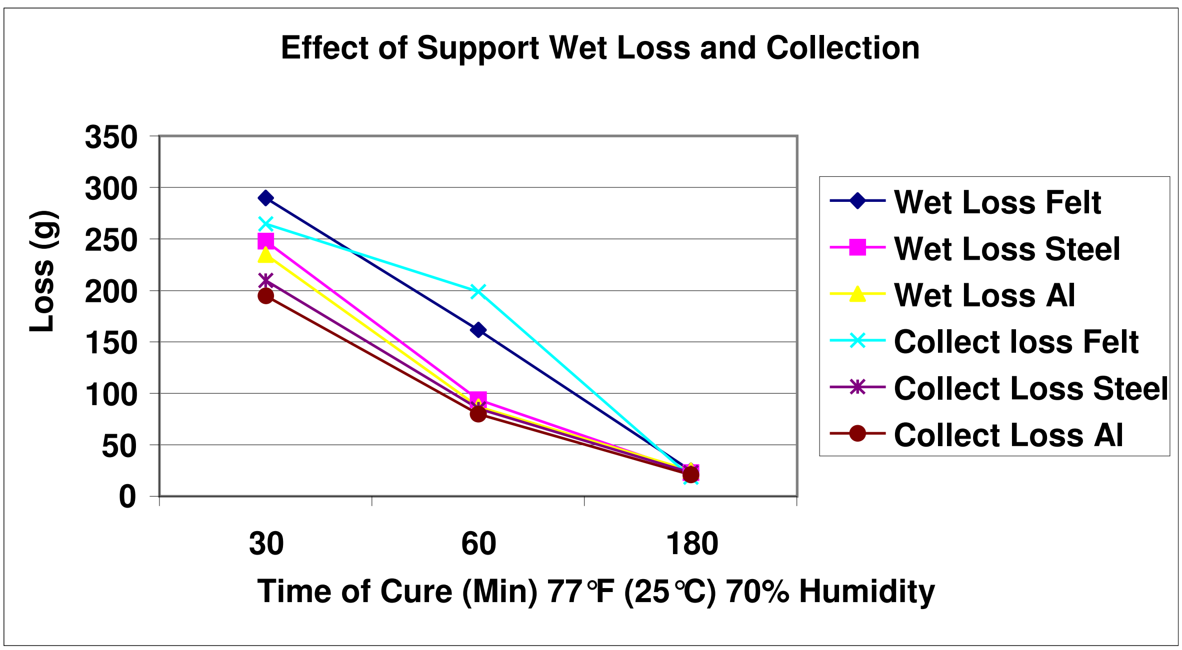


Figure 4.23: Effect of Support Base Type on Wet Loss Method, Mix M2

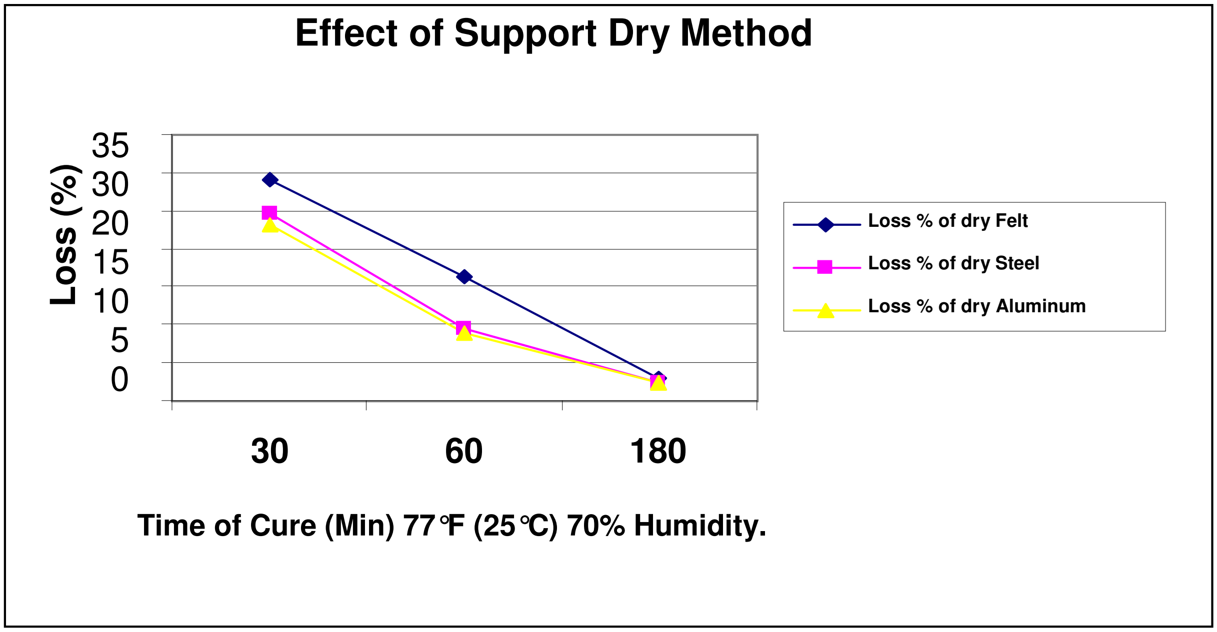


Figure 4.24: Effect of Support Base Type on Dry Loss Method, Mix M2

It was concluded that metal (Steel or Aluminum) support bases are easier to handle and create less aggregate loss. The use of a metal support base is therefore recommended. The Aluminum base is preferred because it is lighter and more resistant to corrosion.

The recommended assessment method is the Wet Loss Method. Even though both, the Wet Loss Method and the Dry Loss Method had reproducible results, the Wet Loss Method was preferred since immediate results can be obtained. A comparison of the loss measured with the two methods shown in Figure 4.25.

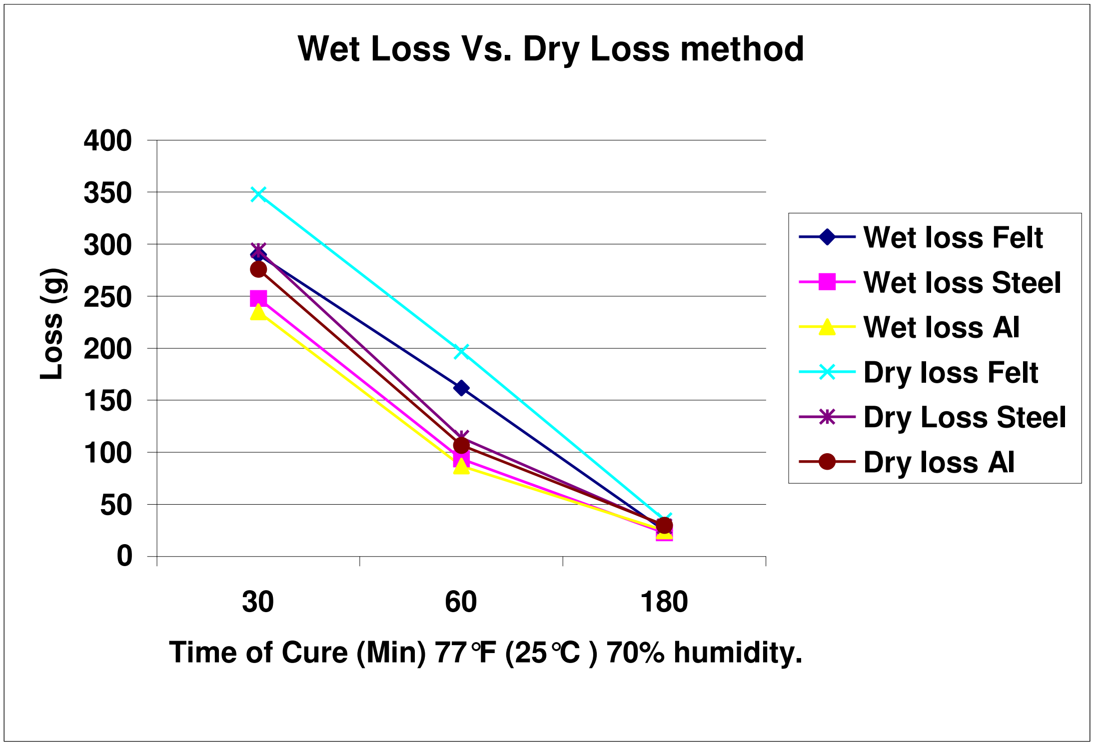


Figure 4.25: Comparison of Losses as Determined by Wet and Dry Loss Methods

Aggregate and Emulsion Effects

The Aluminum base support was used and the tests repeated with two mixes, Mix M2a and Mix M2b. These mixes were cured at 77°F (25°C) and 70% humidity. The mix proportions were as follows:

Mix M2a

- 100 grams of aggregate
- 1 gram of cement
- 9 grams of water (Based on the weight of dry aggregate)
- 0.5 gram of additive
- 15 grams of emulsion

Mix M2b

- 100 grams of aggregate
- 0.5 gram of cement
- 10 grams of water (Based on the weight of dry aggregate)
- 0.5 gram of additive
- 15 grams of emulsion

The differences in the samples were the amount of water and cement. Test results are summarized in Table 4.8. The decrease in loss with time is shown in Figures 4.26 and 4.27.

Table 4.8: CAT Results for Mix M2a and M2b

Mix	Pre-treat Compaction	Time of cure (min)	Loss wet (g)	Loss Oven dry (g) %
A	N	30	265/250	26.1
	N	60	165/170	12.6
	N	180	77/72	6.4
A	Y	30	-	-
	Y	60	145/155	-
	Y	180	-	-
B	N	30	433.9/455	28.8
	N	60	275/285	19.2
	N	180	239.5/225	15.9
B	Y	30	-	
	Y	60	220	-
	Y	180	-	

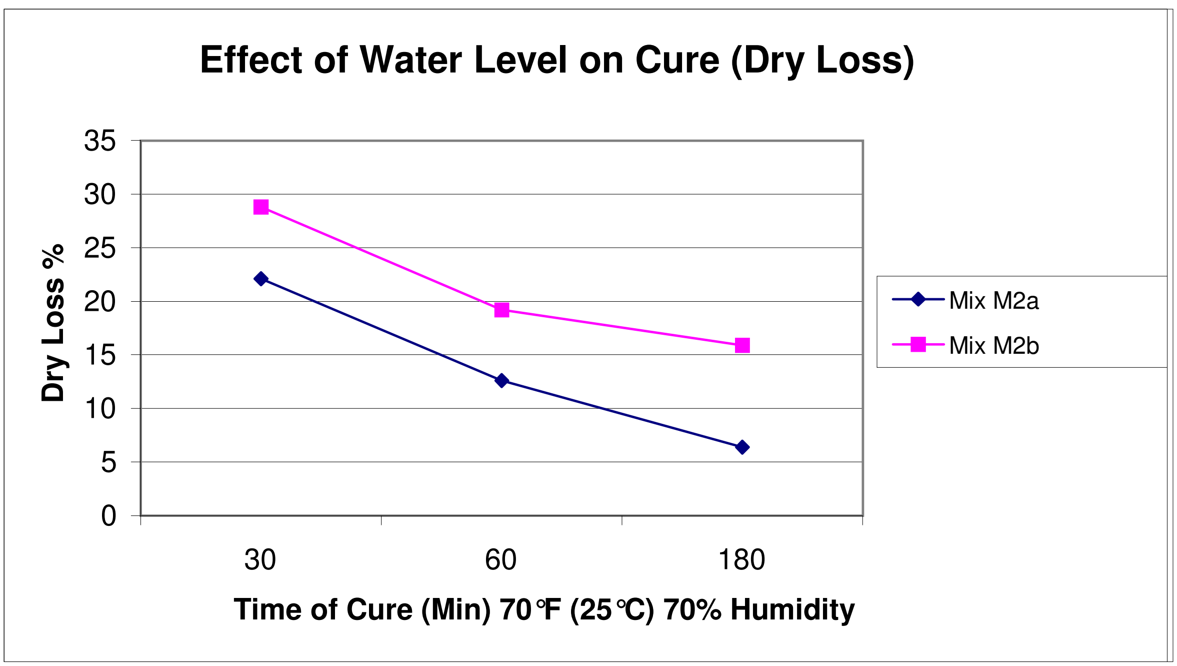


Figure 4.26: Effect of Water Level on Cure M2 Mixes (Dry Loss Method)

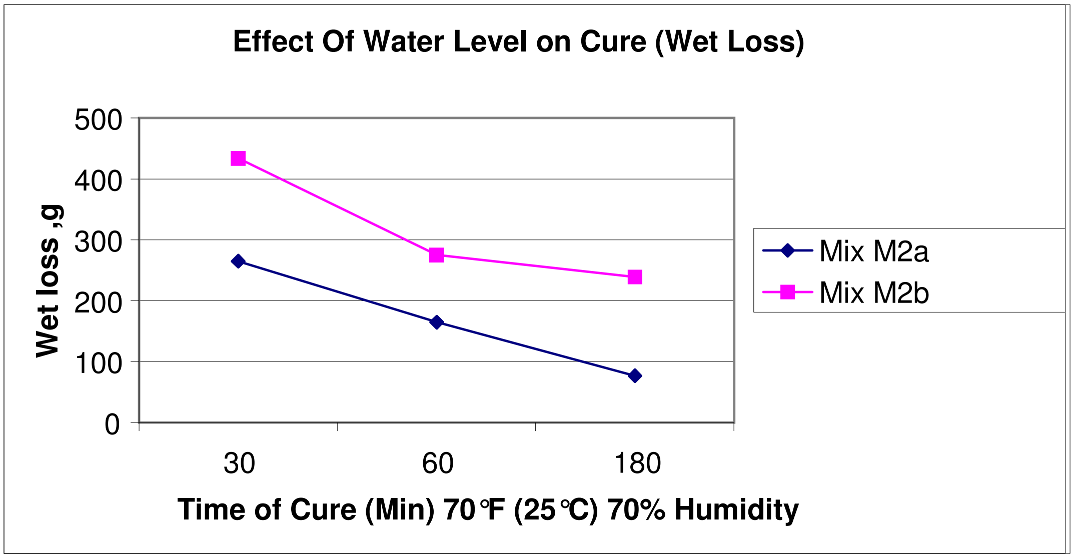


Figure 4.27: Effect of Water Level on Cure M2 Mixes (Wet Loss Method)

Compaction was conducted on selected samples and accomplished by exerting pressure on to the sample surface with a roller and mopping up any water with paper towels of high absorbency.

Figure 4.28: CAT Hand Roller

Both systems were correctly defined by this test as quick set; the aggregate effect was clearly distinguished. Compaction did consolidate the surface to some extent but an analysis of the data indicates that there is no significant difference between the compacted and non-compacted specimens and as a result compaction is not recommended. This is illustrated in Figure 4.29.

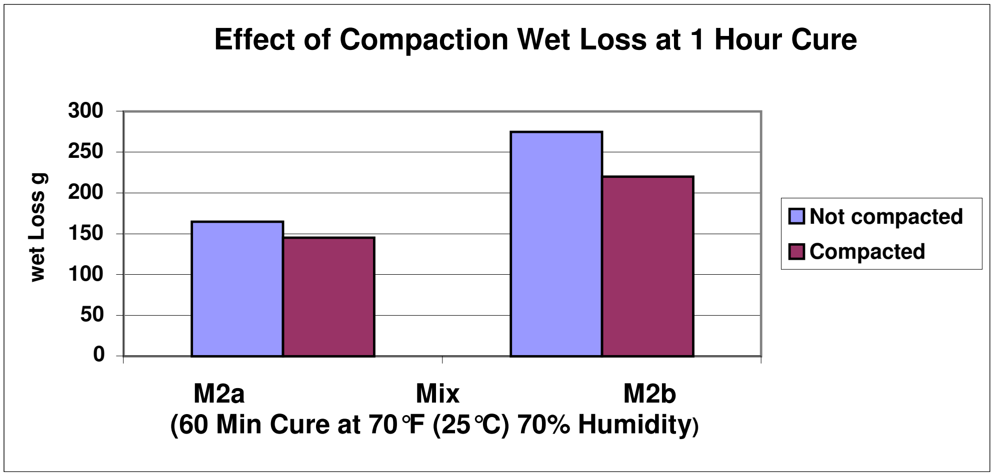


Figure 4.29: Effect of Compaction on M2 Mixes (Wet Loss Method)

4.2.4 Effect of Tack Coat

Tack coat was applied on the metal base using a brush. The base plate was covered with a thin, even coat of emulsion. The tack coat was allowed to dry to the touch. As illustrated in Figure 4.30, the tack seemed to reduce losses perhaps by holding the sample firmly and preventing shear at the base.

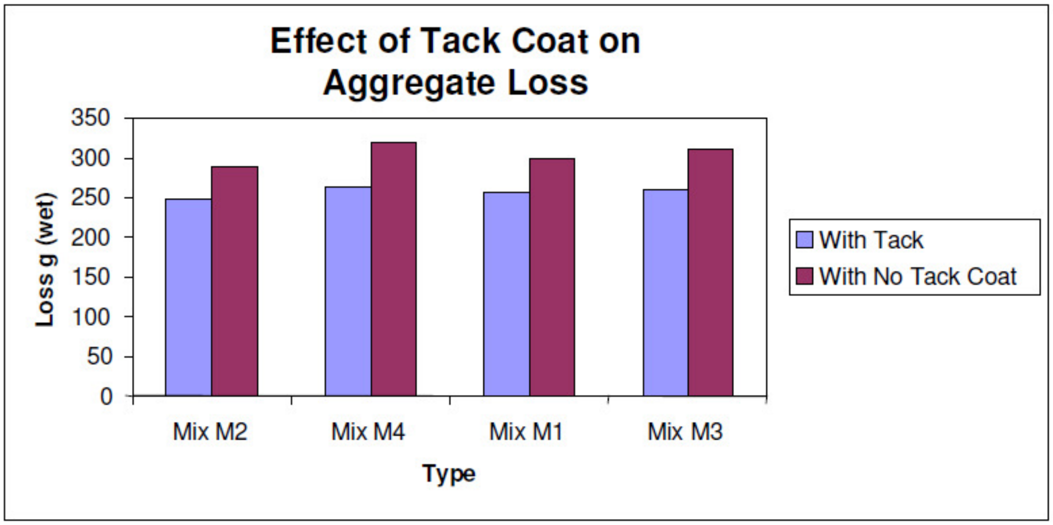


Figure 4.30: Effect of Tack Coat

4.2.5 High Traffic and Rut Resistant System CAT Results

An exercise to evaluate the CAT system and its effects on high traffic systems was conducted.

The procedure was repeated with the mixes M1 and M3 with optimum mix components established from TB-113 and the AMT. The results are illustrated in Table 4.9 and Figure 4.31.

Mix M1

- 100 grams of aggregate
- 1 gram of cement
- 8 grams of water
- 0.5 gram of additive
- 14 grams of emulsion

Mix M3

- 100 grams of aggregate
- 1 gram of cement
- 10 grams of water
- 0.5 gram of additive
- 16 grams of emulsion

Table 4.9: Wet Loss Method Results

Time (Min)	Wet Loss M1 (g)	Wet Loss M3 (g)	Dry Loss M1 (%)	Dry Loss M3 (%)
30	256	236	19	19.4
60	49	64.4	4.2	5.1
180	14	10	1.8	1.6
300	6.3* (1)	2*(<1)	0.8*(0)	0.6*(0)

*1 hr soak

These results are plotted in figure 4.31. The M1 emulsion system set faster but the M3 aggregate still had the tendency to strip at short cure times. Samples were also cured at 5 hrs, soaked for 1 hour, and tested as noted in table 4.9 (note that loss after 5 hours cure are shown in brackets as noted in Table 4.29).

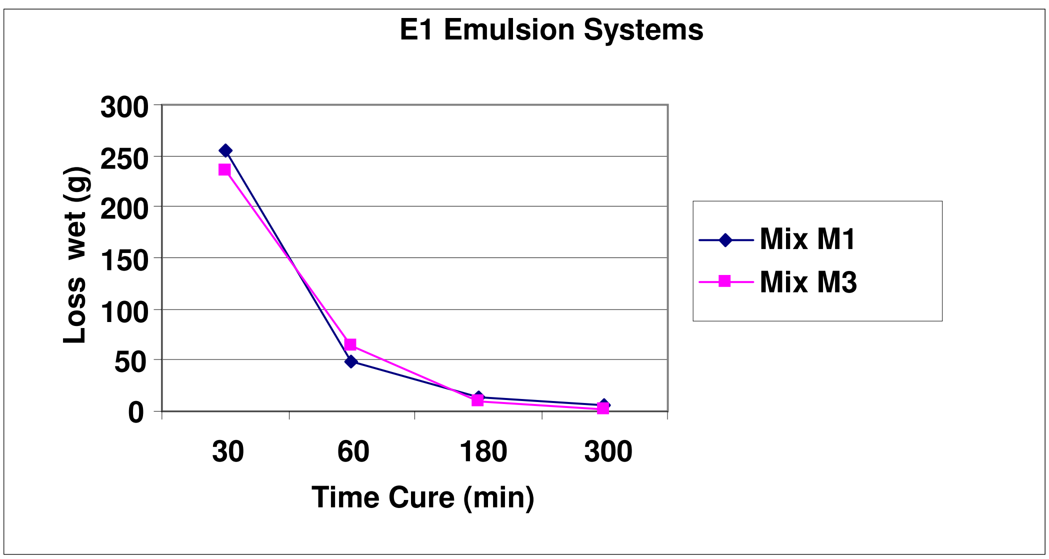
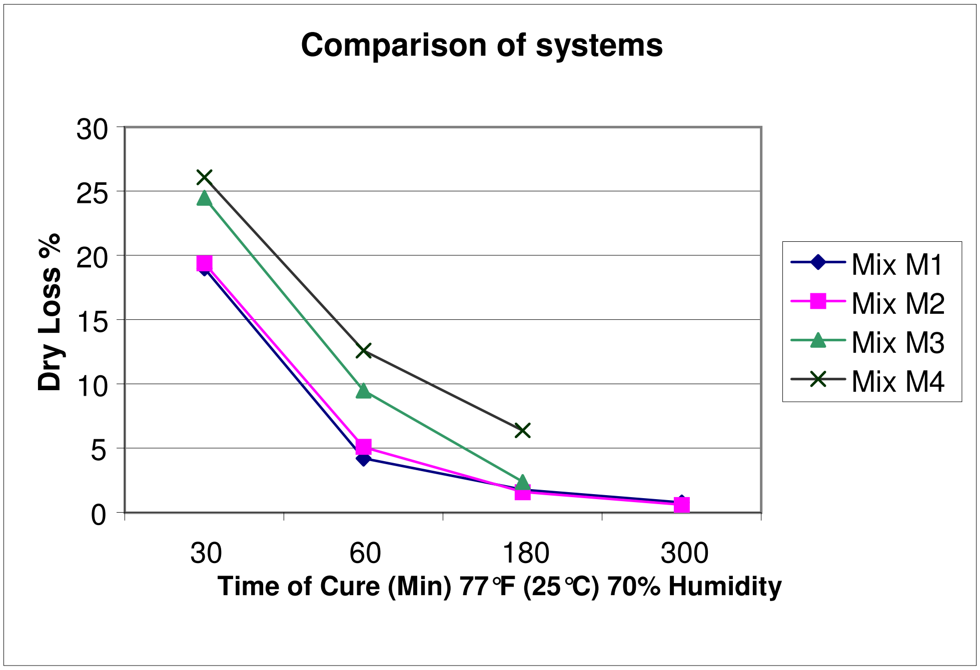


Figure 4.31: Losses with Microsurfacing Systems

The results were compared to the E-2 systems for Table Mountain and Lopke (M2 and M4) and are illustrated in Figure 4.32.



1 hr soak

Figure 4.32: Comparison of Different Systems Using CAT

The test appears to distinguish between system types at 77°F (25°C) and 70% humidity.

The existing wet track abrasion test, TB-100 was measured for all systems and compared to the CAT test which is noted in Table 4.10.

Table 4.10: TB-100 Test Results

System	Loss WTAT /1 Hour Soak (g/cm^2)	Loss 5 hr cure*dry 1 hour soak (g/cm^2)
M2	0.8	0.5
M4	1.02	0.9
M1	0.8	0.4
M3	1.1	0.4

* 77°F (25°C) 70% humidity

The data indicates that the abrasion loss is similar for the wheels in the CAT tests compared to WTAT for the comparable level of cure and soaking, since both show low losses based on observation. For long term abrasion and determination of the base binder level it is suggested that the range of soak periods are the same as are used for CAT test. The WTAT will be needed to determine the long term performance properties of the S3 mixes.

4.3 LABORATORY TEST METHODS EVALUATION

4.3.1 Evaluation of Automated Mixing Test (AMT)

The proposed AMT test method covers measurement of constructability of slurry surfacing materials once the basic ratios of the components have been established. By automatic and constant recording of the complete torque-measurement-curve, the mixing curve indicates each variation during the breaking process—the process where the mixture changes from a homogenous flowing consistency to a stiff non-flowing consistency.

The AMT procedure was developed with the intention of providing additional information about the breaking process for a particular mix system after initial mix proportions were established by using TB-113 and to eliminate operator variability.

Differences between proposed and current test methods:

- In TB-113, the curing condition for humidity is not specified.
- The current hand mixing method allowed the use of various mixing bowls or containers, and mixing stirrers.
- The current hand mixing method required a specified rpm during the manual mixing, but that would vary from operator to operator.
- The original hand mixing method did not specify any details to the direction of rotation or depth of the stirrer into the mixture during the mixing process, so that would vary from technician to technician.
- In TB-113, mix proportions were adjusted to meet the minimum mixing times in the project specifications. This tended to produce a mix with a higher viscosity than the viscosity of the system used during placement in the field.

Advantages of the proposed test method:

The AMT method standardizes testing conditions for humidity, mixing bowl, stirrer, mixing rotations and mixing rate. In the current TB-113 procedure, these variables greatly influence the final result and it varies from technician to technician and laboratory to laboratory.
In addition, another advantage is that this method evaluates the mix system for the type of break the system has by measuring the mixing torque, spread time and maximum torque.

Correlation between the proposed and current methods:

In the original hand mixing method per TB-113, the mix proportions were adjusted to determine mixing times relatively close to the minimum mix time requirements: 3 minutes for slurry seal systems and 2 minutes for micro-surfacing systems. When the minimum proportions were used for the AMT, as determined by using TB-113, predictably the mixes would be changing much more quickly and recorded as such during the AMT evaluation.

In both test methods (proposed and current), when there were more total liquids in the systems, the viscosities were lower. In both test methods, mix systems with higher total liquids will deliver very extended mixing times.

Suitability of the proposed test method:

The equipment as developed still requires that the operator has a certain level of experience in order to set up and run the test in a short period of time.

As developed, the equipment needs to be modified to accurately control mixing temperatures other than 77°F (25°C) and mixing humidity above 50%.

Another challenge is the operation of the IKA software. This software was originally developed for use with multiple mixers, mediums and applications.

Additional research needed for this test method:

All the mixes used during the evaluation of the AMT were mixes where the aggregate was larger than a Type 2 aggregate. More evaluations should be performed on different aggregate sizes.

The test method does require that the laboratory technician have experience in preparing the mix and setting the mixture into the testing equipment. Somehow making that process mechanical would decrease the amount of experience a technician is required to have to perform the AMT method and decrease the amount of error when the stirrer is not properly placed into the mixture.

An environmental chamber that won't affect the motor of the mixer or the shaft of the mixing tool needs to be developed for evaluating mix systems for temperatures at 59°F (15°C) or 95° (35°C) and at higher humidity conditions.

Developing a specific software program for slurry system applications as it relates to the AMT method would make the test method easier to use from one laboratory to another.

4.3.2 Evaluation of Cohesion-Abrasion Test (CAT)

The proposed CAT test method covers the measurement of the wearing qualities of slurry seal and micro-surfacing mixture systems under wet abrasion conditions and early cohesion properties at different levels of cure.

Currently, test practices for abrasion are not performed on uncured mix specimens. The cohesion abrasion test is appropriate for measuring early cohesion build up as the mixture cures under various curing conditions. If high losses during initial curing of the mix are observed, generally this indicates that the mix will have a poor performance.

Differences between proposed and current test methods:

- In the original wet track abrasion test per TB-100, the test is performed on the aggregate after it has been scalped over the #4 sieve.
- In the proposed method, testing is performed on the bulk sample that has 100% passing the 3/8 inch (9.65 mm) sieve.
- In the original wet track abrasion test per TB-100, the test specimens are aged in a 140°F (60°C) oven before initiating moisture conditioning.
- In the proposed method, testing is performed on specimens that are cured at specified temperatures, representing ambient field conditions at 59°F (15°C), 77°F (25°C), or 95°F (35°C). Additionally, this is done at varying ambient field moisture conditions at 50% or 90% humidity.
- In the original wet track abrasion test per TB-100, the test specimens are not compacted before curing.
- In the proposed method, one set of test specimens are compacted before curing and another set of test specimens are not compacted before curing to note the difference.
- In the original wet track abrasion test per TB-100, the abrasion head rotates a fixed rubber hose along the surface of the sample.
- In the proposed method, the abrasion head rotates a set of two free-spinning rubber wheels along the surface of the sample.
- In the original wet track abrasion test per TB-100, the test specimen loss is determined from the original weight of an oven cured test specimen after it has been abraded, and fines rinsed, and the remaining test specimen is oven dried.
- In the proposed method, the test specimen loss is determined from the final weight of the test specimen after it has been abraded, and the fines rinsed, without oven drying.

Advantages of the proposed test method:

The most noticeable advantage of this method is that the evaluation is performed on a complete aggregate gradation. None of the material is scalped as specified in the current method so it represents the mixture as it will be used in the field.

The other advantage of this method is that it tests the mix system as it begins to cure under various conditions. This will provide an indication of the behavior of the mix system at different ambient conditions in the field. This is a reliable indicator of performance of the mix system representing the early curing and cohesion build up of a mix.

Correlation between the proposed and current methods:

In the original wet track abrasion test per TB-100, and the proposed test method, the test specimen loss decreases as the emulsion content increases.

Suitability of the proposed method:

The cohesion abrasion test method includes equipment that is easy to operate and the method is simple to follow and perform.

Currently, test practices for abrasion are not performed on uncured mix specimens. The cohesion abrasion test method is appropriate for measuring early cohesion build up as the mixture cures under various curing conditions. If we see high losses during initial curing of the mix, we can expect to predict a problematic mix.

Additional research needed:

The cohesion abrasion test method would benefit from field validation of various mixes in predetermined conditions and test sections.

Potentially, this test method could be used to measure early cohesion build up and predict the early performance of the mix shortly after placement. If an on-site laboratory were available, this test method may be used to measure early curing in the field to validate the recently placed mix. The limitation, at this time, is that there has not been a method mutually accepted by industry and agencies that successfully captures a representative sample of the mixture during production at the time of placement.

4.4 REVISED MIX DESIGN METHOD (VERSION 2)

After the evaluation of the proposed mix design method, and due to the available time available to complete the project, the following revisions were made to the mix design method:

- To determine the optimum binder content (step 4), it was the original intent to run the LWT at three different temperatures: 95°F (35°C), 77°F (25°C), and 59ºF (15°C). This will be modified to run the LWT at 77°F (25°C) only.
- To determine deformation properties, the proposed mix design method recommended using TB-109. The revised method will measure deformation properties using TB-147 instead.

The mix design method reflecting the two revisions discussed above will be as follows:

Step 1: Materials Selection
To begin the mix design, the current ISSA recommendations will be used. Step 1 is subdivided into the following steps, in the order given:

- Selection of aggregate: The first step is to choose the aggregate grading based on the existing ISSA specifications. In addition, the selected aggregate must meet the minimum requirements for mechanical and chemical properties in the specifications prepared as a result of this study.
- Selection of the emulsion and binder: This will be largely a matter of the climatic conditions where it will be applied, and available supply. These parameters are included in the project's specifications.
- Selection of a locally available potable water source.
- Selection of a mineral filler, Portland cement, or hydrated lime, which meets the specification requirements.
- Selection of a liquid retardant such as Aluminum Sulfate when necessary.
- Include a set control additive at the addition rate recommended by the emulsion supplier if necessary.

Step 2: Create a Mix Matrix and Determine Mix Constructability
After the materials have been selected, it will be necessary to determine the proportions of aggregate, water, emulsion, and additives to create a mix matrix. This step will involve the use of the AMT test to determine the mix and spread indices. With the results of the AMT, the conditions at which the materials can be mixed safely and placed in a timely fashion can be determined. These tests will be performed at standard laboratory conditions and repeated for selected mixes for a range of anticipated application conditions.

This process should be repeated with different filler types (if necessary) to optimize the mixture for constructability and performance criteria. This will lead to a recommended filler type and additives levels to be used.

Step 3: Determine the Short-term Constructability Properties
This step consists of taking the acceptable mixes and conducting cohesion testing using the ACT. The cohesion test is performed at 60 minutes and after 24-hours of cure. This testing would be repeated for specified application conditions of the project. If the results do not meet the standards, then the mixes and materials would be modified as required. In all cases, it is important to ensure that the mix time and spreadability are acceptable. Spreadability is a measure of the ability of the mix to be placed and finished on the pavement surface.

After the proportions have been selected, the ACT test should be performed and repeated for anticipated curing conditions to evaluate the short-term abrasion properties.

The mix proportions can then be modified if necessary and a check performed to confirm that the cohesion at 60 minutes provides an acceptable traffic time and the cohesion at the 24-hour cure period is also acceptable.

The results of step 3 are used to establish a target optimum for the next step in the design, and to evaluate the short-term abrasion properties of the selected mix.

Step 4: Determine the Optimum Binder Content
This involves preparing selected samples for the specific application conditions and varying the emulsion content ±2% from the target optimum. The additive and filler proportions will remain as determined from the targets developed in step 3.

Under this step the WTAT will be performed at 1-hour and 6-day soak periods followed by tests using the LWT to determine the excess asphalt at 77°F (25°C).

The recommended optimum binder content will be selected by evaluating the abrasion loss in the WTAT test and the binder content versus sand adhesion from the Loaded Wheel Tester (LWT).

NOTE: The specification minimums established by this study will be used for abrasion loss and the maximum for sand pick up from the LWT.

Step 5: Evaluate the Cohesion Properties at Various Curing Conditions
The selected curing conditions should be representative of the project's estimated humidity and temperature conditions at the time of construction. CAT test is then performed at 30 minutes, 1 hour, and 3 hours.

Step 6: Evaluate the Long Term Properties of the Mixture
This step consists of evaluating the following:

- Abrasion: Using the CAT.
- Water Resistance: Using the CAT.
- Deformation (rut-filling mixes only): TB-109

Finally, any necessary adjustments and re-check of the mixing indices (spreadability, traffic, and 24 hour cohesion) will be made.
After selecting the best mix from the short-term test methods noted above, the mix will be tested for the following long-term performance properties:

- Abrasion resistance
- Water resistance
- Deformation

Abrasion Resistance:
This property will be measured using the CAT test using fully cured specimens, soaked for 6 days, under project specific environmental conditions.

Water Resistance:
The CAT abrasion test will be run on the final mix design after being soaked for 6 days at a temperature of 77°F (25°C) and comparing the loss to that of a 1-hour soak and express this as a ratio. This information will be compared to the results of an existing mixture in order to determine the appropriate specification limits. The test will then be checked with a mix of known standard properties using other materials with which the team and advisory group have experience.

Deformation:
This property will be measured using TB-147 "Test Methods for Measurement of Stability and Resistance to Compaction, Vertical and Lateral Displacement of Multilayered Fine Aggregate Cold Mixes".

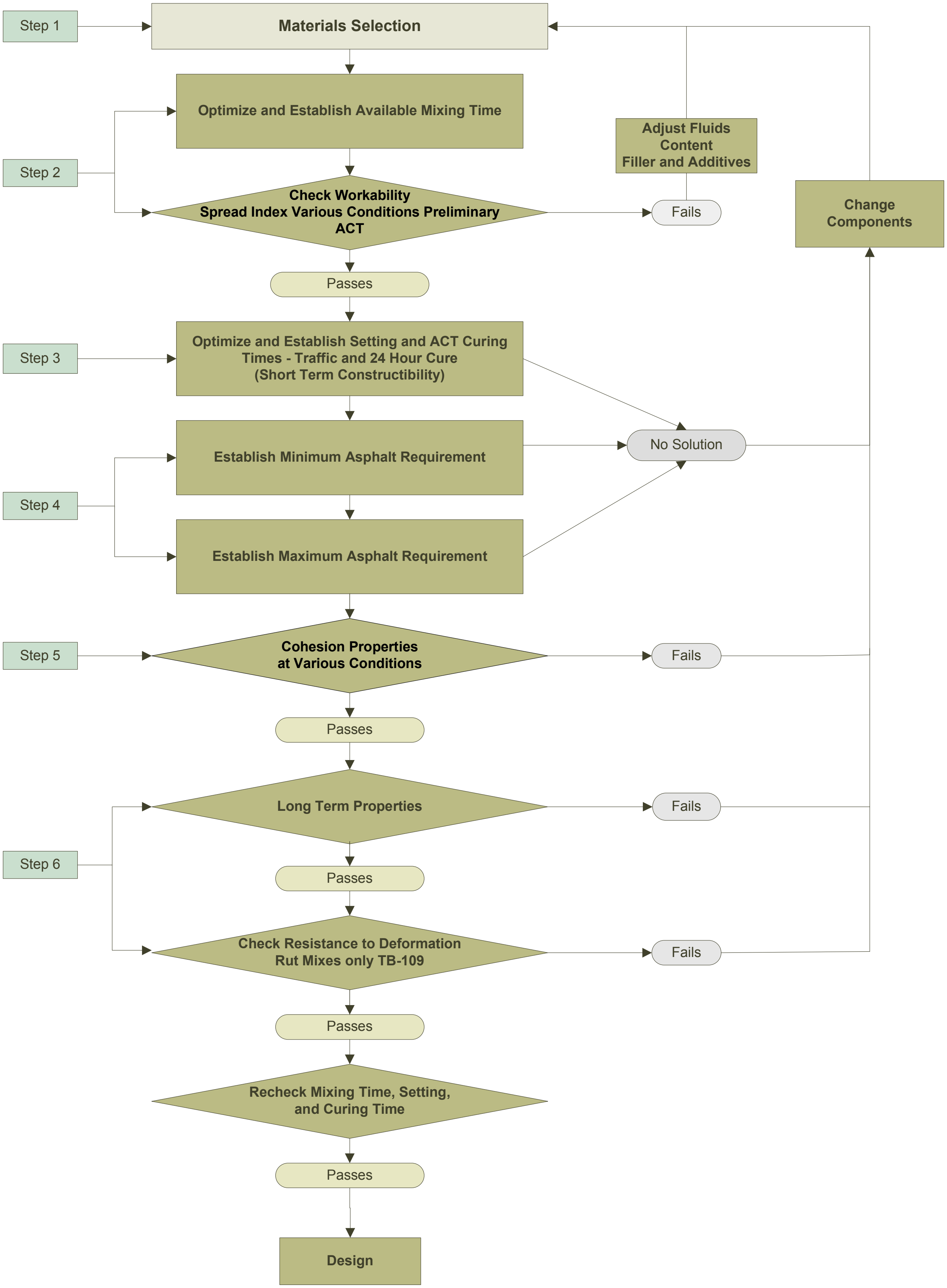


Figure 4.33: Revised Mix Design Method

5.0 CHAPTER 5 RUGGEDNESS TESTING

5.1 PURPOSE OF THE EXPERIMENTS

The overall purpose of a *Ruggedness Testing Experiment* is to evaluate the sensitivity of the output of a particular test to allowable variation in the test conditions.[13] For example, consider a simple hypothetical test method involving a device that can be used to measure the sodium content in a given sample of water. Under the range of typical test conditions, the result of this test may be sensitive to the variability of such factors as the temperature of the water, the amount of solar radiation, and the level of other chemicals and contaminants in the water. A ruggedness test for this device (test method) would involve the design and conduct of an experiment to determine the overall effect of the variation of these other factors on the primary test result (i.e., the sodium content of the water). If the test result is unaffected by the variation of the other factors (within their typical ranges), then the test method is considered *rugged*.

Obviously, ruggedness is a desirable attribute for all test methods, including those that will be used for slurry/micro-surfacing mix design. For any given test method associated with the mix design process, the evaluation of ruggedness can best be done by performing all of the tests in one laboratory, so that there is no laboratory effect to consider. The results from the ruggedness experiment will then provide a basis for evaluating the effect of test conditions under later round-robin testing of the test methods.

5.2 STATISTICAL MODEL

For each of the test devices/methods undergoing the ruggedness testing, the *statistical model* that will be used to evaluate the effect of the variability of test conditions will be a simple linear model. This means that each of the condition variables (X1, X2, X3, and so on) will be evaluated as if they have a linear effect on the dependent variable (i.e., the value of the test result). Considering the overall purpose of the analysis, it is reasonable to assume that the sensitivity can be characterized and evaluated using first order (linear) effects (see Figure 5.1a). Although the relationship may have some curvilinearity, the linear model does capture the primary effect in the region between the low and high levels of the condition variable.

The one case where this assumption can break down is the situation where the condition variable has a quadratic effect and the low and high levels of the condition variable are set at points where they have a near-equal effect on the test result (see Figure 5.1b). In this case, the model would indicate a near zero effect, when the effect is actually significant. Considering the small likelihood of this happening versus the cost of expanding the experiment design to test for it, the project team recommended erring on the side of minimizing the cost of testing.

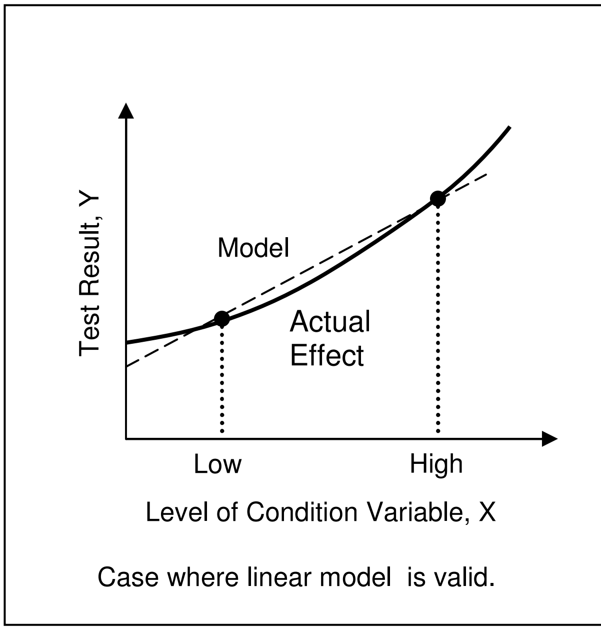


Figure 5.1a: Linear Statistical Model

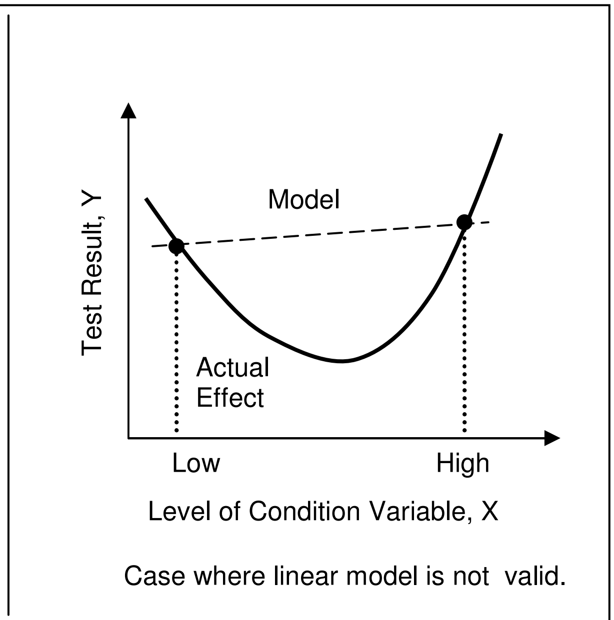


Figure 5.1b: Non Linear Statistical Model

5.3 PROPOSED EXPERIMENTAL PLAN

Following is a description of the experimental plans and designs for ruggedness testing of the three different test methods associated with the new mix design method. For each test method, a certain number of tests must be performed in order to determine its ruggedness. The individual tests performed for each test method are completed according to a statistically designed experiment involving a) a specified number of tests conducted in a random order prescribed by the experiment design, and b) two (high and low) levels of the condition variables. For each test method, the condition variables are identified as individual independent variables, in accordance with the general form of the *simple linear model*. The levels of each of the condition variables for an individual test observation are coded as follows:

- -1 for low levels
- +1 for high levels

These levels will be far enough apart for the estimated coefficients to be precise, but close enough for the linear model to provide a reasonable fit, two conflicting requirements.

Following are the planned experiment designs for each test method:

- AMT Mixing Test
- CAT Short Term Test
- ACT Test

5.3.1 AMT Test

For this test, the condition variables are:

- X1 - Filler Proportion
- X2 - Additive Proportion
- X3 - Water Content
- X4 - Emulsion Content
- X5 - Temperature
- X6 - Humidity

With six condition variables, a Plackett-Burman design with three replications will be a good choice. If the replications are assumed to be run in 3 *blocks,* there will be 12 degrees of freedom for the estimation of the standard deviation of the measurements and this should provide the precision in the estimates of the parameters in the model as well as for their standard deviations.

A Plackett-Burman design for the six condition variables associated with this test method is given below.

Table 5.1: Plackett-Burman Design for the Six Condition Variables

Observation	X1	X2	X3	X4	X5	X6
1	+1	+1	+1	-1	+1	-1
2	-1	+1	+1	+1	-1	+1
3	-1	-1	+1	+1	+1	-1
4	+1	-1	-1	+1	+1	+1
5	-1	+1	-1	-1	+1	+1
6	+1	-1	+1	-1	-1	+1
7	+1	+1	-1	+1	-1	-1
8	-1	-1	-1	-1	-1	-1

Ruggedness tests results for the AMT are contained in Appendix C.

5.3.2 CAT Test

For this test, the condition variables are:

- X1 Cure Time
- X2 Cure Temperature
- X3 Humidity of Cure
- X4 Test Time (Abrasion Time)
- X5 Test Temperature
- X6 Duration of Test

Since compaction was evaluated and considered not necessary, this is not a variable for which its value is to be controlled as is the case for the other condition variables whose effects are being studied. The experiments will be the same and the same as the Plackett-Burman experiment given for the AMT, with three replications of selected combinations. There will not be an X7 variable, but the other six variables will be as given.

5.3.3 ACT Test

For this test, the condition variables are:

- X1 Cure Temperature
- X2 Cure Time
- X3 Cure Humidity

Three replications of a half replication of a 2-cubed factorial will be used for this experiment. One such plan is given below with the coded values for the conditions:

Table 5.2: Three Replications of a Half Replication of a 2-Cubed Factorial

Observation.	X1	X2	X3
1	-1	-1	+1
2	-1	+1	-1
3	+1	-1	-1
4	+1	+1	+1

5.3.4 Randomization Requirements

It is essential that the experiments be carried out in a randomized order so that there will be a valid estimation of the true experimental error standard deviation as well as the precise estimation of the effects of the condition variables. Randomization made the conduct of the equipment less efficient; however, it was necessary to properly address ruggedness. This was originally intended to be done by the project team using the procedure specified by the project statistician.

5.4 CONCLUSIONS AND RECOMMENDATIONS

As noted earlier in Section 1.0, a second no-cost extension to the project was denied and the conclusions and recommendations section of the ruggedness testing was not conducted. More research should be considered in order to evaluate the ruggedness of the testing apparatus developed for this project.

6.0 CHAPTER 6 SLURRY SURFACING SYSTEM (3S) STRAWMAN SPECIFICATION

6.1 DESCRIPTION

This work consists of furnishing and placing a slurry surfacing system meeting the requirements of this specification. The mixture shall consist of a combination of an emulsified asphalt, mineral aggregate, mineral filler, water, and other necessary additives, mixed and placed on the pavement surface in accordance with the dimensions shown on the plans.

Any modified ingredient shall be milled or blended into the asphalt or blended into the emulsifier solution prior to the emulsification process. The emulsion supplier shall provide a certificate that the emulsion supplied to the project conforms to the requirements of Table 1.

6.1.1 ASPHALT EMULSION

The asphalt emulsion used shall conform to the requirements of Table 1. Any modified ingredient shall be milled or blended into the asphalt or blended into the emulsifier solution prior to emulsification process. The emulsion supplier shall provide a certificate that the emulsion supplied to the project conforms to the requirements of Table 6.1.

Table 6.1: Asphalt Emulsion Requirements

PROPERTY	Test Method	Minimum	Maximum
Viscosity, Saybolt Furol @ 77°F (25°C), Seconds	AASHTO T 59	20	100
Storage Stability test, one day, %	AASHTO T 59	-	1
Particle Charge test	AASHTO T 59	Positive	
Sieve Test, %	AASHTO T 59	-	0.1
Tests on Distillation			
Oil distillate, by volume or emulsion, % residue	AASHTO T 59	60	-
Tests on Residue			
Penetration, 77°F (25°C), 100g, 5 sec	AASHTO T 49	55	90
Ductility, 77°F (25°C), 50 mm/min	AASHTO T 51	70	-
Solubility in trichlorethylene, %	AASHTO T 44	97.5	
Softening Point, minimum	AASHTO T 53	135°F (57.2°C)	

6.1.2 AGGREGATE

Mineral aggregate shall meet the quality requirements in Table 6.2 and meet the grading requirements in Table 6.3. The grade of aggregate shall be as specified on the project plans.

Table 6.2: Aggregate Quality Requirements

Test	Test Method	Requirement
Sand Equivalent, min	AASHTO T-176	65
Los Angeles Abrasion, loss at 500 rev., max*	AASHTO T-96	35
Percentage of Crushed Particles, minimum	AASHTO T	100
Magnesium sulfate soundness, max. loss, %, 4 cycles	AASHTO T-104	20
Micro-Duval, loss, %**	AASHTO	Report

Note * The abrasion test is to be run on the parent aggregate
** The Micro-Duval is to be run on the project stockpile aggregate

Table 6.3: Aggregate Grades

Grade	US Sieve Size		Passing by Weight, %	Job Mix Formula Tolerance Limits, %+ -
I	⅜	9.5 mm	100	5
	#4	4.75 mm	70-90	5
	#8	2.36 mm	45-70	5
	#16	1.16 mm	28-50	5
	#30	600µm	19-34	3
	#50	330 µm	12-25	3
	#200	75 µm	5-15	2
II	⅜	9.5 mm	100	5
	#4	4.75 mm	94-100	5
	#8	2.36 mm	65-90	5
	#16	1.18 mm	40-70	5
	#30	600 µm	25-50	3
	#50	330 µm	18-30	3
	#200	75 µ	5-15	2
III	⅜	9.5 mm	100	
	#4	4.75 mm	100	5
	#8	2.36 mm	90-100	5
	#16	1.16 mm	65-90	5
	#30	600µm	40-65	5
	#50	330 µm	25-42	4
	#200	75 µm	10-20	2

6.2 STOCKPILE AND STORAGE.

If the mineral aggregates are stored or stockpiled, they must be handled in a manner that will prevent segregation and contamination. The aggregate will be accepted at the job site stockpile or when loading into the units for delivery to the laydown machine. The stockpile shall be accepted based on five gradation tests according to AASHTO T-2. If the average of five tests is within the gradation tolerances, the materials will be accepted. If the test results indicate that the material is outside the gradation limits, the material will be removed from the stockpile site or blended with other aggregate from the stockpile to achieve an acceptable product. Materials used for blending shall meet the requirements of Table 6.3 and shall be blended in an acceptable manner to assure a consistent product. Blending will require a new mix design.

The aggregate shall be passed over a 3/8 inch (9.5-mm) scalping screen prior to transfer to the laydown machine to remove oversize material.

6.2.1 WATER AND ADDITIVES.

Water shall be potable and free from harmful soluble salts or other contaminants.

The slurry surfacing mixture shall be homogeneous during and following mixing and spreading and possess sufficient stability to prevent premature breaking in the spreading equipment. Additives may be added to the emulsion mix or any of the component materials to provide control of the setting characteristics of the mixture. They must be included as part of the mix design and be compatible with the other components of the mix.

6.2.2 MINERAL FILLER.

Mineral filler may be used in the mixture and shall be introduced into the mineral aggregate and shall be an approved brand of non-air entrained Portland cement or hydrated lime that is free from lumps. Visual inspection and supplier certification are required. The amount of mineral filler to be added shall be part of the mix design process and shall be considered as part of the aggregate gradation. If additional consistency is required during the placement of the mixture, a +/- one percent change in mineral filler will be permitted without requiring a new mix design.

6.3 PAVING MIXTURE

Prior to the beginning of work, the contractor shall submit a proposed mix design for approval to the contracting agency. A laboratory capable of performing the tests that are noted in Table 6.4

shall perform the mix design. The proposed slurry surfacing mixture shall conform to the requirements of Table 6.4. The percentages of each individual material shall be shown on the design form.

Field adjustments may be necessary once the work is under way but individual materials shall be within the limits contained in Table 6.5.

Table 6.4: Slurry Surfacing Mix Design Requirements

Set Time	*Test or field Condition*	*Units*	Traffic			Temperature			Humidity	
			Hi	Med	Low	Hi 95°F (35°C)	Med 77°F (25°C)	Low 50°F (10°C)	Hi 90%	Normal 50%
	PFS-1 (Mixing)									
	Mixing Torque - maximum	*kg-cm*	9	9	9	9	9	9	9	9
	Mixing time - minimum	*sec.*	120	120	120	120	120	120	120	120
	Spread index - maximum @ 120 sec.	*kg-cm*	12	12	12	12	12	12	12	12
	Blot test - 30 sec.	-	clear water	clear water	N/A	clear water	clear water	clear water	clear water	clear water
	Coating	-	100%	100%	95%	95%	95%	100%	100%	95%
Rapid	***PFS-2 (Wet Cohesion)***									
	30 min. cohesion - minimum	*kg-cm*	12	12	12	12	12	12	12	12
	60 min. cohesion - minimum	*kg-cm*	23	20	20	20	20	20	20	20
	90 min. cohesion - minimum	*kg-cm*	25	25	25	25	25	25	25	25
	12 hr. cohesion - minimum	*kg-cm*	28	28	28	28	28	28	28	28
	PFS-3 (Abrasion Loss)									
	30 min. loss - maximum	*g/m²*	200	200	400	300	300	300	300	300
	1hr. loss - maximum	*g/m²*	100	100	300	100	200	100	100	200
	3 hr. loss - maximum	*g/m²*	100	100	200	100	100	100	100	100
	PFS-1 (Mixing)									
	Mixing Torque - maximum	*kg-cm*	9	9	9	9	9	9	9	9
	Mixing time - minimum	*sec.*	120	120	120	120	120	120	120	120
	Spread index - maximum @ 120 sec.	*kg-cm*	12	12	12	12	12	12	12	12
	Blot test - 30 sec.	-	clear water	clear water	N/A	clear water	clear water	clear water	clear water	clear water
	Coating	-	100%	100%	95%	95%	95%	100%	100%	95%
Slow	***PFS-2 (Wet Cohesion)***									
	30 min. cohesion - minimum	*kg-cm*	12	12	12	12	12	12	12	12
	60 min. cohesion - minimum	*kg-cm*	23	20	20	20	20	20	20	20
	90 min. cohesion - minimum	*kg-cm*	25	25	25	25	25	25	25	25
	12 hr. cohesion - minimum	*kg-cm*	28	28	28	28	28	28	28	28
	PFS-3 (Abrasion Loss)									
	30 min. loss - maximum	*g/m²*	200	200	400	300	300	300	300	300
	1hr. loss - maximum	*g/m²*	100	100	300	100	200	100	100	200
	3 hr. loss - maximum	*g/m²*	100	100	200	100	100	100	100	100

Table 6.5: Allowable Field Adjustment

Component	Adjustment
Slurry System Residual Binder Content	5.5% - 9.5% by dry mass of aggregate
Water and Additives	As needed
Mineral Filler	0% - 3% by dry mass of aggregate

6.4 APPLICATION RATE

The slurry surfacing shall be of the proper consistency at all times in order to provide the application rate required by the plans and specifications to meet the surface conditions. The average single application rate, if not specified, shall be in accordance with the requirements of Table 6.6.

Table 6.6: Application Rates

Aggregate Grade	Facility	Application Rate	
A	Primary and Interstate Routes	15-30 lbs./yd^2	8.1-16.2 kg/m^2
	Wheel Ruts	See Section 6. (d). 2	
B	Urban, Residential Streets, Airfield Runways & Taxiways	10-20 lbs./yd^2	5.4-18.6 kg/m^2
C	Parking Areas, Residential Streets, Airfield Runways & Taxiways	8-12 lbs./yd^2	3.6-5.4 kg/m^2

6.5 QUALITY ASSURANCE

Prior to the beginning of the project, the contractor shall provide an orientation session for project personnel, a test strip, and project documentation.

6.5.1 ORIENTATION SESSION FOR PROJECT PERSONNEL.

The contractor shall provide a minimum 45-minute orientation session with the project personnel to discuss the construction process, materials control, materials measurement requirements of the project, and any unique project conditions that need to be addressed. This session may be waived at the direction of the engineer.

6.5.2 TEST STRIP.

With the coordination of the owner, the contractor shall arrange for a test strip to be constructed on or near the project site under as reasonable as possible the anticipated placement conditions of time of day, temperature, and humidity. The test strip shall be 300 to 500 feet (91.4 – 152.4 m) in length and shall be constructed with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mix design shall be permitted provided they do not exceed the values stated in Table 6.4. The test strip shall be evaluated by the owner to determine if the mix design and placement techniques are acceptable once the mixture has set and cured. If modifications to the mix design in excess of the values noted in Table 6.4 are necessary, a new mix design shall be prepared and another test strip constructed. The cost of the materials and placement of the rejected test strip shall be borne by the contractor including any removal costs.

6.5.3 PROJECT DOCUMENTATION.

After the project is underway, the contractor shall, on a daily basis, furnish the owner project documentation that includes the total amount of material delivered to the project and the total amount placed through the mixing machine from the dial gauges. The owner's agent shall verify the dial gauge readings and material weights delivered and this information will be used to independently verify the mix proportions.

6.6 CONSTRUCTION REQUIREMENTS

6.6.1 WEATHER LIMITATIONS.

Slurry systems shall not be applied if either the pavement temperature or the air temperature is below 50°F (10°C) and falling. No material shall be applied when there is the eminent possibility of rain or if the finished product is subject to freezing within 24 hours. The mixture shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

6.6.2 MIXING EQUIPMENT.

The materials shall be mixed in a specifically designed piece of equipment, either truck mounted for small applications and residential work, or continuous run machine for larger projects such as highways and airports. The machine must be a continuous-flow mixing unit able to accurately proportion and deliver the aggregate, emulsified asphalt, mineral filler, additives, and water to a continuous flow mixing chamber. The machine shall have sufficient storage capacity for all the mixture ingredients to maintain an adequate supply to the mixing chamber.

6.6.3 PROPORTIONING DEVICES.

Individual volume or weight controls for proportioning each material shall be provided and properly identified. These devices are used in material calibration and may be used to determine the material output on demand.

6.6.4 SPREADING EQUIPMENT.

The mix shall be agitated and spread uniformly in a specially designed box that is equipped with twin shafted paddles or spiral augers that are permanently fixed to the box. A front seal shall be provided to insure there is no loss of the mixture. The rear seal shall be adjustable and act as the final strike-off of the mixture. The spreader box and rear strike-off shall be designed so that a uniform mixture is delivered to the rear strike-off.

The box shall be able to be shifted laterally to compensate for variability in the geometry of the pavement.

6.6.4.1 Secondary Strike-Off.

Where required on the plans, the spreading equipment shall be equipped with a secondary strike-off to provide a satisfactory surface texture. It shall be capable of having the same leveling adjustments as the spreader box.

6.6.4.2 Rut Box.

When the plans require that wheel ruts, depressions, and utility cuts, and others be filled prior to placing the finished wearing course, material shall be placed with a specially designed rut filling spreader box when rut depths are greater than 1/2 inch (12.7 mm). For ruts of less than 1/2 inch (12.7 mm), a full width scratch course using the conventional spreader box is acceptable. Rut boxes are typically designed to be 5 feet (1.8 mm) or 6 feet (1.8 mm) wide. Where ruts exceed 1 1/2 inches (39 mm), multiple passes with the rut box are necessary. All rut filling should be allowed to cure under traffic for at least 24 hours before the final surface course is placed. Mixtures for filling ruts, depressions, utility cuts, and others shall meet the requirements of Type A as specified in Table 6.3 Aggregate Grades (page 84).

6.6.5 MACHINE CALIBRATION.

Each unit to be used for the placement of slurry systems shall be calibrated in the presence of the owner's representative. Previous calibration covering the same materials to be used may be acceptable provided that no more than 60 days has elapsed. The calibration documentation shall include an individual calibration of each material at various settings that can be related to the metering devices on the machine. No equipment shall be permitted to work on the project without a completed calibration.

6.6.6 WORKMANSHIP.

When placing slurry surfacing mixtures, the longitudinal and transverse joints shall be uniform, neat in appearance, and not contain material build-up or uncovered areas. Longitudinal joints shall be placed on lane lines, edge lines, or shoulder lines and shall have a maximum overlap of 3 inches (75 mm). Longitudinal joints shall be straight in appearance along the centerline, lane lines, shoulder lines, and edge lines.

The finished surface shall have a uniform texture free from excessive scratch marks, tears, or other surface defects. A total of four tear marks are considered to be excessive when they exhibit the following criteria:

- 1/2 inch (12.7 mm) wide or wider
- 6 inches (150 mm) or more long
- Within 100 yd^2 (85 m^2) of any mark that is:
    - 1 inch (25 mm) wide or wider
    - or 4 inches (100 mm) long.

The contractor is expected to produce neat and uniform longitudinal and transverse joints. Transverse joints shall be constructed as butt-type joints. Joints are acceptable if there is no more than a 1/2 inch (13 mm) vertical space for longitudinal joints, and no more than 3/8 inches (9.5 mm) for a transverse joint between the pavement surface and a 4 feet (1.2 m) straightedge placed perpendicular on the joint.

6.6.7 SURFACE PREPARATION.

Immediately before applying the slurry surfacing, the pavement surface shall be cleaned of all loose material, vegetation, and other objectionable materials. Any standard cleaning procedure is acceptable. If water is used, cracks shall be permitted to dry thoroughly before applying the slurry mixture. A suitable method shall be used to cover service entrances (i.e., manhole covers, valve boxes). No dry aggregate, either spilled from the mixing machine or existing on the pavement surface, will be permitted.

6.6.8 TACK COAT.

If required on the plans, a tack coat consisting of one part SS or CSS emulsion and three parts water shall be applied with a standard distributor. The distributor shall be capable of applying the diluted emulsion at the rate of 0.05 to 0.10 gallons/yd^2 (0.16-0.32 liters/m^2). The tack shall be allowed to cure sufficiently before the application of the slurry surfacing.

6.6.9 CRACKS.

Existing cracks on the surface of the pavement shall be treated with an acceptable material well in advance of the placement of the slurry surfacing. The surface of the crack filling material shall be 1/8 inch (3.175 mm) below the surface of the roadway.

6.6.9.1 Handwork.

In areas where the placement equipment cannot work because of space limitations, these areas should be surfaced using hand tools to provide a complete and uniform coverage. These areas should be cleaned and lightly dampened before placing the mix. The finished texture shall be uniform and have a neat appearance as nearly as possible to that produced by the spreader box.

6.6.9.2 Application.

The surface of the pavement shall be pre-wetted by fogging ahead of the spreader box. The rate of application shall be adjusted during the placement based on the temperature, texture of the pavement surface, and humidity.

6.6.9.3 Clean Up.

All areas including service entrances, gutters, and intersections shall be cleaned of the slurry surfacing on a daily basis as well as any debris associated with the placement.

6.7 METHOD OF MEASUREMENT

6.7.1 AREA

On small projects, less than 50,000 yd^2 (41,805 m^2), the method of measurement and payment shall be based on the area covered, which is measured in square feet, square yards, or square meters.

On projects larger than 50,000 yd^2 (41,805 m^2), the measurement is based on the quantity of aggregate (tons or metric tons) and emulsified asphalt (gallons or liters) that are used. The aggregate is measured by the actual weight delivered to the project laydown site or is weighed at the stockpile with certified scales. Delivery tickets or printed weights shall be used for measurement. The emulsified asphalt will be measured by certified tickets for each load delivered to the project. Unused or returned emulsion will be deducted.

6.8 BASIS OF PAYMENT

The slurry surfacing shall be paid for by the unit area or the quantities of the aggregate and emulsified asphalt used and accepted on the project. The price shall include furnishing, mixing, and applying the slurry surfacing; labor, equipment, tools, mix design, test strips, surface preparation, and incidentals necessary to complete the project.

7.0 CHAPTER 7 SUMMARY AND CONCLUSIONS

7.1 SUMMARY

This study, "Slurry Seal/Micro-Surfacing Mix Design Procedure", was conducted from July 2003 to November 2008 by Fugro Consultants Inc., Austin, Texas serving as the prime contractor with support from Applied Pavement Technology, Inc., Urbana, IL, MACTEC Engineering and Consulting Co., North Highlands, CA and CEL Laboratories, Oakland CA. The project was the result of a 14 state pooled fund solicitation managed by the California Department of Transportation.

The purpose of the study was to develop a rational mix design procedure for slurry seal and microsurfacing mixtures. After conducting an extensive national and international literature review and an industry survey of existing practices, the research team posited a mix design process that formed the basis for the remainder of the study. A number of possible test methods were identified that would potentially assist the study in identifying the characteristics of slurry surfacing mixes that relate to mixing, spreading, and curing. The intention was to use procedures, either existing or developed ones that would minimize operator (technician) bias and also relate to various placement conditions in the field.

Two test procedures that had been used in Europe, the "German" mixing test which the team renamed the Automated Mixing Test (AMT) and the "French" Wet Track Abrasion Test renamed the Cohesion Abrasion Test (CAT) were identified in the literature survey and were selected to be studied in comparison to existing International Slurry Surfacing Association test methods TB-113 and TB-100. A third procedure, an automated cohesion tester, was developed by an equipment manufacturer for the study and was named the ACT.

The benefit of using the AMT mixing test, once all the equipment details were worked out, was the standardization of the mixing process under various temperature and humidity conditions that could be expected in the field. The CAT was adopted since the method used standard equipment used in TB-100 but used the entire gradation of the mix unlike TB-100 which the plus #4 material is scalped off. The ACT eliminates the operator bias associated with the torque wrench that is used to apply the load to the specimen.

In addition to the test procedure development, test protocols were developed for both the AMT and CAT and ruggedness testing was conducted for both test methods.

Delays in the progress of the research because of personnel transfers and equipment issues caused the research team to request two no-cost time extensions to the contract. The first was granted which extended the project for one year through October 2008 and the second one was not. The result was that there was approximately $75,000 in contract funds unspent and we were not able to complete the ruggedness testing and test protocols for the ACT nor were we able to construct test sections to validate the new test methods. The details for the construction of the test sections are included as an appendix to the final report should some agency wish to pursue this activity.

7.2 CONCLUSIONS

It is reasonable to conclude that the study, in spite of the delays and setbacks, was successful in attempting to identify test procedures that relate mixtures produced in the laboratory to field performance. As stated in the report and summarized above, we unfortunately were not able to validate the laboratory procedures to performance. Significant progress was accomplished during this study to develop test procedures that reduce operator bias but more work needs to be done to possibly improve the ACT test equipment, develop a test protocol, and conduct ruggedness experiments.

Agencies or industry partners should be encouraged to further the work by conducting field projects to validate this study and to modify where necessary the test methods proposed.

As often happens with any experimental research study, unanticipated circumstances arose to preclude this study from reaching a concise and implementable conclusion but the work conducted and reported on improves the state of the knowledge of slurry surfacing systems.

APPENDIX A PROPOSED TEST METHOD FOR THE AUTOMATED MIXING TEST (AMT)

Constructability of Asphalt Emulsions and Aggregate Mixture Systems [Automated Mixing Test (AMT)]

AASHTO Designation xxxx: Draft Proposed Test Method

1.0 SCOPE

1.1 The test method covers measurement of the constructability of slurry surfacing materials once basic ratios of components have been established. By automatic and constant recording of the complete torque-measurement-curve, the mixing curve indicates each variation during the breaking process. The evaluation takes place under controlled conditions and the control system provides an automatic report of results.

1.2 The main parameters that are measured are:

- Mixing Torque (Mix Index)
- Mixing Time
- Spread Time
- Maximum Torque (Spread Index)

1.3 The test method is in development.

1.4 The values stated in SI units are to be regarded as the standard.

2.0 REFERENCED DOCUMENTS

2.1 International Slurry Surfacing Association (ISSA) Technical Bulletin (TB), TB-113, Trial Mix Procedure for Slurry Seal Design.

2.2 Thin Lift in Cold-Applied Micro-Surfacing, Instructions for the Electric Mixing Test, (Translated from German).

2.3 Computer software: Labsoftworld 4.5.

2.4 IDA Werke EUROSTAR Power control-visc manual.

2.5 Velp Scientific mixing stirrer manual.

3.0 TERMINOLOGY

3.1 Definitions:

3.1.1 Mixing Torque (Mix Index), N-cm: the torque value measured in the initial, relatively flat portion of the torque-time plot, where mixing takes place without a significant increase in the measured torque.

3.1.2 Mixing Time, minutes: the amount of time over which mixing takes place without significant increase in the measured torque; or the amount of time corresponding to the initial, relatively flat portion of the torque-time plot before the torque-time plot begins to increase.

3.1.3 Spread Time, minutes: the amount of time over which the torque increases from the Mixing Torque value to a value of 12 N-cm.

3.1.4 Maximum Torque (Spread Index), N-cm: the maximum torque measured before the mix breaks and becomes brittle.

3.1.5 Breaking Time, minutes: the total amount of time until the mixture breaks by observation.

3.1.6 Pre-Wet Water: The amount of water added to the dry aggregate and dry additive, when applicable. This moistens the aggregate before adding the liquid additive and asphalt emulsion.

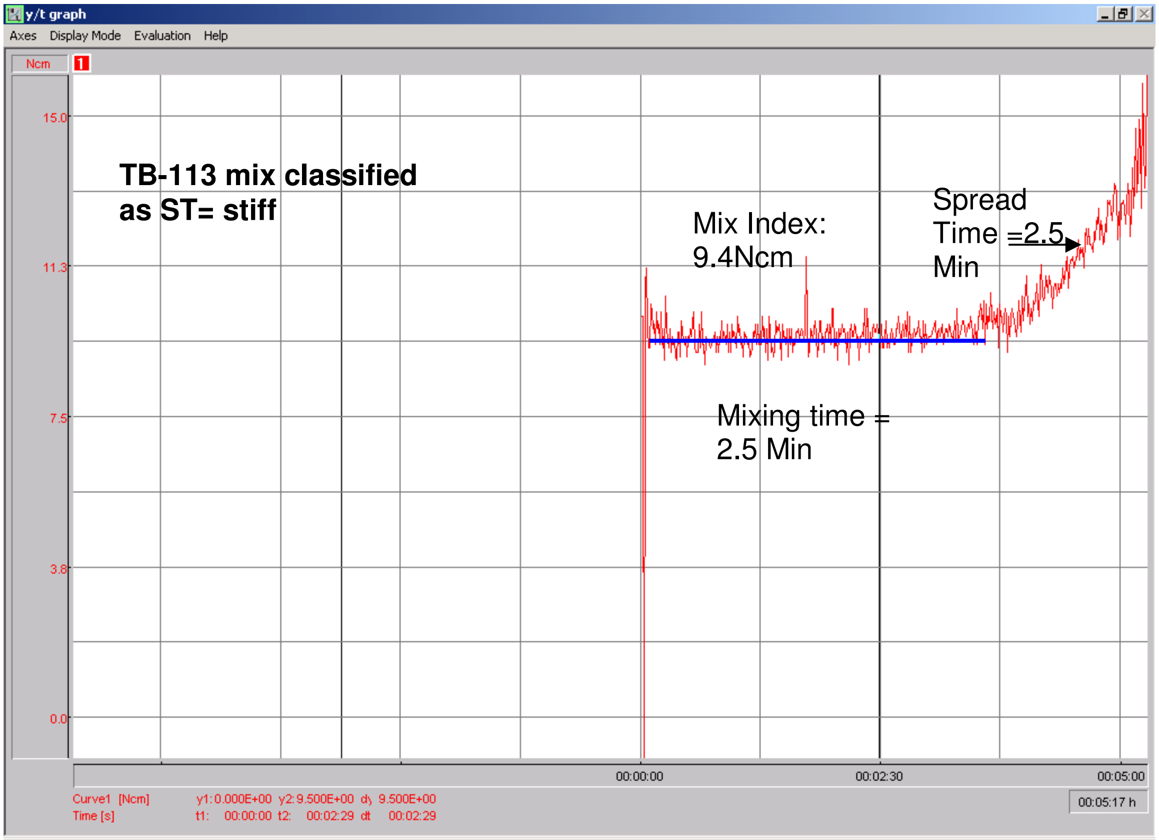


Figure A.1: Representation of Definitions

4.0 SUMMARY OF METHOD

4.1 The asphalt emulsion, aggregate, set control additives, and water are the components of the mix. The mix components, at the prescribed temperature, are weighed into a test container. Other components to be added are determined by the mix design or through pre-testing using the hand mixing method, ISSA TB-113. The asphalt emulsion and water (with additive) are placed in the container after being conditioned at the test temperature. The mixing cup is centered under the stirrer and lowered to 0.06 inches (1.5 mm) from the bottom of the cup. Then rotation of the stirrer is started manually and maintained at 50 rpm for 5 sec. The test measurements are captured by the control system. The mix is stirred until it either breaks or 10 minutes have elapsed.

4.2 The breaking of the mixture is also visually observed. The surface of the mixture in the bowl will appear very rough and coarse. At this point the mixture fragments into parts and free liquid may be observed.

4.3 If the mix does not break, the test is terminated at 10 minutes mixing and observations made as to greater than or less than the specification level.

5.0 SIGNIFICANCE AND USE

5.1 This test method will measure compatibility and setting parameters of asphalt emulsions and mineral aggregates.

5.2 This procedure is suggested for establishing design criteria of the mix system. In addition, it provides a means of quality control during the production of asphalt emulsion, mineral aggregates, and additives.

5.3 This method facilitates research and development of new combinations of raw materials.

5.4 This method documents the temperature influences on the consistency of the mixed materials.

5.5 This method measures the affect of compositional changes on mixing.

6.0 APPARATUS

6.1 The AMT System set-up is illustrated in Figure A.2.

6.2 IKA Werke EUROSTAR power control-visc, R-1826 Plate Stand, R-182 Boss Head, RH-3 Strap Clamp

6.3 Velp Scientific stirring shaft with propeller: 3 stainless steel blades, 2.4 inches (61 mm), shaft 15.75 x 0.25 inches (400 X 6.4 mm)

6.4 Mixing bowl: stainless steel, 10 oz, 2.75 inches (70 mm) tall, 2 inches (50.8 mm) radius with a rounded flat bottom (Vollrath #99637)

6.5 Balance accurate to 0.1 g

6.6 PC capable of running labworldsoft 4.5 software by IKA Werke (Windows 2000 or higher), with Excel® software program.

6.7 Thermometer calibrated between 32°F (0°C) and 122°F (50°C)

6.8 Spatulas

6.9 Constant temperature cabinet or room

Figure A.2: Testing Apparatus

7.0 SAMPLE PREPARATION

7.1 Aggregates: Sample representative portions of aggregates used for slurry seal mix or micro-surfacing mix. Use material of the type, grade, and source proposed for the project . Aggregates shall be dried at 140°F (60°C) to a constant mass and cooled to the prescribed test temperatures prior to performing the test.

7.2 Bitumen emulsions maintained at the test temperature and representative of the material to be used in the project.

7.3 Set control additives both solid and liquid that shall be used in the project.

7.4 Distilled drinking water with a pH between 6.0 and 7.0 shall be used.

8.0 PROCEDURE

8.1 Maintain the aggregate, emulsion, water, and additives at the test temperature 77°F (25°C).

8.2 Set up the IKA Werke EUROSTAR ready for test with the control system ready on the correct measurement configuration. See the Appendix for establishing the signal flow.

8.3 The amounts of materials shall be quantified by a mix design, from TB-113 or in a matrix to determine specific mix effects.

8.4 Add 300g of aggregate into the mixing bowl.

8.5 Add the required amount of solid additives, when applicable, and mix well by hand.

8.6 Add pre-wet water, followed by the liquid additive, when applicable, and mix well by hand. Pre-wet water refers to the amount of water added to dry aggregate to ensure that it is moist prior to mix it with emulsion or liquid additive.

8.7 Add the emulsion and quickly blend with the aggregate within 5-10 seconds.

8.8 Within 5 seconds, quickly place the bowl and mix contents in the EUROSTAR, such that the bottom of the propeller is 0.04-0.08 inches (1-2 mm) above the inside bottom of the bowl.

8.9 Start the mixer manually and mix for 5 seconds

8.10 Start test and monitor torque.

8.11 Switch off test at 10 minutes or when torque rises to a maximum and then falls off, which ever comes first.

9.0 REPORT

Report the following:

9.1 Mixing Torque, N-cm

9.2 Mixing Time, minutes

9.3 Spread Time, minutes

9.4 Maximum Torque, N-cm

9.5 Breaking Time, minutes

9.6 If the mixture mixes beyond 10 minutes without increasing in torque or breaking, note results as greater than 10.

9.7 Blot Test results.

10.0 PRECISION AND BIAS

Additional studies are required. The equipment is still open for further development.

11.0 BLOT TEST

11.1 General Information

The Blot Test is the second step for evaluating the mix proportions determined and tested using the hand mixing method, ISSA TB-113. The Blot Test results indicate several conditions of the mix that represent break.

11.2 Terminology

11.2.1 Definitions:

11.2.1.1 BT: brown color transfer to white absorbent paper towel

11.2.1.2 A: aggregate and clear water transfer to white absorbent paper towel

11.2.1.3 CW: clear water transfer to white absorbent paper towel

12.0 PROCEDURE

12.1 Perform the test at temperatures used in TB-113.

12.2 Weigh 100 g of aggregate into a suitable mixing bowl.

12.3 Add the desired amount of dry mineral filler or additive and hand mix dry with spatula at 60 rpm in a circular motion for 10 seconds or until distribution of the dry ingredients are uniform.

12.4 Add the desired amount of pre-mix water and hand mix at 60 rpm in a circular motion for 10 seconds or until distribution of the water is complete and uniform.

12.5 Add the desired amount of liquid set additive and hand mix at 60 rpm in a circular motion for 10 seconds or until distribution of the liquid additive is complete and uniform.

12.6 Add the desired amount of emulsion and hand mix at 60 rpm in a circular motion for 120 seconds.

12.7 Remove approximately one-quarter of the mixture onto roofing felt. Spread the mix evenly to a depth of 3.9 to 5.9 inches (99 -150 mm). Begin timing.

12.8 At the end of 30 seconds, blot the mix surface with a white absorbent paper towel. Note the color transfer onto the paper towel.

12.9 Repeat the procedure for various mix proportions used for evaluating the mix system being tested.

12.2 Report

12.2.1 Mix proportions tested.

12.2.2 Record the Blot Test results as BT: brown color transfer, A: aggregate and clear water transfer, or CW: clear water transfer.

13.0 Labworldsoft® Signal Flow Diagram Construction for the Automated Mixing Test

13.1 General Information

The Labworldsoft® Computer software is laboratory automation software used in conjunction with the Microvisc (or equivalent) stirrer to measure torque, speed, and time and calculate viscosity per the proposed draft test method, "Constructability of Asphalt Emulsions and Aggregate Mixture Systems."

The laboratory software application controls all of the laboratory equipment with an RS-232 serial interface or analog interface to perform measuring, controlling, and regulating operations. It is operated with the mouse and/or keyboard in the same manner as all Windows® applications.

13.2 Installation

To install, follow the procedures provided with the installation CD. If it is to be started whenever Windows® is launched, copy or drag the "Labworldsoft®" application icon into the "auto start" window.

13.3 Starting the Program

1. Switch on Computer
2. Start Windows ®(if not automatic)
3. Connect laboratory instrument to PC
4. Double-Click on application symbol (Labworldsoft® 4.5)

Note: Closing all other programs running in the background will allow the Labworldsoft® program to run at optimum speeds during operation.

13.4 Generating a Signal Flow Diagram for IKA®-Werke Eurostar Power Control-Visc

After starting the program, a blank screen will appear with a menu bar at the top. For purposes of this procedure, the term signal flow diagram is also known as measurement sequence and configuration file.

The first step is choosing functional units for use. Functional units are represented with icons and color coded according to their purpose, listed below.

Blue – Lab instruments (Hardware)
Yellow – Averaging and/or arithmetic operations
Red – Manual or auto control of instruments or files
Green – Displaying results - graphical, numerical, and saving

1. Click on "Laboratory Instruments" in the menu bar. A drop down menu will appear. On the drop down menu, go to "IKA Werke." Another drop down menu will appear. On it, go down to "Eurostar Power control-visc" and left click on it. An icon representing this instrument will appear on the page.

2. Click on "Module" in the menu bar. A drop down menu will appear. On this drop down menu, go to "Signal Processing." Again, another menu appears. Choose "Mean Value" by left clicking on it. An icon representing mean value will appear on the page.

This process will continue until all functional units are chosen. The following chart is an abbreviation of the steps above.

Menu Bar (click on item)	1st Drop Down Menu	2nd drop down menu
Lab Instruments	IKA Werke	IKA Eurostar Power Control Visc
Module	Signal Processing	Mean Value
Module	Controlling	Rated Value
Module	Visualization	y/t graph
Module	Visualization	Digital Instruments
Module	Files	Write

Now that all the functional unit icons are selected, position them on the "page" using the diagram in Figure A.3 by clicking on the icon and dragging it to its location.

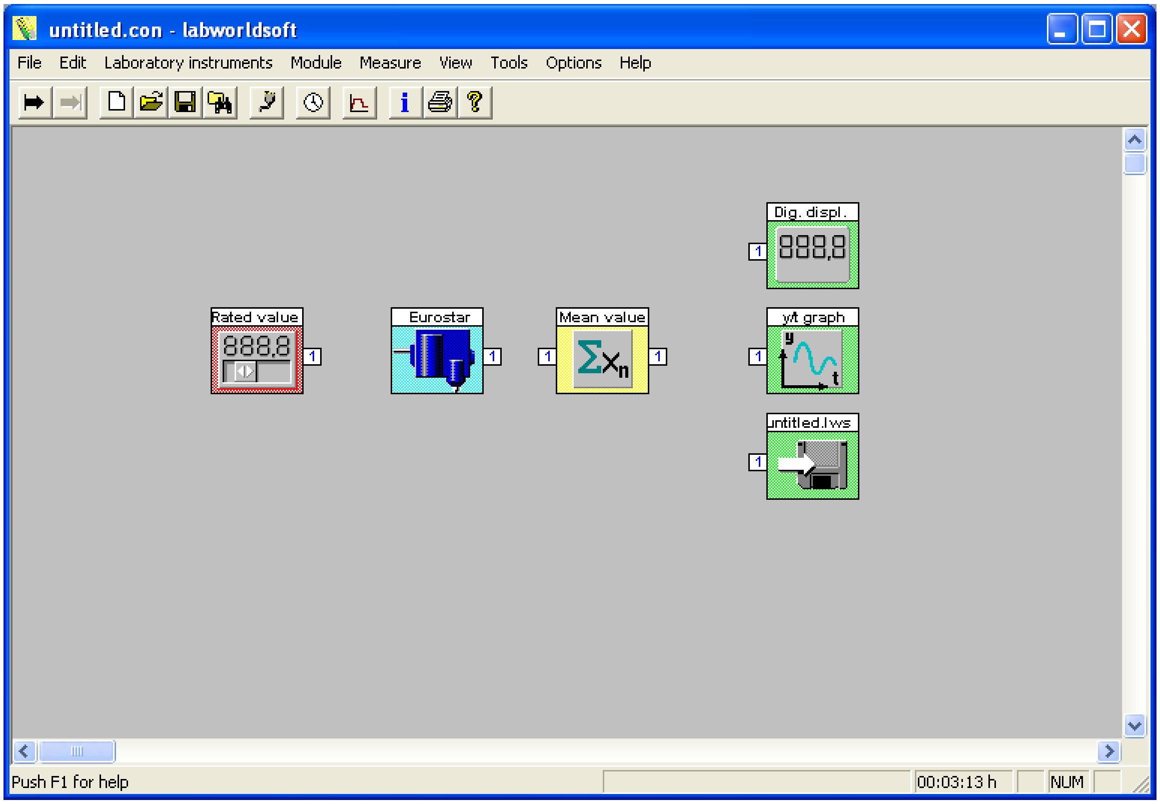


Figure A.3: Position of Functional Unit Icons.

If a need arises to remove a functional unit, use the right mouse button; double-click on the icon to be removed.

In the second step, parameters of the functional groups are set in their respective parameter window. This includes the port number for the RS-232 interface and input/output paths for controlling variables or results. After choosing parameters, they appear as numbers on the related symbol.

To change and/or set parameters of each functional unit, double-click on its respective icon. This will bring up the parameter window, when open; you make change/set parameters according to the following. Left click on "OK" when changes have been completed for each functional unit.

– Rated value – change description to "RPM"; go to the RPM window and Restore Up; set rate to "50" and minimize RPM window, if desired

- Eurostar mixer – the parameter window will open
    - Click on the drop down menu in the "Port" section. Make sure correct port is chosen, COM1.
    - In the "Control" box, check on "rated speed".
    - In the "Measured values" box, check on "Torque trend".
- Mean Value – select "Sliding arithmetic mean", Enter "1" for No. of values to be averaged
- Digital Display – change the Description to "Torque"; go to drop down menu for unit and select "Ncm".
- y/t Graph – this plots torque (y) over time. Go to the drop down menu in the Settings area and select "Ncm" under units. Change the Y-max scale to 20.0. Go to the y/t graph window and Restore Up. Select drop down menu "Display mode", select "Color and Lines", click on "Drawing surface", click on "Color" box and select the white colored tile, and click on "OK". Additionally, click on "Axes", select "Time Scale" and set at 10 minutes.
- Save Data – the parameter window will open. Can choose multiple channels for saving multiple pieces of data. For now, make sure one channel is specified. Check the box to "also save data in ASCII file." To save data in a specific location, use the "Path" box. Clicking on that opens the "Save" window and a location/path can be chosen.

See Figure A.4, which should show a final representation of the changes made above.

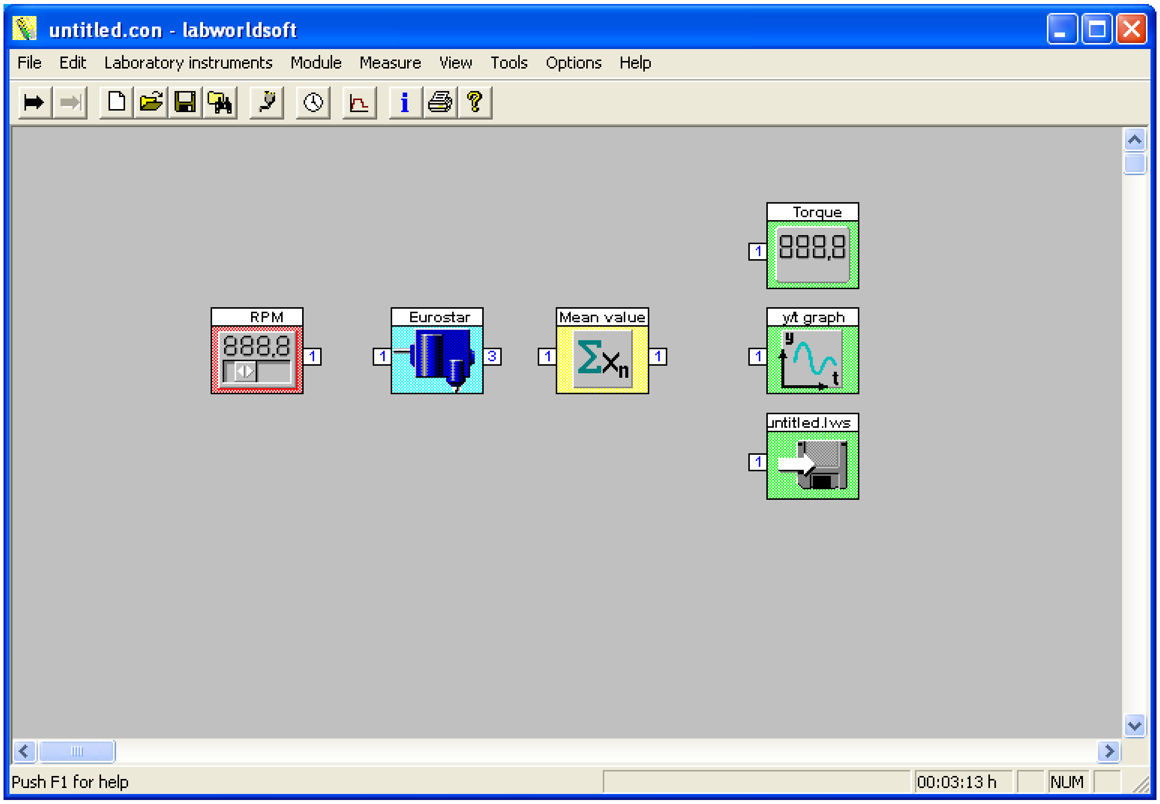


Figure A.4: Final Representation of Set Parameters.

In the third step, the signal flow begins to take shape by connecting the input/output paths using anchor points described earlier.

1. Left click on the output/number field of the left-handed functional unit. The mouse pointer will change to a hand with a writing instrument.
2. Press the left mouse button down and drag the arrow to the input path/number field to be connected.
3. Release the mouse button and the connection is created.

Connect each functional unit as in Figure A.5.

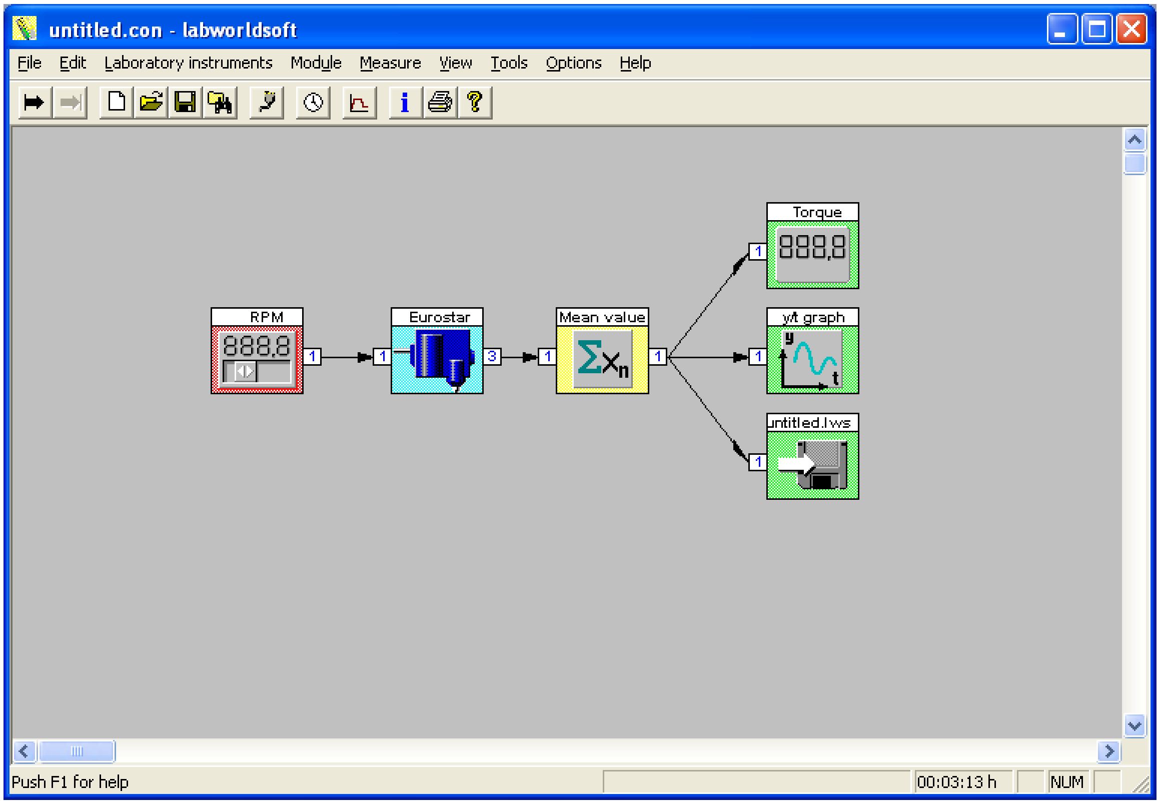


Figure A.5: Display of Functional Units Connection.

If a need arises to remove the connections created, with the right mouse button, double click on the number field of the connection input path to be deleted.

13.5 Displaying Control and Result Windows

Actual control of the sequence takes place in special windows. Depending on the functional control unit (push button, ramping), its control feature will be present. After beginning the measurement sequence, results are displayed in special windows. Depending on the functional result unit, numerical, graphical, and and/or results recording are visible when the window is visible. These windows are not visible initially. A minimized icon version is at the lower edge of screen.

To Restore/maximize control/result windows:

– Click on the full screen icon in the right had corner of the minimized icon.

To reduce/minimize control/result windows:

– Click on the minimize icon in the upper right hand corner of the enlarged window.

13.6 Test Sample

Refer to the proposed AASHTO test method for instructions regarding equipment and test specimen preparations prior to testing.

13.7 Controlling Measurement Sequence

Before starting the test, have the windows restored as in Figure A.6.

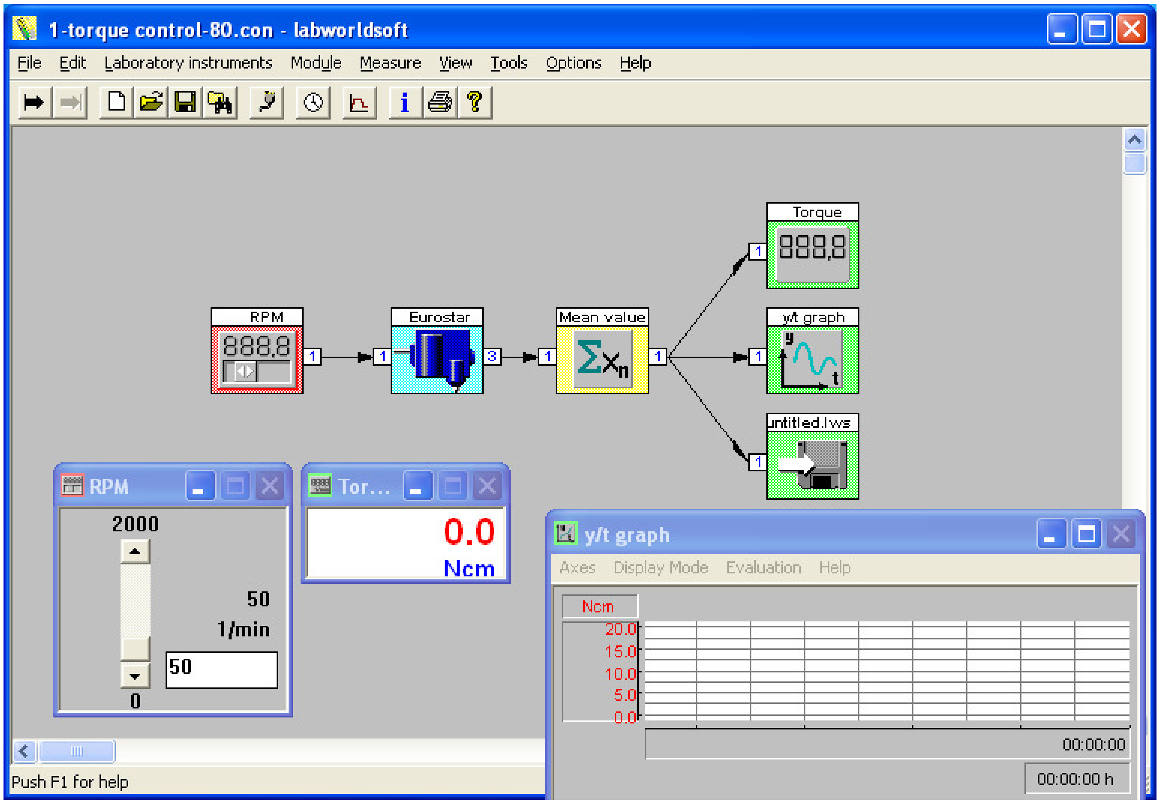


Figure A.6: Display of Restored Windows

For the proposed test method, starting and stopping of the measurement sequence will be controlled manually:

- Select the drop down menu “Measure”
- Place premixed mixture and bowl in testing apparatus
- Set stirrer into the mixture at required distance from the bottom of the bowl
- Turn on power control-visc
- Click on “Start”; a window will pop up prompting to overwrite the file, click on “Yes” immediately to begin recording the torque.

To stop the test, select the drop down menu “Measure” and click on “Stop”. A window will pop up prompting to end current measurement. Click “Yes”.

13.8 Saving Measurement Sequence

To save the signal flow diagram created, standard windows functions are used. Hold down “CTRL” + “Alt”, press “Print Screen” and paste the y/t graph into a Microsoft Work document. Add the mix details: mix description, test temperature, aggregate (g), mineral filler (%), water (%), set additives (%), emulsion (%), mix index, mixing time, spread time, maximum torque, and total time for break.

Save file with an appropriate file name.

To differentiate from other files managed by this software, signal flow configuration files have the extension*.con.

13.9 Other Options

Other options, such as printing, opening, creating new file, etc., are available in the menu bar and icon bar, using standard window functions.

APPENDIX B PROPOSED TEST METHOD FOR THE COHESION-ABRASION TEST (CAT)

DRAFT Proposed Method of Test for Measurement of Cohesion Build Up and Wearing Qualities of Asphalt Emulsions and Aggregate Mixture Systems [Cohesion Abrasion Test (CAT)]

AASHTO Designation xxx: DRAFT Proposed Test Method

1.0 SCOPE

1.1 The test method covers measurement of the wearing qualities of slurry seal and micro-surfacing mixture systems under wet abrasion conditions at different levels of cure. The method is also suitable for measuring early cohesion of slurry and microsurfacing mixes under different cure conditions.

1.2 The test method is applicable to mixes after the formulation of the slurry seal or micro-surfacing and, its set additives and water contents have been adjusted to prepare homogenous flowing consistency.

1.3 The method may be used to assess the stripping potential of aggregates in early life.

1.4 The test method is in development.

1.5 The values stated in SI units are to be regarded as the standard.

2.0 REFERENCED DOCUMENTS

2.1 ASTM D-3910-80a, Practice for Design, Testing, and Construction of Slurry Seal.

2.2 ASTM D-6372, Practice for Design, Testing and Construction of Micro-Surfacing.

2.3 ISSA TB-100, Test Method for Wet Track Abrasion of Slurry Surfaces.

2.4 SCREG Surface Cohesion Test for Slurry Systems, C. Deneuvillers, ISSA 37th Annual Meeting, Mexico, 1999.

2.5 ISSA TB-113

2.6 AMT Mixing Test

3.0 SUMMARY OF METHOD

3.1 Asphalt emulsion, aggregate, setting additives, and water are the components of the mix.

3.2 The proportions of the components will be derived after optimizing the binder content from previous testing as recommended in the mix design. The mix is cured for specific times under prescribed temperature and humidity conditions. After curing, the specimen is weighed and then placed in a circular pan on the planetary type mechanical mixer. Water is placed over the sample; in some cases the sample may be soaked in water before hand. The specimen surface comes in contact with the abrading dual wheel head. The wheels move across the surface in a planetary movement and abrasion occurs for 60 seconds. After the end of abrasion, the specimen debris is rinsed off. The remaining test specimen is dried with an absorbent paper and the final weight is recorded. The difference of the original and final weights is the measured loss of the test specimen.

3.3 A loss mass below 100 g is representative of a high cohesion slurry seal or micro-surfacing mix. A loss of mass of 100-300 g represents an average cohesion. When the loss of mass is close to 400 g, it is expected that the slurry seal or micro-surfacing mix will not resist traffic early in the curing stages of the system.

4.0 SIGNIFICANCE AND USE

4.1 The test method will measure early stage abrasion resistance and abrasion resistance of cured mixtures.

4.2 The test method can quantify the influence of some formulation parameters on setting time and cohesion build up (such as variations of the mix components or the environmental temperature and/or humidity conditions while laying).

5.0 APPARATUS

5.1 The CAT system set-up is illustrated in Figure B.1

5.2 Planetary type mechanical mixer, such as Hobart N-50 equipped with a dual wheel abrasion head, quick-clamp mounting plate, and flat bottom metal pan. See Figure 5.1.

5.2.1 Ridged Wheels: 4 inches (100 mm) diameter with 0.8 inches (20.3 mm) contact width.

5. 2.2 Wheel hardness of 75 and 95 (durometer reading) foot.

5. 2.3 Abrasion head should weigh between 1100 g and 1150 g.

5. 2.4 Aluminum abrasion pan, approximately 2.16 inches (55 mm) high with an inside diameter approximately 11 inches (279.4 mm).

Figure B.1: Testing Apparatus

5.3 Stainless steel or aluminum casting plates: 0.8 inches (2 mm) thick, 10.8 inches (274.3 mm) diameter.

5.4 Suitable specimen casting mold with .55 inches (14 mm) depth and 9.8 - 9.9 inches (250-252 mm) inside diameter. A raised lip mold is preferred but a flat surface polymethyl methacrylate or equivalent mold is satisfactory.

5.5 Mold strike-off apparatus, such as a wooden dowel, with minimum dimensions: 0.78 - 17.7 inches (20 mm diameter by 450 mm long).

5.6 Scales, with capacity of 2000.0 g, accurate to +/- 0.1 g.

5.7 Wooden prop block or device to support the pan and mounting plate assembly during the test.

5.8 Suitable rust-resistant mixing containers and spoons. Additionally, plate removal device with tapered flat tip (for example, a paint can lid opening tool), as pictured in Figure B.2, is needed for carefully placing and removing specimen plates into and from the abrasion pan.

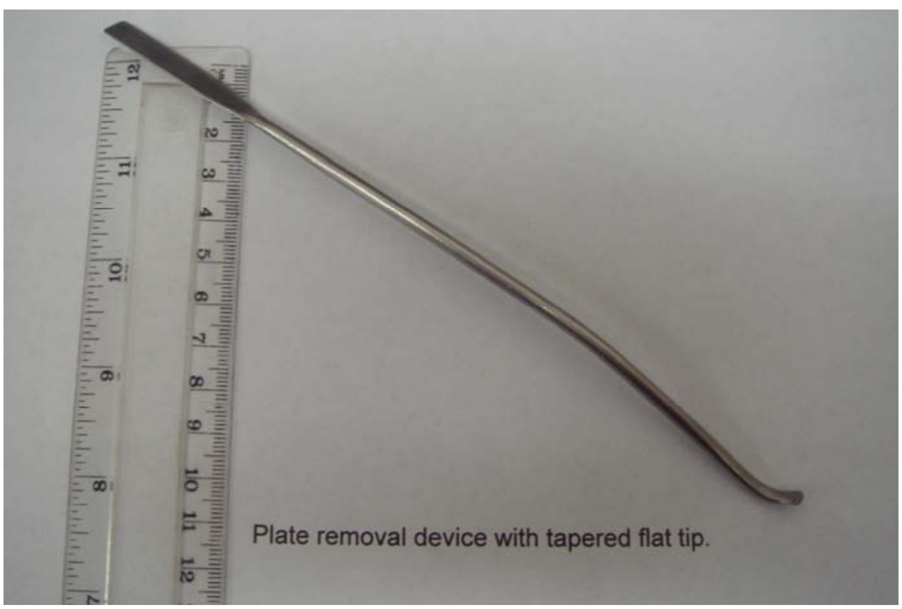


Figure B.2: Plate Removal Device

5.9 Constant temperature water bath controlled at specified temperatures.

5.10 Absorbent paper towels, single fold, CS Scott or equivalent.

5.11 Environmental chambers which can maintain specified curing temperatures and humidity conditions.

5.12 Forced air draft ovens for curing long term evaluation specimens at 140°F +/- 3°F (60°C +/- 3°C.).

6.0 MATERIALS

6.1 Aggregates: Sample representative portions of aggregates used for slurry seal mix or micro-surfacing mix. Use material of the type, grade, and source proposed for the project. Use the aggregates that pass the 3.8 inches (96.5 mm) sieve. Aggregates shall be dried at 140°F (60°C) to a constant mass and cooled to the prescribed test temperatures prior to performing the test.

6.2 Asphalt emulsion shall be representative of the material to be used in the project.

6.3 Set control additives, both solid and liquid, shall be representative of the materials to be used in the project.

6.4 Distilled potable water with a pH between 6.0 and 7.0 shall be used.

7.0 EVALUATION PARAMETERS

7.1 Curing duration of specimens: 30 minutes, 1 hour, and 3 hours.

7.2 Curing temperatures of specimens: 59°F (15°C), 77°F (25°C), and 95°F (35°C).

7.3 Curing humidity of specimens: 50% and 90%.

8.0 PREPARATION OF TEST SPECIMEN

8.1 Aggregate, asphalt emulsion, set control additives and mixing water shall be maintained at 77°F (25°C).

8.2 The amounts of material components will be quantified as described by the mix design or through determinations from pre-testing using the Automated Mixing Test method.

8.3 Split or quarter a sufficient amount of the dried aggregate to obtain in one quarter 1300g to 1400 g, depending on the aggregate specific gravity and maximum nominal size.

8.4 Brush about 5g of tack coat emulsion (use the same emulsion as is used in the mixture) onto the casting plate so it is evenly covered. See Figure B.3. Allow to dry completely.

Figure B.3: Applying Tack Coat

8.5 Center the specimen casting mold over the casting plate with tack coat as in Figure B.4.

Figure B.4: Centered Casting Mold

8.6 Weigh 1300 g of aggregate into the mixing bowl. Typically, 1300 g of aggregate should be enough aggregate to slightly over-fill the specimen mold during casting. Using a spoon mix in prescribed amount of dry set additive to the aggregate and mix for 1 minute or until uniformly distributed. Add the pre-wet amount of water and mix again for 1 minute or until uniformly distributed. Add the liquid set additive(s) to the mix and mix for 1 minute or until uniformly distributed. Finally, add the predetermined asphalt emulsion and mix for 1 minute or until uniformly distributed. Immediately pour into the centered specimen casting mold.

8.7 Strike off the slurry mixture level with the top of the mold with a minimum of manipulation. Use a sawing motion with the wooden dowel and even out the surface as seen in Figure 8.3. Discard excess material. Remove the mold and cure under prescribed conditions of duration, temperature, and humidity.

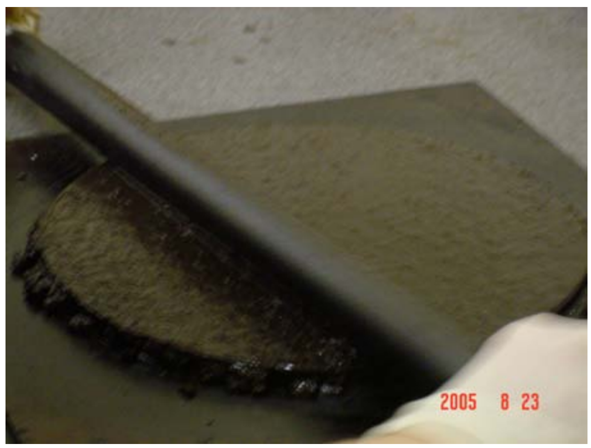


Figure B.5: Surface Preparation

8.8 After the prescribed curing conditions, record the weight of the specimen immediately before placing into the abrasion pan. If there is excess water along the edges of the specimen and surface of the casting plate, carefully remove by dabbing with an absorbent paper towel before recording the initial weight.

9.0 TEST PROCEDURE

9.1 Place the cured specimen into the abrasion pan. Clamp the specimen plate to the inside of the abrasion pan; tighten the quick clamps to press against the specimen plate that is in the abrasion pan on the mounting plate.

9.2 Completely cover the specimen with water at the specified temperature so that there is approximately 0.11-0.15 inches (2.8 – 3.8 mm) of water over the surface of the test specimen. Soak for 1 minute.

9.3 Lift the mounting plate until the surface of the specimen comes in contact with the abrading wheels.

9.4 Switch to the low speed of the Hobart machine. Abrade for 60 seconds.

9.5 Lower the mounting plate and remove the specimen plate with the aid of a plate removal device. Carefully rinse the loose debris with 1000 ml to 1500 ml of water. Carefully dry the specimen and casting plate with an absorbent paper towel. Record the final weight.

10.0 REPORT

Report the following information:

10.1 Aggregate: percent used, type of aggregate, source and the date received for testing.

10.2 Asphalt emulsion: percent used, type of emulsion, source, and the date received for testing.

10.3 Set additive(s): percent used, type, source, and the date received for testing.

10.4 Percent of pre-wet water used to initially wet the aggregate, if needed.

10.5 Curing conditions: duration, temperature, humidity, and soaking time.

10.6 Testing conditions: machine used, running time.

10.7 Abrasion Loss as the result of the initial weight before abrasion minus the final weight after abrasion. The loss is reported in grams.

10.8 Observation of failure and stripping of aggregate in test, when applicable.

11.0 PRECISION AND BIAS

Additional studies are required. The equipment is still open for further development.

APPENDIX C RESULTS OF RUGGEDNESS AMT TESTING

Mix 5 was used for performing the AMT ruggedness tests. The target optimized proportions for M5 were 10% emulsion, 8% water, 0% liquid additive, and 0.5% type 2 cement. There were six conditions which were adjusted for evaluation. The room temperature used was either 73.4°F (23°C) or 80.6°F (27°C). The humidity condition used was either 40% or 60%. The emulsion content used was either 8% or 12%. The liquid additive used was either 0% or 0.1%. The mineral filler proportion used was either 0% or 1%.

The AMT data for the trials are contained in Table C.1 and the traces fro the trials are illustrated in Figures C.1 through C.4..

Table C.1: AMT Ruggedness Trial Data

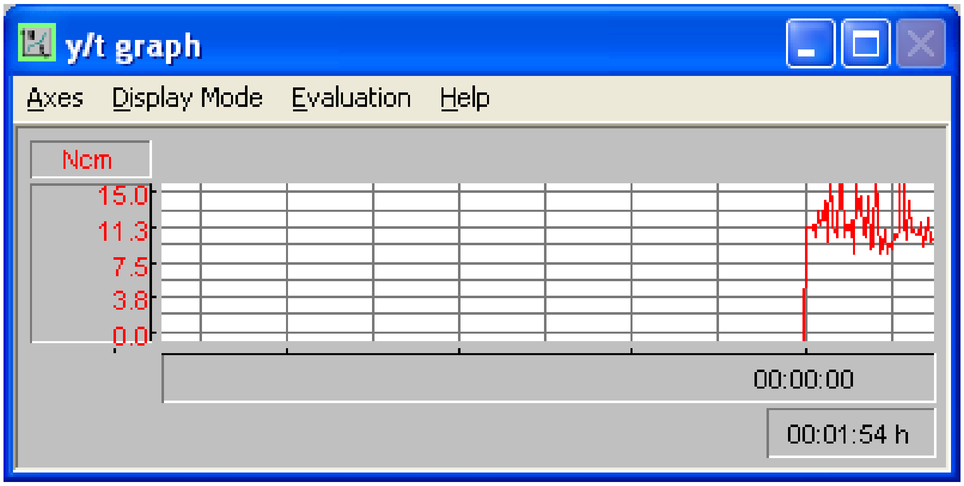
AMT Ruggedness - Mix: M5

Parameter	Trial #	Cement, %	Liquid Add, %: Al Sulfate	Water, %	Emulsion, %	Temperature		Humidity, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increase of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken
						°F	°C										
1	10	1	0.1	10	8	80.6	27	40	300	3	30	0.3	24	10.0	1:15	2:00	3:00
2	3	0	0.1	10	12	73.4	23	60	300	0	30	0.3	36	9.0	2:30	n/a	5+
3	6	0	0	10	12	80.6	27	40	300	0	30	0	36	9.5	1:15	n/a	5+
4	12	1	0	6	12	80.6	27	60	300	3	18	0	36	9.5	1:15	2:00	3:00
5	5	0	0.1	6	8	80.6	27	60	300	0	18	0.3	24	9.0	0:15	0:30	1:00
6	7	1	0	10	8	73.4	23	60	300	3	30	0	24	9.5	2:30	3:45	4:30
7	9	1	0.1	6	12	73.4	23	40	300	3	18	0.3	36	11.3	1:15	2:30	3:00
8	1	0	0	6	8	73.4	23	40	300	0	18	0	24	11.0	0:15	0:40	1:15
	Unit	%	%	%	%	%		%									
	design	0.5	0	8	10	25	25	50									

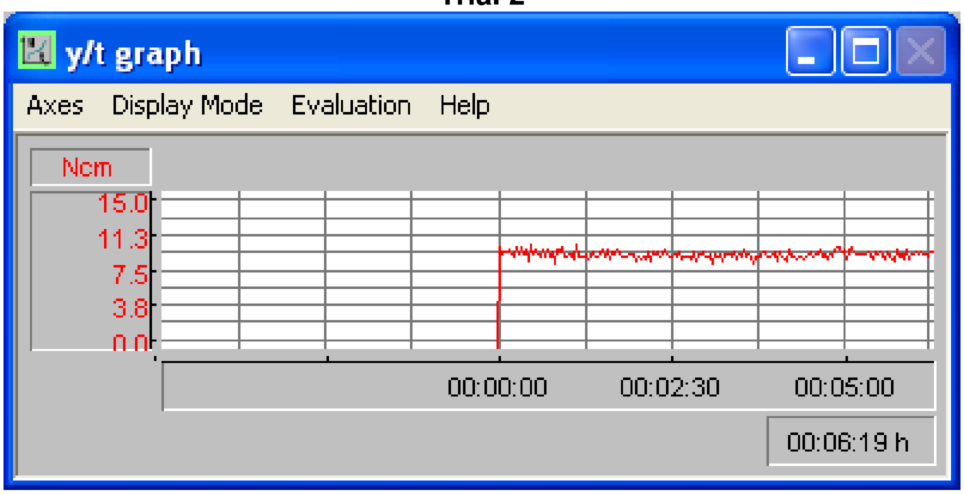
Parameter	1. Fill	2. Additive	3. Water	4. Emulsion	5. Temperature		6. Humidity
					°F	°C	
1	0.05	0.1	2	-2	80.6	27	40
2	-0.05	0.1	2	2	73.4	23	60
3	-0.05	-0.1	2	2	80.6	27	40
4	0.5	-0.1	-2	2	80.6	27	60
5	-0.5	0.1	-2	-2	80.6	27	60
6	0.5	-0.1	2	-2	73.4	23	60
7	0.5	0.1	-2	2	73.4	23	40
8	-0.5	-0.1	-2	-2	73.4	23	40
Unit	%	%	%	%	%	C	%

Figure C.1: Ruggedness Trials

Trial 1



Trial 2



Trial 3

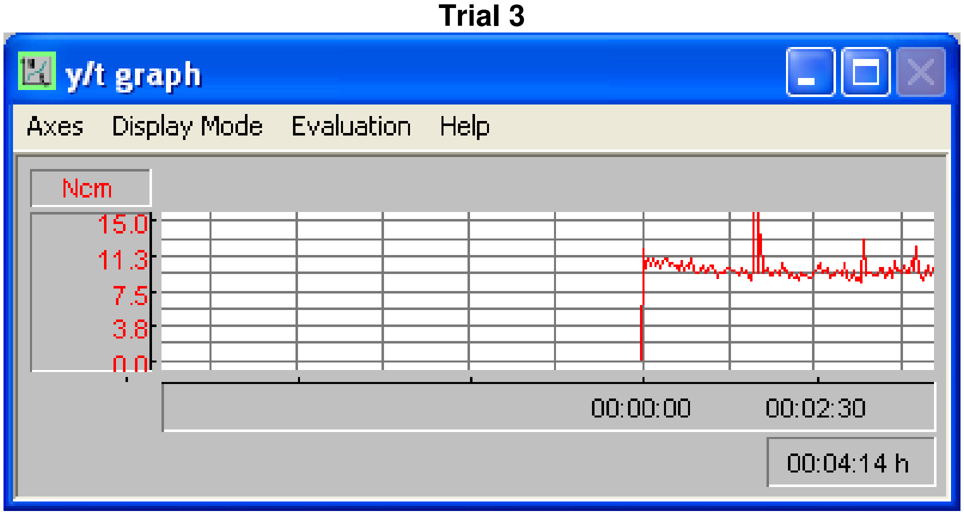
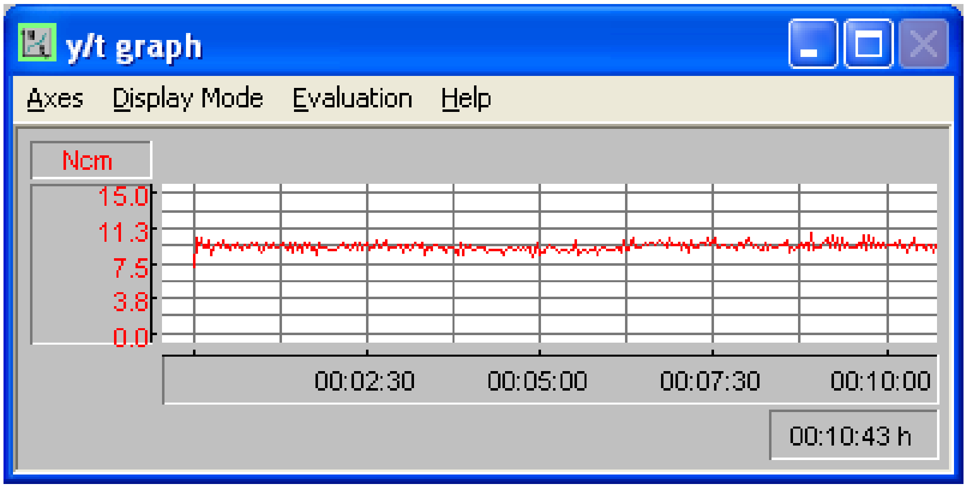
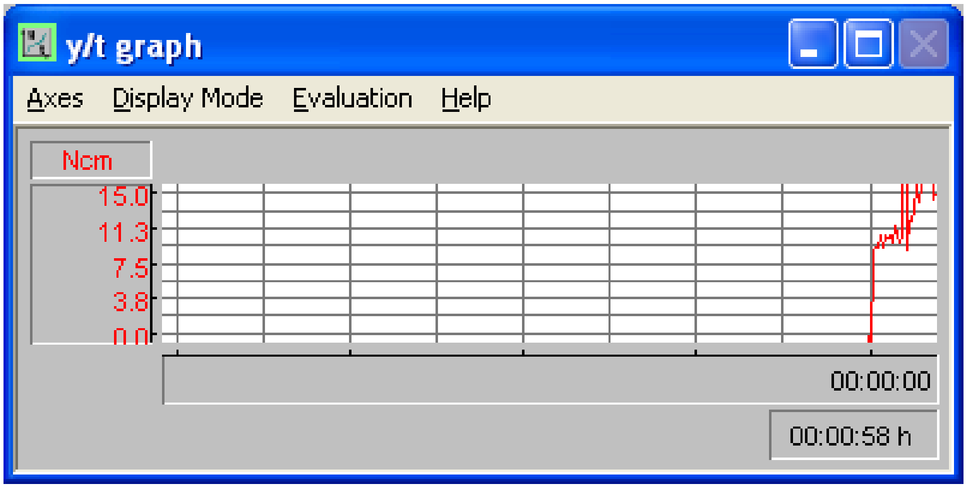


Figure C.2: Ruggedness Trials

Trial 4



Trial 5



Trial 6

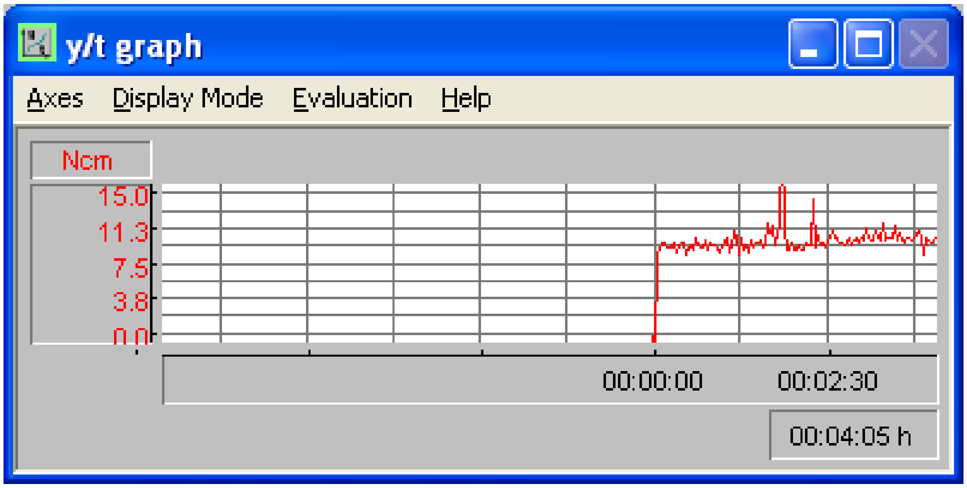
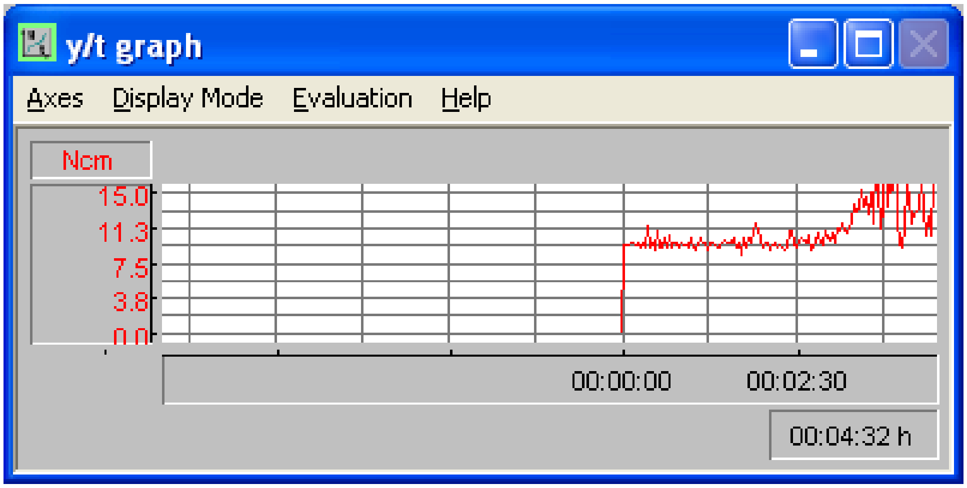
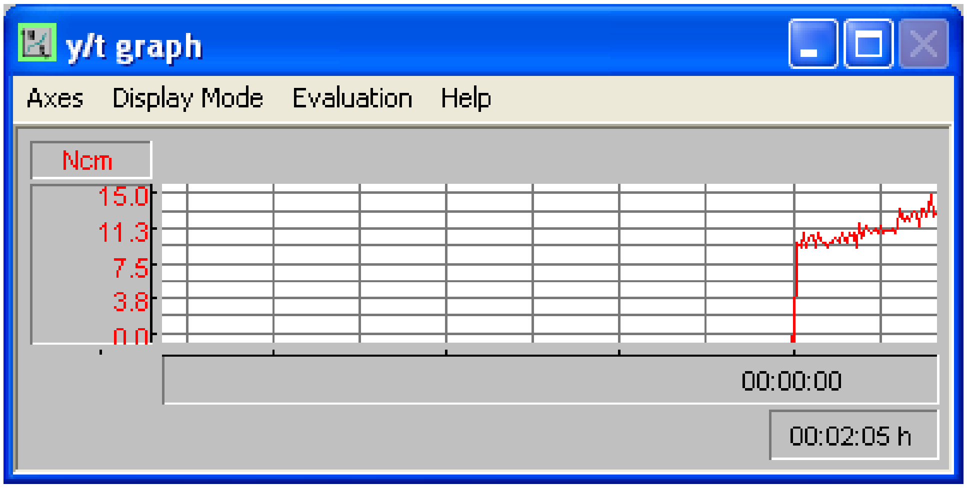


Figure C.3: Ruggedness Trials

Trial 7



Trial 8



Trial 9

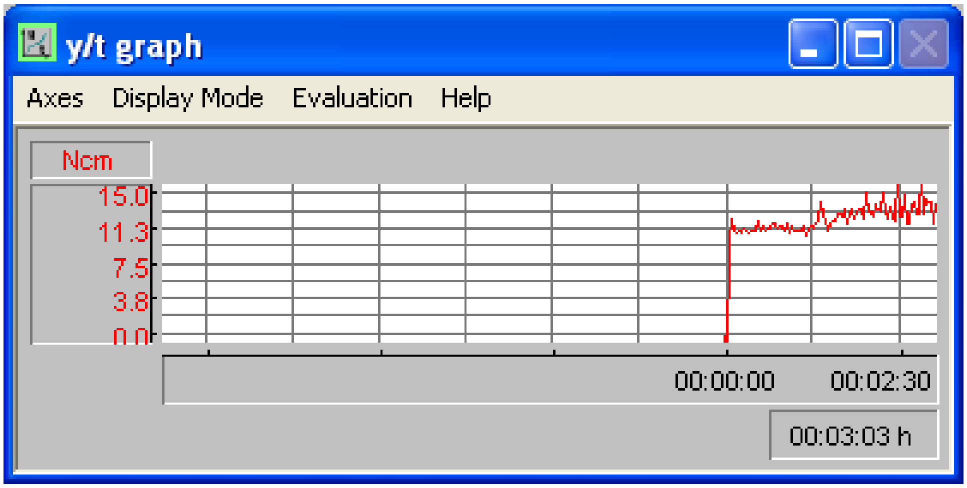
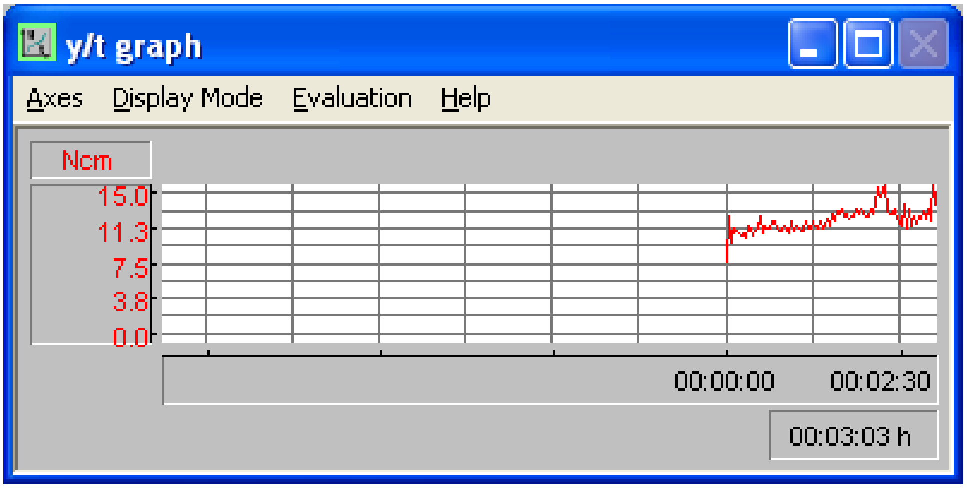
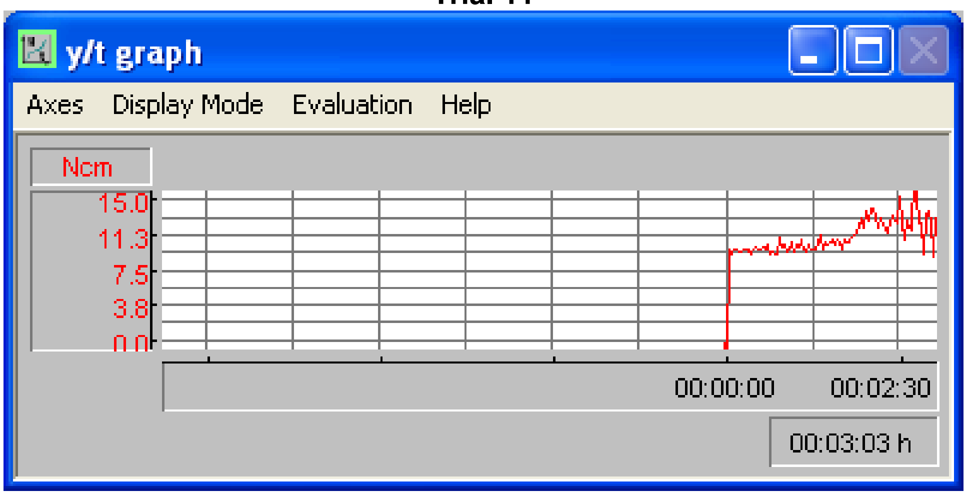


Figure C.4: Ruggedness Trials

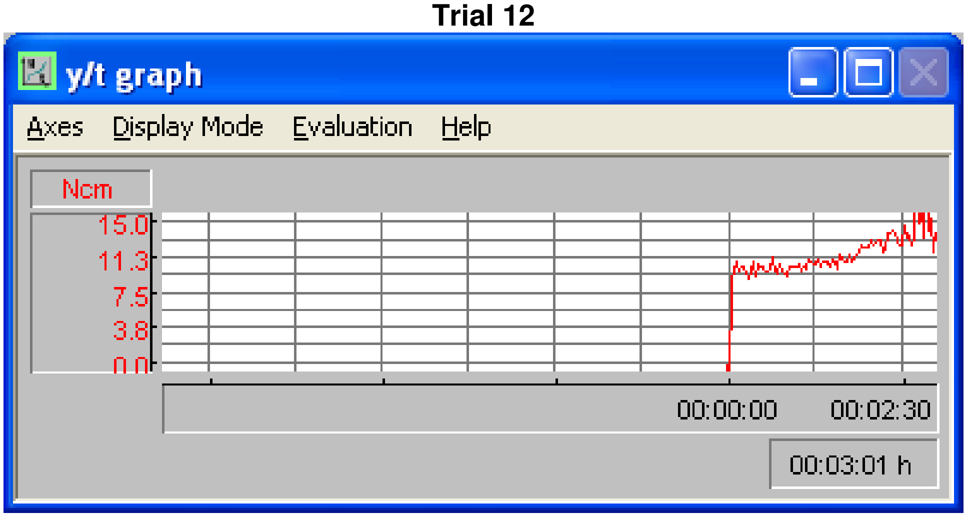
Trial 10



Trial 11



Trial 12



APPENDIX D RESULTS OF CAT RUGGEDNESS TESTING

CAT: Cohesion Abrasion Test (French WTAT): short term

Parameter	Values		Test No.									
	High (H)	Low (L)	1	2	3	4	5	6	7	8		
1. Cure Time (60min)	5	-5	H	L	L	H	L	H	H	L	min	55/65
2. Cure Temp. 77℉ (25℃)	2	-2	H	H	L	L	H	L	H	L	C	23/27
3. Humidity (50%)	10	-10	H	H	H	L	L	H	L	L	%	40/60
4. Test Time (1min)	5	-5	L	H	H	H	L	L	H	L	s	55/65
5. Test Temp. 77℉ (25℃)	5	-5	H	L	H	H	H	L	L	L	C	20/30
6. Test Duration (1min)	5	-5	L	H	L	H	H	H	L	L	s	55/65

CAT: Cohesion Abrasion Test (French WTAT): Short Term
MIX 4

CEL#:	10-17749	LAB #:	
Date Tested	Apr-07	Tested By:	LH
Project Name:	Slurry/Micro Mix Design		
Aggregate:	Type 3	Emulsion:	**LMCQS-1h**
Source:	**LOPKE**	Source:	VSS Emultech
Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M4: Ruggedness Evaluation # 1

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ___________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

	Control	Eval#1	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1864.2	65	80.6	27.0	60	55	30	55	1533.3	330.9
1875.7	65	81	27.2	60	55	30	55	1617.1	258.6
1866.6	65	80.2	26.8	60	55	31	55	1563.8	302.8

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#: 10-17749 LAB #: Date Tested Apr-07

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **LMCQS-1h**

Source: **LOPKE** Source: ERGON

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: Aluminum sulfate

Additive mid-range target: Additive:

Additive mid-range target: Additive:

M4: Ruggedness Evaluation # 2

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#2	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***

Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1884.2	55	80.2	26.8	61	65	20	65	1520.1	364.1
1869.1	55	80.4	26.9	60	65	20	65	1589.1	280
1870	55	80.6	27.0	59	65	20	65	1537.8	332.2

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#: 10-17749 LAB #: Date Tested: Apr-07

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **LMCQS-1h**

Source: **LOPKE** **Source: VSS Emultech**

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M4: Ruggedness Evaluation # 3

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#3	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1879.2	55	73.4	23.0	60	65	30	55	1554.6	324.6
1880.5	55	73.4	23.0	60	65	30	55	1610	270.5
1863.8	55	73.6	23.1	60	65	30	55	1581.7	282.1

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#: 10-17749 LAB #: Date Testec Apr-07

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **LMCQS-1h**

Source: **LOPKE** **Source: VSS Emultech**

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M4: Ruggedness Evaluation # 4

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ___________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

	Control	Eval#4	
Temperature, ℃	25	**23**	℃
Temperature, ℉	77	**73.4**	℉
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp ℉	Cure Temp ℃	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1845.1	65	73.2	22.9	39	65	29	65	1600.3	244.8
1868.8	65	73.6	23.1	42	65	30	65	1598.8	270
1865.4	65	73.4	23.0	39	64	30	65	1579	286.4

CAT: Cohesion Abrasion Test (French WTAT): Short Term
Mix 4

CEL#:	10-17749	LAB #:	
Date Testec	Apr-07	Tested By:	LH
Project Name:	Slurry/Micro Mix Design		
Aggregate:	Type 3	Emulsion:	**LMCQS-1h**
Source:	**LOPKE**	Source:	VSS Emultech
Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M4: Ruggedness Evaluation # 5

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#5	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1852.2	55	80.4	26.9	44	55	30	65	1604.5	247.7
1863.4	55	80.8	27.1	44	55	30	65	1648.1	215.3
1870	55	80.8	27.1	44	55	31	65	1494.1	375.9

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#: 10-17749 LAB #: Date Testec Apr-07

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **LMCQS-1h**

Source: **LOPKE** Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M4: Ruggedness Evaluation # 6

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#6	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1913	65	72.7	22.6	58	55	20	65	1564.7	348.3
1882.1	65	73.8	23.2	58	55	21	65	1531	351.1
1897.9	65	73.8	23.2	59	55	21	65	1553.2	344.7

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#:	10-17749	LAB #:	Date Testec	Apr-07
Project Name:	Slurry/Micro Mix Design		Tested By:	LH
Aggregate:	Type 3	Emulsion:	**LMCQS-1h**	
Source:	**LOPKE**	Source:	VSS Emultech	
Emulsion mid-range target:	11.0			
Pre-wet water mid-range target:	16.0			
Additive mid-range target:	1.0	Additive:	cement type 2	
Additive mid-range target:	0.0	Additive:	Aluminum sulfate	
Additive mid-range target:		Additive:		
Additive mid-range target:		Additive:		

M4: Ruggedness Evaluation # 7

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#7	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1840.5	65	80	26.7	40	65	20	55	1550.4	290.1
1892.3	65	80.4	26.9	40	65	20	55	1627.6	264.7
1865.7	65	80.4	26.9	38	65	20	55	1525	340.7

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

CEL#: 10-17749 LAB #: Date Tested: Apr-07

M4: Ruggedness Evaluation # 8

Project Name: Slurry/Micro Mix Design — Tested By: LH

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **LOPKE** — Source: VSS Emultech

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: Aluminum sulfate

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#8	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Cure Temp °F	Cure Temp °C	Cure Humidity	Test time in pan bfore abras, sec	Test Temp	Test Duraction sec	B Final Wt, g	C=A-B Loss Wt, g
1880.3	55	73.4	23.0	40	55	20	55	1593.2	287.1
1888.1	55	72.9	22.7	39	55	20	55	1531.7	356.4
1884.9	55	73.2	22.9	38	55	21	55	1546.4	338.5

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 4

2.CAT-Cohesion Abrasion Test: French WTAT, short-term : Mix 4

	1	**2**		**3**	**4**	**5**		**6**				
Parameter	**Cure Time**	**Cure Temp**		**Humidity**	**Test Time**	**Test Temp.**		**Test Duration**				
Test No. 1	*5*	*℉*	*2℃*	*60*	*-5*	*86 °F*	*30 °C*	*-5*	*original*	*final*	*loss*	*nal loss*
	65	80.6	27.0	60	55 sec	*86*	30	55	1864.2	1533.3	330.9	331
	65	81.0	27.2	60	55 sec	*86*	30	55	1875.7	1617.1	258.6	259
	65	80.2	26.8	60	55 sec	88	31	55	1866.6	1563.8	302.8	303
Test No. 2	*-5*	*℉*	*2℃*	*60*	*5*	*68*	*20*	*5*	*original*	*final*	*loss*	*nal loss*
	55	80.2	26.8	61	65	68	20	65	1884.2	1520.1	364.1	364
	55	80.4	26.9	60	65	68	20	65	1869.1	1589.1	280.0	280
	55	80.6	27.0	59	65	68	20	65	1870.0	1537.8	332.2	332
Test No. 3	*-5*	*℉*	*-2℃*	*60*	*5*	*86*	*30*	*-5*	*original*	*final*	*loss*	*nal loss*
	55	73.4	23.0	60	65	*86*	30	55	1879.2	1554.6	324.6	325
	55	73.4	23.0	60	65	*86*	30	55	1880.5	1610.0	270.5	271
	55	73.6	23.1	60	65	*86*	30	55	1863.8	1581.7	282.1	282
Test No. 4	*5*	*℉*	*-2℃*	*40*	*5*	*86*	*30*	*5*	*original*	*final*	*loss*	*nal loss*
	65	73.2	22.9	39	65	84.2	29	65	1845.1	1600.3	244.8	245
	65	73.6	23.1	42	65	*86*	30	65	1868.8	1598.8	270.0	270
	65	73.4	23.0	39	64	*86*	30	65	1865.4	1579.0	286.4	286
Test No. 5	*-5*	*℉*	*2℃*	*40*	*-5*	*86*	*30*	*5*	*original*	*final*	*loss*	*nal loss*
	55	80.4	26.9	44	55	*86*	30	65	1852.2	1604.5	247.7	248
	55	80.8	27.1	44	55	*86*	30	65	1863.4	1648.1	215.3	215
	55	80.8	27.1	44	55	88	31	65	1870.0	1494.1	375.9	376
Test No. 6	*5*	*℉*	*-2℃*	*60*	*-5*	*68*	*20*	*5*	*original*	*final*	*loss*	*nal loss*
	65	72.7	22.6	58	55	68	20	65	1913.0	1564.7	348.3	348
	65	73.8	23.2	58	55	70	21	65	1882.1	1531.0	351.1	351
	65	73.8	23.2	59	55	70	21	65	1897.9	1553.2	344.7	345
Test No. 7	*5*	*℉*	*2℃*	*40*	*5*	*68*	*20*	*-5*	*original*	*final*	*loss*	*nal loss*
	65	80.0	26.7	40	65	68	20	55	1840.5	1550.4	290.1	290
	65	80.4	26.9	40	65	68	20	55	1892.3	1627.6	264.7	265
	65	80.4	26.9	38	65	68	20	55	1865.7	1525.0	340.7	341
Test No. 8	*-5*	*℉*	*-2℃*	*40*	*-5*	*68*	*20*	*-5*	*original*	*final*	*loss*	*nal loss*
	55	73.4	23.0	40	55	68	20	55	1880.3	1593.2	287.1	287
	55	72.9	22.7	39	55	68	20	55	1888.1	1531.7	356.4	356
	55	73.2	22.9	38	55	70	21	55	1884.9	1546.4	338.5	339
test method	60 min	77	25℃	50%	60 sec	77	25℃	60 sec				
	curing time	curing temp		curing humidity	soakin g time	abrasion water		abrasion time				

CAT: Cohesion Abrasion Test (French WTAT): Short Term
Mix 5

CAT: Cohesion Abrasion Test (French WTAT): short term

Parameter		Values		Test No.									
		High (H)	Low (L)	1	2	3	4	5	6	7	8		
1.	Cure Time (60 min)	5	-5	H	L	L	H	L	H	H	L	min	55/65
2.	Cure Temp 77°F (25°C)	2	-2	H	H	L	L	H	L	H	L	C	23/27
3.	Humidity (50%)	10	-10	H	H	H	L	L	H	L	L	%	40/60
4.	Test Time (1 min)	5	-5	L	H	H	H	L	L	H	L	s	55/65
5.	Test Temp 77°F (25°C)	5	-5	H	L	H	H	H	L	L	L	C	20/30
6.	Test Duration (1 min)	5	-5	L	H	L	H	H	H	L	L	s	55/65

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#: 10-17749 LAB #: Date Testec Mar-08

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON

Emulsion mid-range target: 10.0

Pre-wet water mid-range target: 8.0

Additive mid-range target: 0.5 Additive: cement type 2

Additive mid-range target: 0.00 Additive: Aluminum sulfate

Additive mid-range target: Additive:

Additive mid-range target: Additive:

M5: Ruggedness Evaluation # 1

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ________		

Curing Conditions:

	Control	Eval#1	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1632.7	65	7:50	81.3	27.4	60	8:55	27	59	55 sec	55 sec	30	1391.2	241.5
1633.6	65	8:00	80.2	26.8	59	9:05	27	59	55 sec	55 sec	30	1368.1	265.5
1634.9	65	8:10	80.4	26.9	59	9:15	27	59	55 sec	55 sec	30	1361.6	273.3

Temp of test water: **30** °C
86 °F

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#: 10-17749 LAB #: Date Testec Mar-08

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON

Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 2

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#2	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1572.8	55	12:10	80.8	27.1	60	13:05	27	59	65 sec	65 sec	20	1397	175.8
1613.1	55	12:25	79.8	26.6	60	13:20	27	80	65 sec	65 sec	20	1375.2	237.9
1596.5	55	12:45	80.2	26.8	60	13:40	27	59	65 sec	65 sec	20	1340.9	255.6

Temp of test water: **20** °C
68 °F

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#: 10-17749 LAB #: Date Testec Mar-08

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON'

Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 3

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#3	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1600.8	55	9:30	72.9	22.7	59	10:25	23	59	65 sec	55 sec	30	1251.3	349.5
1619.9	55	9:45	72.9	22.7	60	10:40	23	59	65 sec	55 sec	30	1304.1	315.8
1580.8	55	10:00	73.6	23.1	59	10:55	23	59	65 sec	55 sec	30	1268.8	312.0

Temp of test water: **30** °C
86 °F

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#: 10-17749	LAB #:	Date Testec Mar-08	
Project Name: Slurry/Micro Mix Design		Tested By: LH	
Aggregate: Type 3		Emulsion: MICRO	
Source: **TEXAS**		Source: ERGON	
Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 4

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#4	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1633.2	65	10:20	73.2	22.9	40	11:25	23	40	65 sec	65 sec	30	1259.2	374.0
1632.3	65	10:35	73.4	23.0	40	11:40	23	40	65 sec	65 sec	30	1277.8	354.5
1635.1	65	10:55	73.8	23.2	40	12:00	23	40	65 sec	65 sec	30	1250	385.1

Temp of test water: **30** °C
86 °F

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#:	10-17749	LAB #:	
Date Tested	Mar-08	Tested By:	LH
Project Name:	Slurry/Micro Mix Design		
Aggregate:	Type 3	Emulsion:	**MICRO**
Source:	**TEXAS**	Source:	ERGON
Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 5

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#5	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1604.7	55	9:50	79.8	26.6	41	10:45	27	40	55 sec	65 sec	30	1359.7	245.0
1610.6	55	10:05	80.2	26.8	40	11:00	27	40	55 sec	65 sec	30	1371.1	239.5
1539.8	55	10:50	79.8	26.6	41	11:45	27	40	55 sec	65 sec	30	1297.9	241.9

Temp of test water: **30** °C
86 °F

CAT: Cohesion Abrasion Test (French WTAT): Short Term
Mix 5

CEL#: 10-17749 LAB #: Date Testec Mar-08

M5: Ruggedness Evaluation # 6

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON

Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#6	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**60**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1574.8	65	10:10	72.7	22.6	60	11:15	23	60	55 sec	65 sec	20	1214.9	359.9
1528.8	65	10:25	73.2	22.9	60	11:30	23	60	55 sec	65 sec	20	1201.5	327.3
1564.1	65	10:40	73.6	23.1	60	11:45	23	60	55 sec	65 sec	21	1228.8	335.3

Temp of test water: **20** °C
68 °F

CAT: Cohesion Abrasion Test (French WTAT): Short Term
Mix 5

CEL#: 10-17749 LAB #: Date Tested Mar-08

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON

Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 7

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ___________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ___________		

Curing Conditions:

	Control	Eval#7	
Temperature, °C	25	**27**	°C
Temperature, °F	77	**80.6**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1583.5	65	11:15	81.3	27.4	40	12:20	27	40	65 sec	55 sec	20	1386.5	197.0
1564.3	65	11:30	80.6	27.0	40	12:35	27	40	65 sec	55 sec	20	1367.6	196.7
1624.7	65	11:45	80.8	27.1	40	12:50	27	40	65 sec	55 sec	20	1439.5	185.2

Temp of test water: **20** °C
68 °F

CAT: COHESION ABRASION TEST (FRENCH WTAT): SHORT TERM
MIX 5

CEL#: 10-17749 LAB #: Date Testec Mar-08

Project Name: Slurry/Micro Mix Design Tested By: LH

Aggregate: Type 3 Emulsion: **MICRO**

Source: **TEXAS** Source: ERGON

Emulsion mid-range target:	10.0		
Pre-wet water mid-range target:	8.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	Aluminum sulfate
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

M5: Ruggedness Evaluation # 8

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for time below
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
8.0	water	108.0	water
0.0	Aluminum sulfate	0.0	Aluminum sulfate
10.0	*emulsion (target)*	135.0	emulsion
	Other: ____________		

Curing Conditions:

	Control	Eval#8	
Temperature, °C	25	**23**	°C
Temperature, °F	77	**73.4**	°F
Humidity, %	50	**40**	

Soaking period before testing	***see below***
Compaction w/ roller immediately before testing	***NONE***

A Original Wt, g	**Cure Time** minutes	Start Clock Time	Initial Temp °F	Initial Temp °C	Initial Humidity	End Clock Time	Final Temp	Final Humidity	Soaking Period before test	Abrasion time	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1601.1	55	8:10	73.4	23.0	40	9:05	23	40	55 sec	55 sec	20	1330	271.1
1604.2	55	8:30	72.9	22.7	41	9:25	23	40	55 sec	55 sec	20	1289.8	314.4
1609.6	55	8:45	72.7	22.6	40	9:40	23	40	55 sec	55 sec	20	1344.6	265.0

Temp of test water: **20** °C
68 °F

2.CAT-Cohesion Abrasion Test: French WTAT, short-term : Mix 5

	1	2		3	4	5		6				
Parameter	**Cure Time**	**Cure Temp**		**Humidity**	**Test Time**	**Test Temp.**		**Test Duration**				
Test No. 1	*5*	*°F*	*2°C*	*60*	*-5*	*86°F*	*30°C*	*-5*	*original*	*final*	*loss*	*final loss*
	65 min	81.4	27.4	60	55 sec	86	30	55	1632.7	1391.2	241.5	242
	65 min	80.2	26.8	59	55 sec	86	30	55	1633.6	1368.1	265.5	266
	65 min	80.4	26.9	59	55 sec	86	30	55	1634.9	1361.6	273.3	273
Test No. 2	*-5*	*°F*	*2°C*	*60*	*5*	*68*	*20*	*5*	*original*	*final*	*loss*	*final loss*
	55	80.8	27.1	60	65	68	20	65	1572.8	1397.0	175.8	176
	55	79.8	26.6	60	65	68	20	65	1613.1	1375.2	237.9	238
	55	80.2	26.8	60	65	68	20	65	1596.5	1340.9	255.6	256
Test No. 3	*-5*	*°F*	*-2°C*	*60*	*5*	*86*	*30*	*-5*	*original*	*final*	*loss*	*final loss*
	55	72.9	22.7	59	65	86	30	55	1600.8	1251.3	349.5	350
	55	72.8	22.7	60	65	86	30	55	1619.9	1304.1	315.8	316
	55	73.5	23.1	59	65	86	30	55	1580.8	1268.8	312.0	312
Test No. 4	*5*	*°F*	*-2°C*	*40*	*5*	*86*	*30*	*5*	*original*	*final*	*loss*	*final loss*
	65	73.2	22.9	40	65	86	30	65	1633.2	1259.2	374.0	374
	65	73.4	23.0	40	65	86	30	65	1632.3	1277.8	354.5	355
	65	73.7	23.2	40	64	86	30	65	1635.1	1250.0	385.1	385
Test No. 5	*-5*	*°F*	*2°C*	*40*	*-5*	*86*	*30*	*5*	*original*	*final*	*loss*	*final loss*
	55	79.9	26.6	41	55	86	30	65	1604.7	1359.7	245.0	245
	55	80.3	26.8	40	55	86	30	65	1610.6	1371.1	239.5	240
	55	79.8	26.6	41	55	86	30	65	1539.8	1297.9	241.9	242
Test No. 6	*5*	*°F*	*-2°C*	*60*	*-5*	*68*	*20*	*5*	*original*	*final*	*loss*	*final loss*
	65	72.6	22.6	60	55	68	20	65	1574.8	1214.9	359.9	360
	65	73.3	22.9	60	55	68	20	65	1528.8	1201.5	327.3	327
	65	73.5	23.1	60	55	70	21	65	1564.1	1228.8	335.3	335
Test No. 7	*5*	*°F*	*2°C*	*40*	*5*	*68*	*20*	*-5*	*original*	*final*	*loss*	*final loss*
	65	81.4	27.4	40	65	68	20	55	1583.5	1386.5	197.0	197
	65	80.6	27.0	40	65	68	20	55	1564.3	1367.6	196.7	197
	65	80.7	27.1	40	65	68	20	55	1624.7	1439.5	185.2	185
Test No. 8	*-5*	*°F*	*-2°C*	*40*	*-5*	*68*	*20*	*-5*	*original*	*final*	*loss*	*final loss*
	55	73.4	23.0	40	55	68	20	55	1601.1	1330.0	271.1	271
	55	72.8	22.7	41	55	68	20	55	1604.2	1289.8	314.4	314
	55	72.6	22.6	40	55	68	20	55	1609.6	1344.6	265.0	265
test method	60 min curing time	77	25°C	50% curing humidity	60 sec soakin g time	77	25°C	60 sec abrasion time				
		curing temp				abrasion water						

APPENDIX E LAB RESULTS FOR AGGREGATES AND EMULSIONS USED IN EXPERIMENTAL MIXES

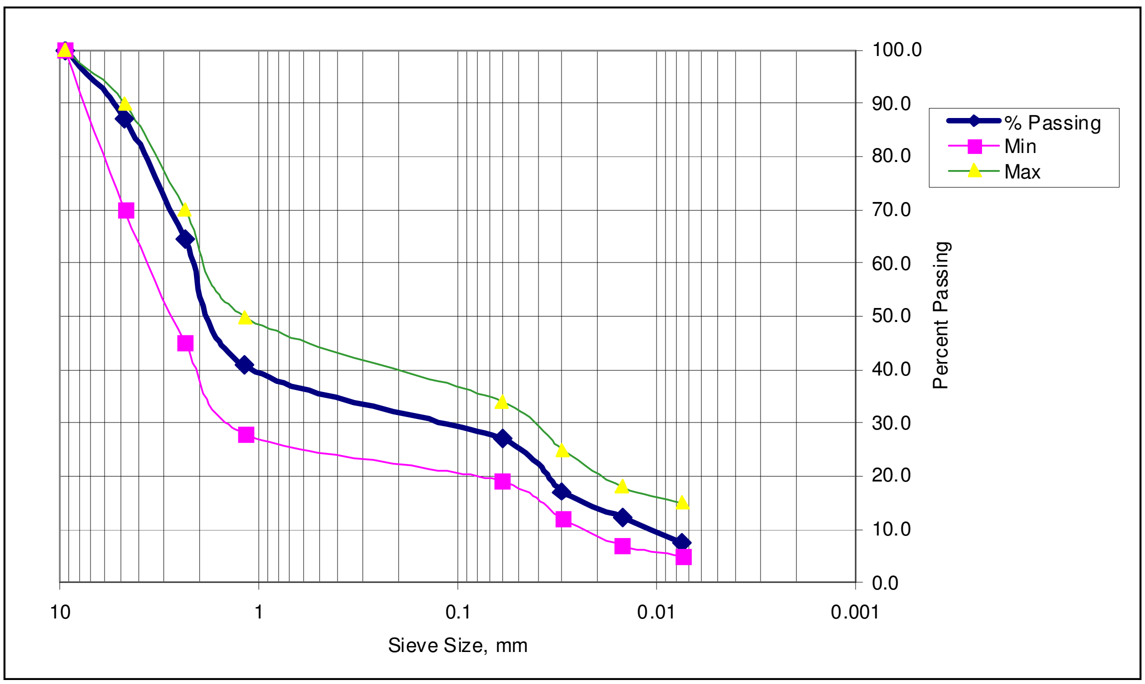
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-01

SIEVE ANALYSIS per AASHTO T27

1021.7 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
130.8	#4	4.75	87.2	70	90
363.7	#8	2.36	64.4	45	70
604.8	#16	1.18	40.8	28	50
745.8	#30	0.06	27.0	19	34
847.0	#50	0.03	17.1	12	25
896.0	#100	0.015	12.3	7	18
946.1	#200	0.0075	7.4	5	15



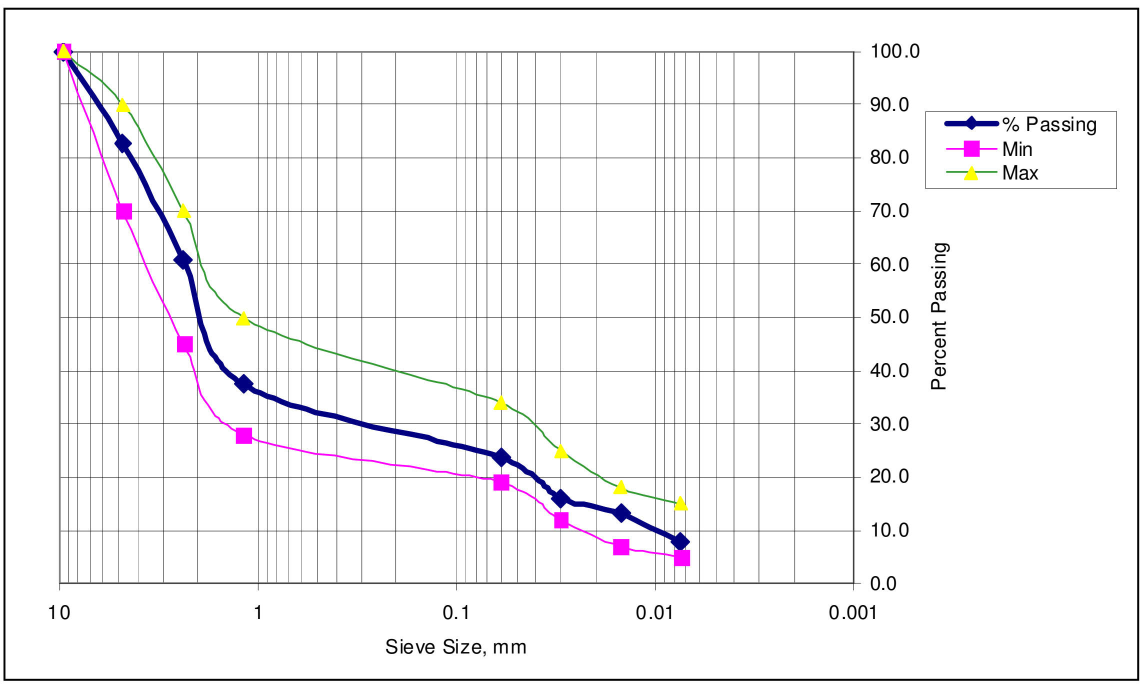
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-02

SIEVE ANALYSIS per AASHTO T27

525.8 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
90.9	#4	4.75	82.7	70	90
206.4	#8	2.36	60.7	45	70
329.1	#16	1.18	37.4	28	50
401.0	#30	0.06	23.7	19	34
441.2	#50	0.03	16.1	12	25
456.4	#100	0.015	13.2	7	18
484.5	#200	0.0075	7.9	5	15



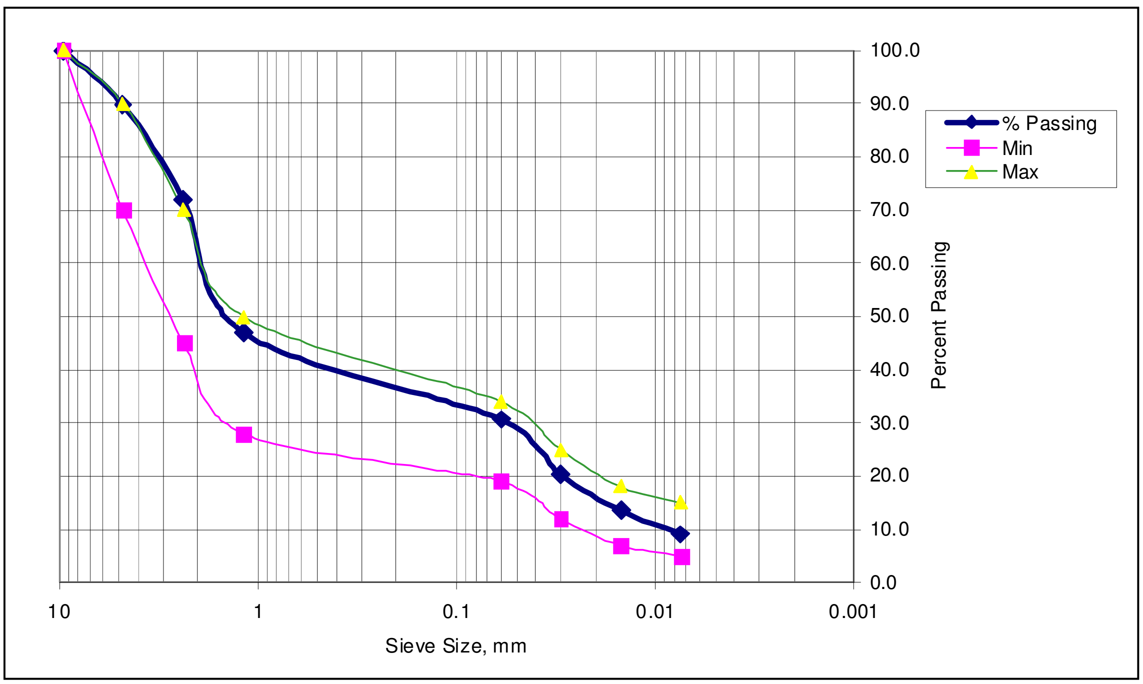
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-03

SIEVE ANALYSIS per AASHTO T27

640.8 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
65.3	#4	4.75	89.8	70	90
180.0	#8	2.36	71.9	45	70
339.7	#16	1.18	47.0	28	50
444.4	#30	0.06	30.6	19	34
510.9	#50	0.03	20.3	12	25
554.1	#100	0.015	13.5	7	18
582.6	#200	0.0075	9.1	5	15



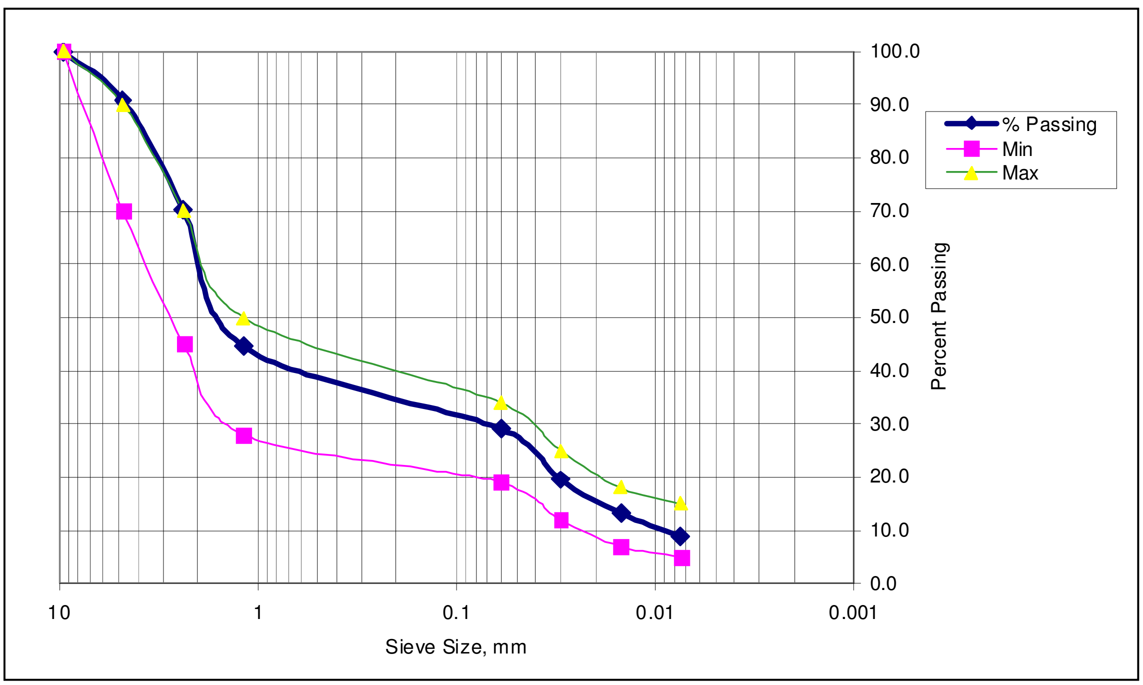
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-04

SIEVE ANALYSIS per AASHTO T27

1004.5	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
92.4	#4	4.75	90.8	70	90
298.9	#8	2.36	70.2	45	70
556.7	#16	1.18	44.6	28	50
712.2	#30	0.06	29.1	19	34
808.7	#50	0.03	19.5	12	25
872.7	#100	0.015	13.1	7	18
914.6	#200	0.0075	8.9	5	15



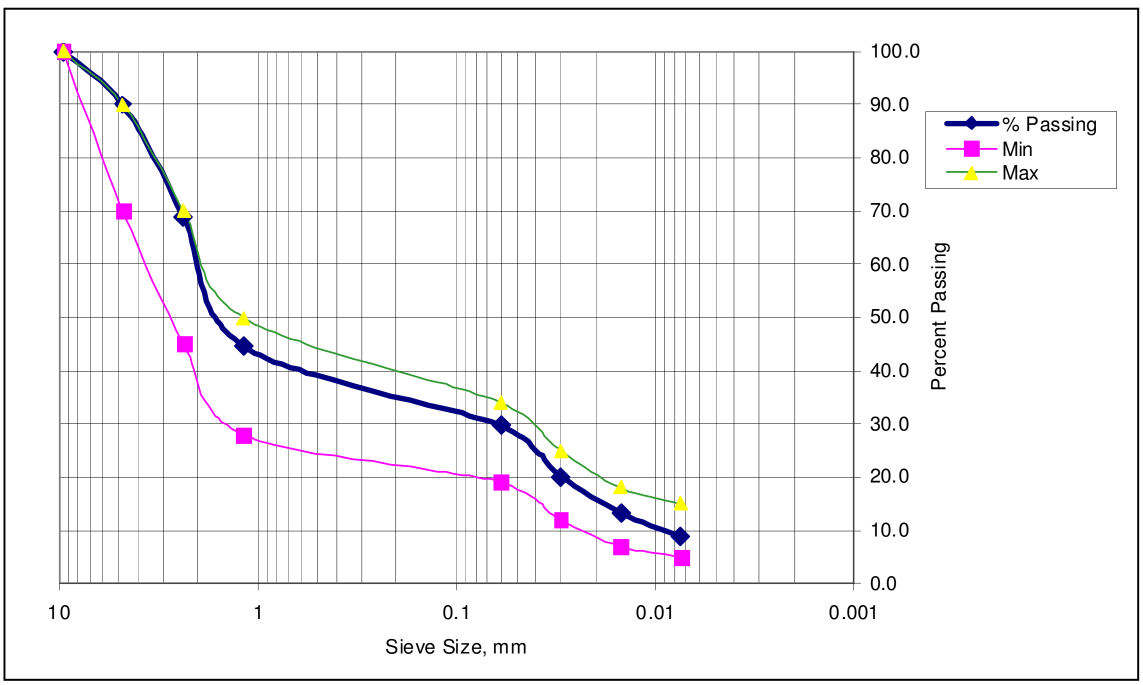
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-05

SIEVE ANALYSIS per AASHTO T27

1060.1	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
105.8	#4	4.75	90.0	70	90
329.9	#8	2.36	68.9	45	70
587.2	#16	1.18	44.6	28	50
745.5	#30	0.06	29.7	19	34
846.9	#50	0.03	20.1	12	25
918.6	#100	0.015	13.3	7	18
966.5	#200	0.0075	8.8	5	15



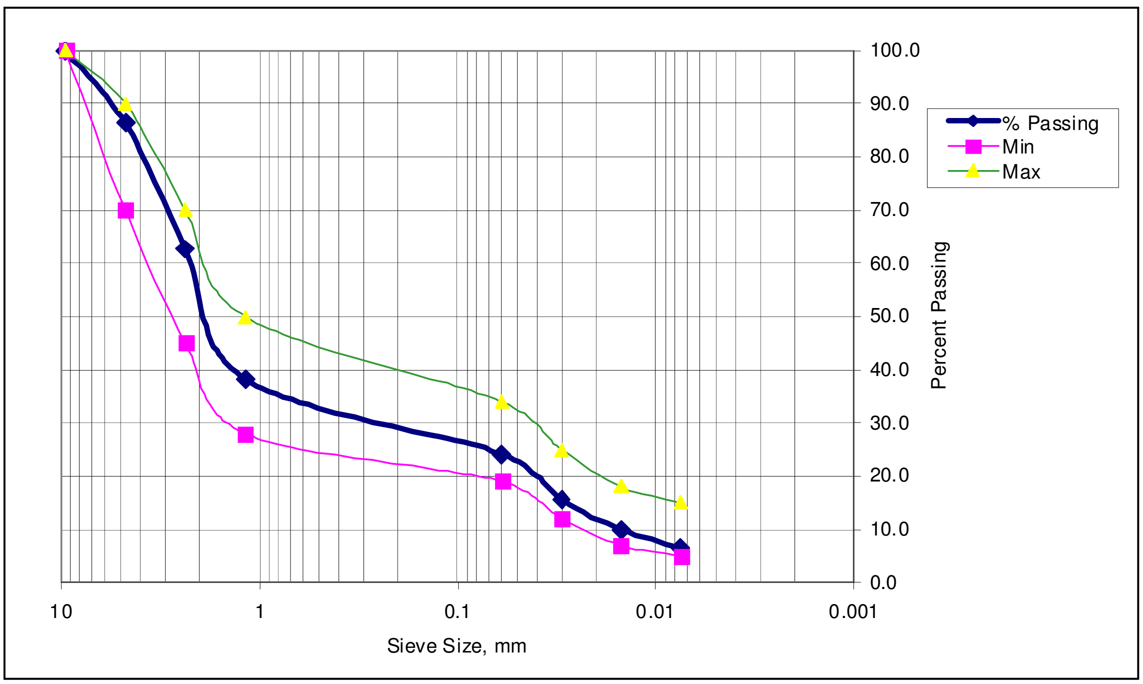
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-06

SIEVE ANALYSIS per AASHTO T27

1087.7 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
147.9	#4	4.75	86.4	70	90
405.7	#8	2.36	62.7	45	70
672.2	#16	1.18	38.2	28	50
824.5	#30	0.06	24.2	19	34
919.1	#50	0.03	15.5	12	25
980.0	#100	0.015	9.9	7	18
1018.1	#200	0.0075	6.4	5	15



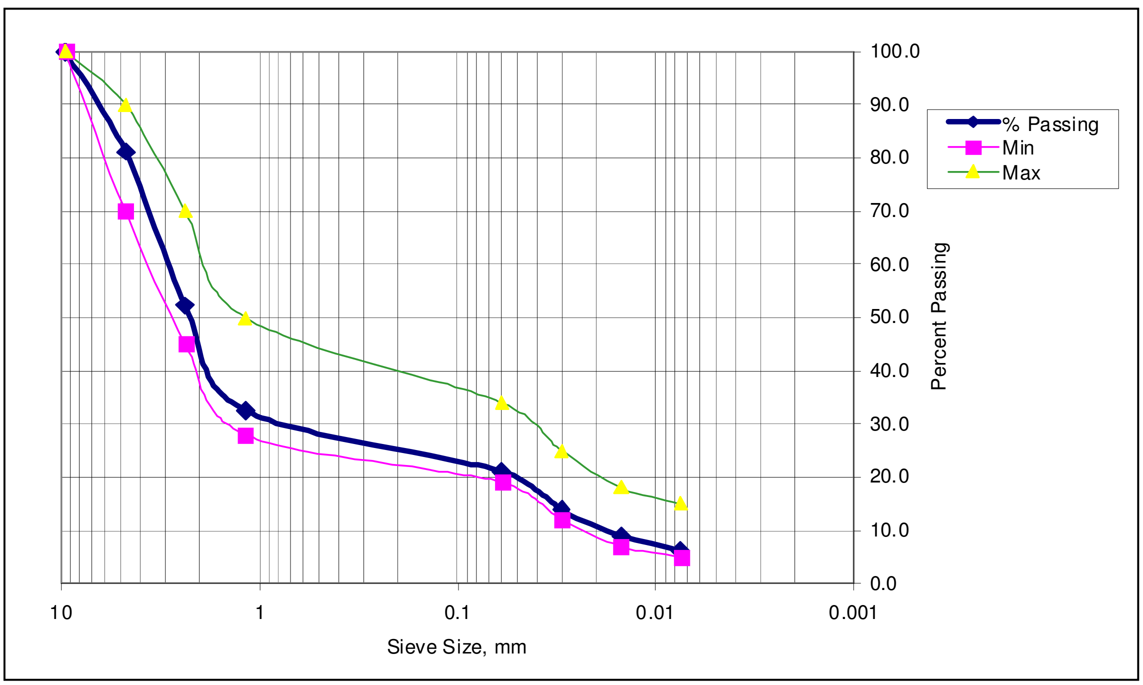
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-07

SIEVE ANALYSIS per AASHTO T27

1136.6 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
213.5	#4	4.75	81.2	70	90
542.5	#8	2.36	52.3	45	70
766.5	#16	1.18	32.6	28	50
897.5	#30	0.06	21.0	19	34
979.7	#50	0.03	13.8	12	25
1033.9	#100	0.015	9.0	7	18
1068.1	#200	0.0075	6.0	5	15



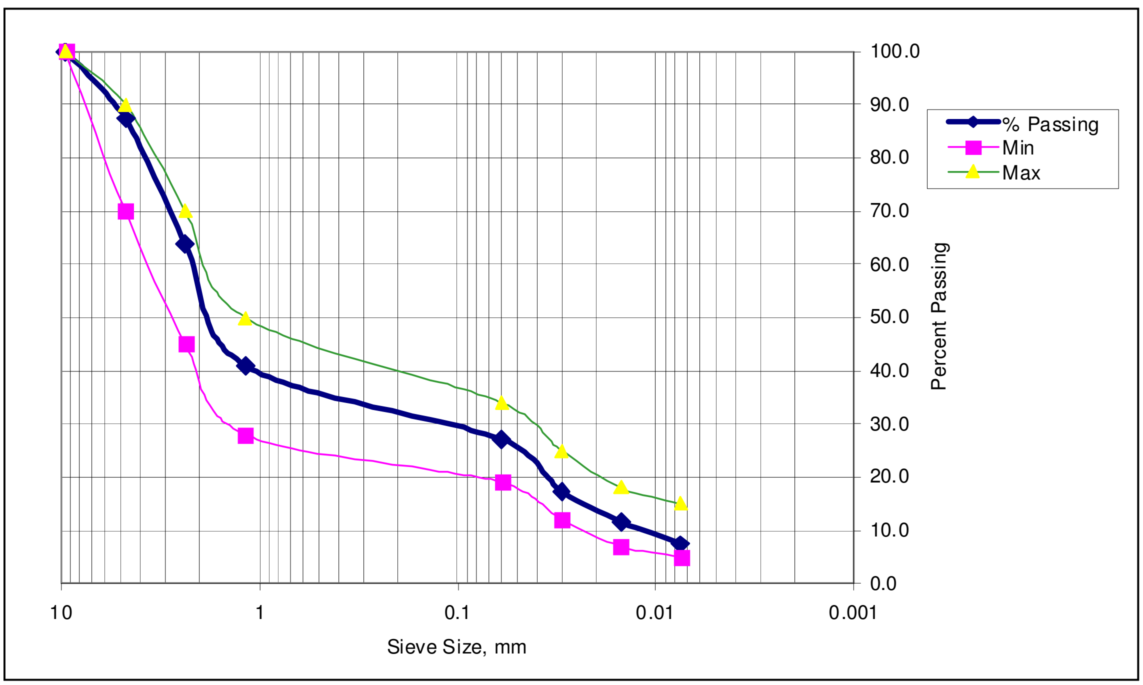
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-08

SIEVE ANALYSIS per AASHTO T27

1032.3	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
130.8	#4	4.75	87.3	70	90
372.9	#8	2.36	63.9	45	70
609.7	#16	1.18	40.9	28	50
752.5	#30	0.06	27.1	19	34
853.5	#50	0.03	17.3	12	25
912.0	#100	0.015	11.7	7	18
956.1	#200	0.0075	7.4	5	15



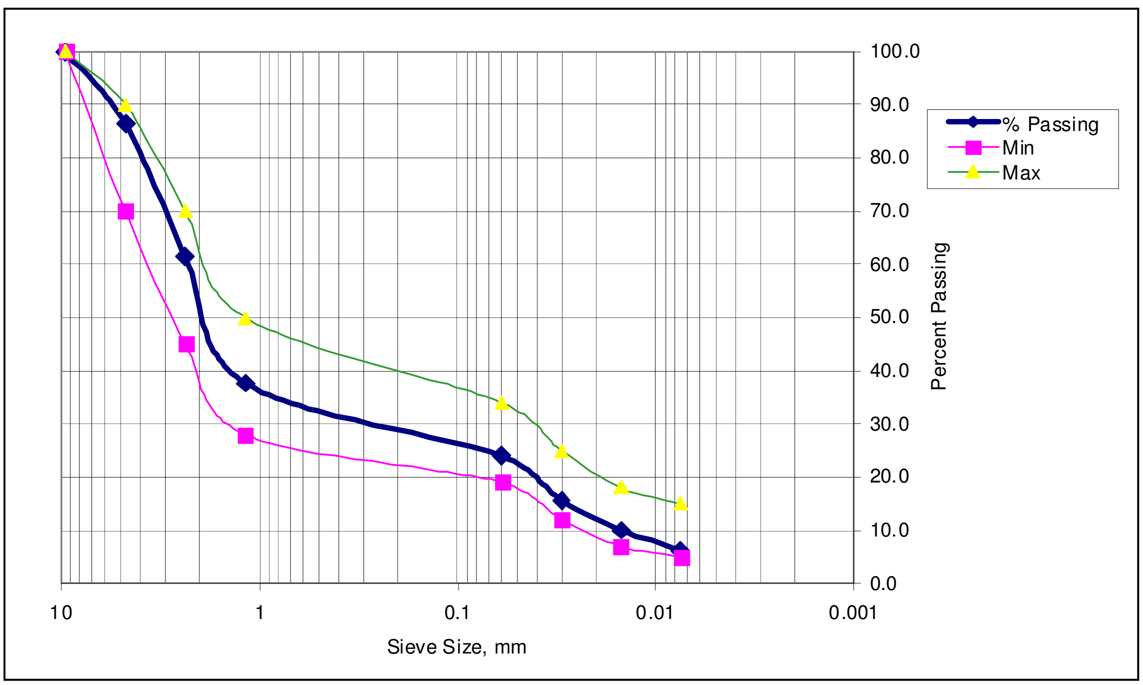
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-09

SIEVE ANALYSIS per AASHTO T27

1003.1	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
135.7	#4	4.75	86.5	70	90
387.5	#8	2.36	61.4	45	70
624.6	#16	1.18	37.7	28	50
763.0	#30	0.06	23.9	19	34
847.6	#50	0.03	15.5	12	25
902.5	#100	0.015	10.0	7	18
940.1	#200	0.0075	6.3	5	15



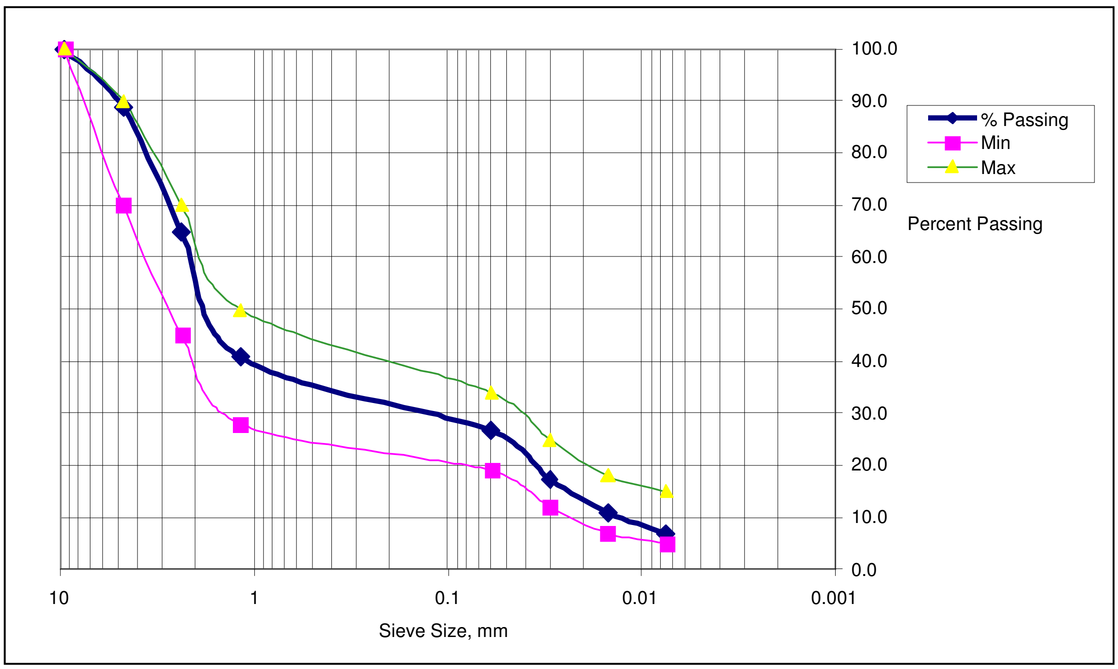
GRADATION ANALYSIS FOR AGGREGATE A1

Source: George Reed, Table Mountain (A1)
Aggregate: ISSA Type 3
Sampled ID: 1-10

SIEVE ANALYSIS per AASHTO T27

523.8 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
58.6	#4	4.75	88.8	70	90
184.4	#8	2.36	64.8	45	70
310.1	#16	1.18	40.8	28	50
384.0	#30	0.06	26.7	19	34
433.1	#50	0.03	17.3	12	25
466.2	#100	0.015	11.0	7	18
487.7	#200	0.0075	6.9	5	15



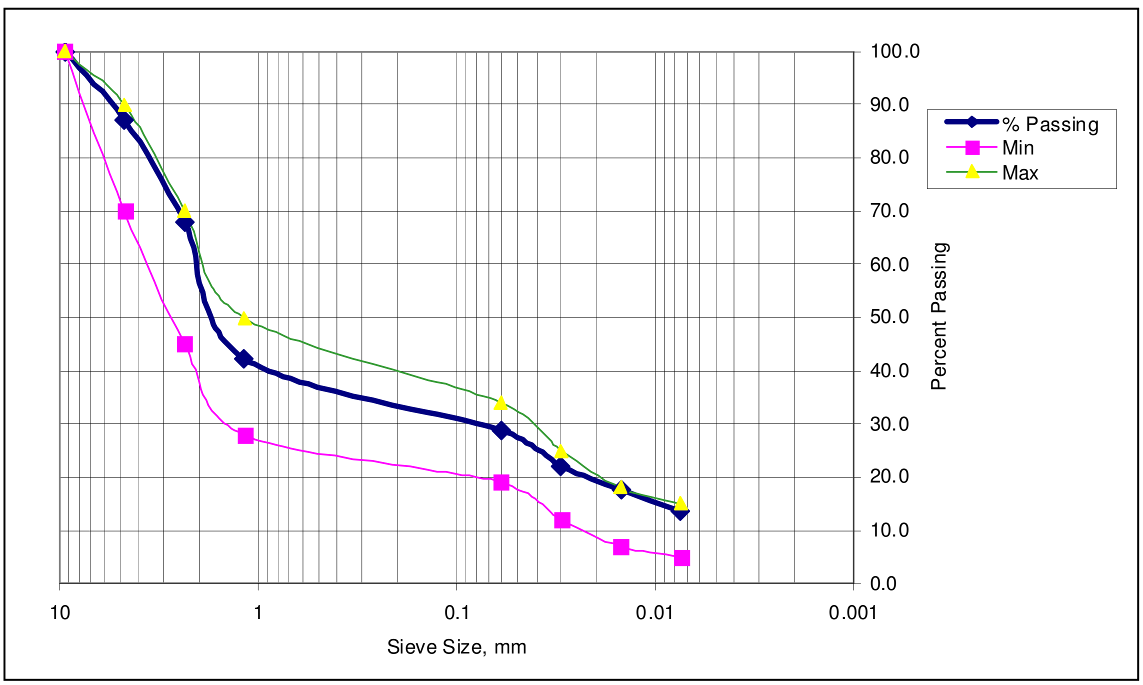
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-01

SIEVE ANALYSIS per AASHTO T27

1012.9 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
129.7	#4	4.75	87.2	70	90
325.1	#8	2.36	67.9	45	70
584.4	#16	1.18	42.3	28	50
721.2	#30	0.06	28.8	19	34
790.1	#50	0.03	22.0	12	25
833.6	#100	0.015	17.7	7	18
874.1	#200	0.0075	13.7	5	15



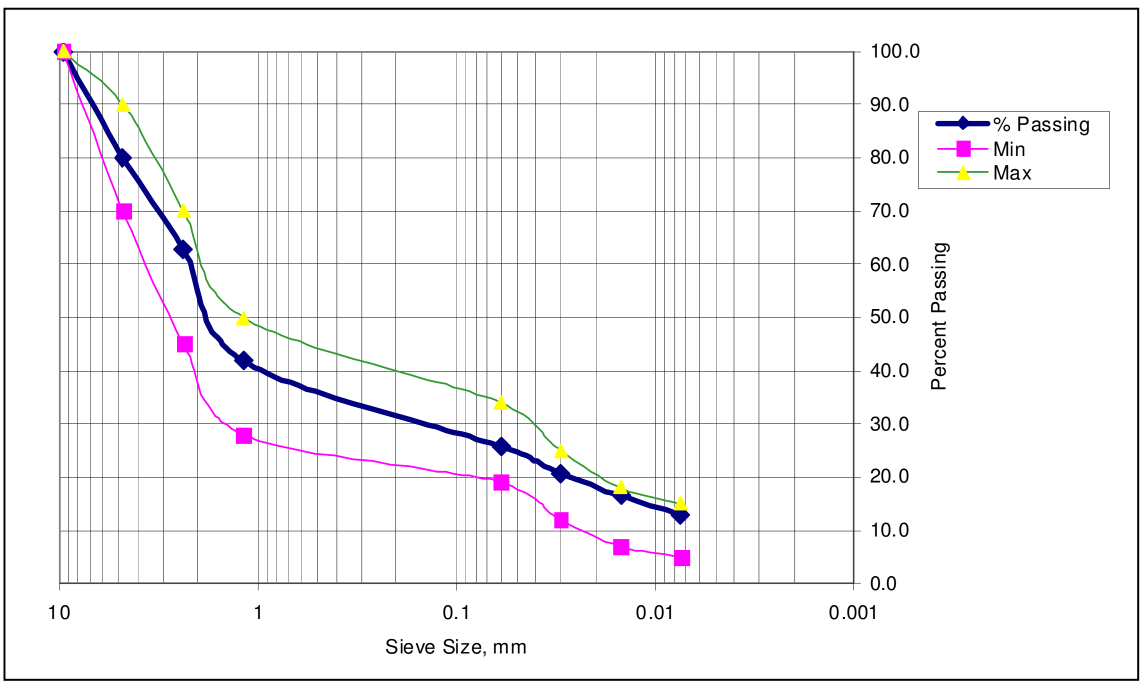
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-02

SIEVE ANALYSIS per AASHTO T27

682 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
136.1	#4	4.75	80.0	70	90
253.6	#8	2.36	62.8	45	70
396.7	#16	1.18	41.8	28	50
506.0	#30	0.06	25.8	19	34
540.2	#50	0.03	20.8	12	25
569.5	#100	0.015	16.5	7	18
593.4	#200	0.0075	13.0	5	15



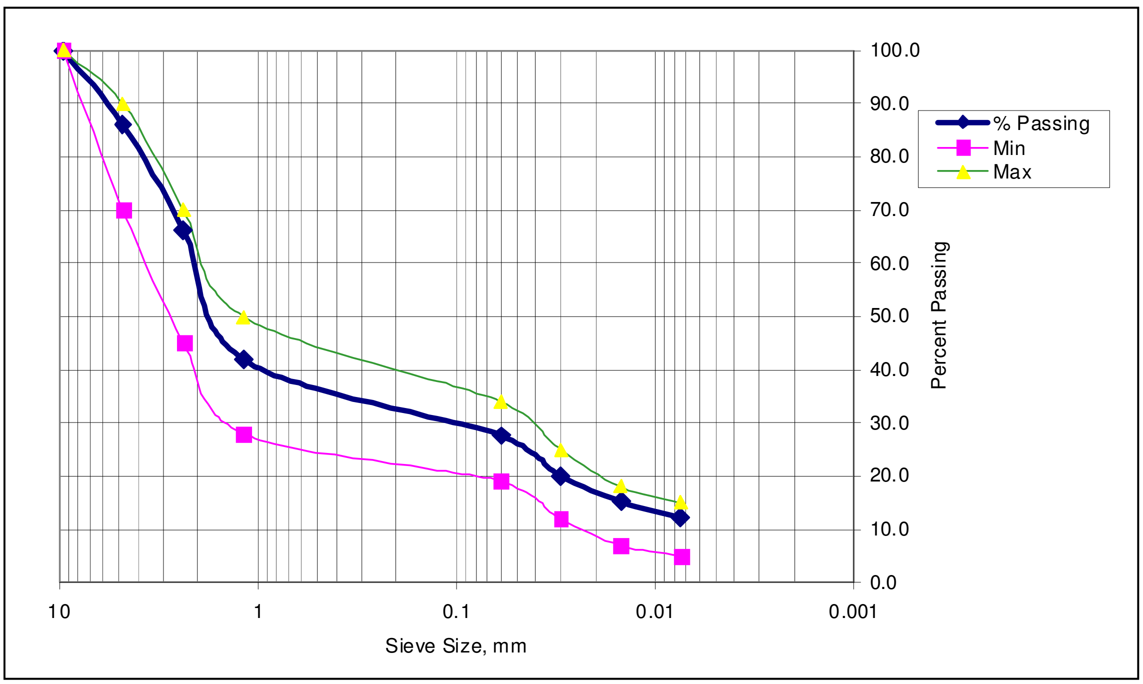
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-03

SIEVE ANALYSIS per AASHTO T27

1000.3	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
139.0	#4	4.75	86.1	70	90
337.1	#8	2.36	66.3	45	70
581.2	#16	1.18	41.9	28	50
724.2	#30	0.06	27.6	19	34
800.2	#50	0.03	20.0	12	25
848.3	#100	0.015	15.2	7	18
878.3	#200	0.0075	12.2	5	15



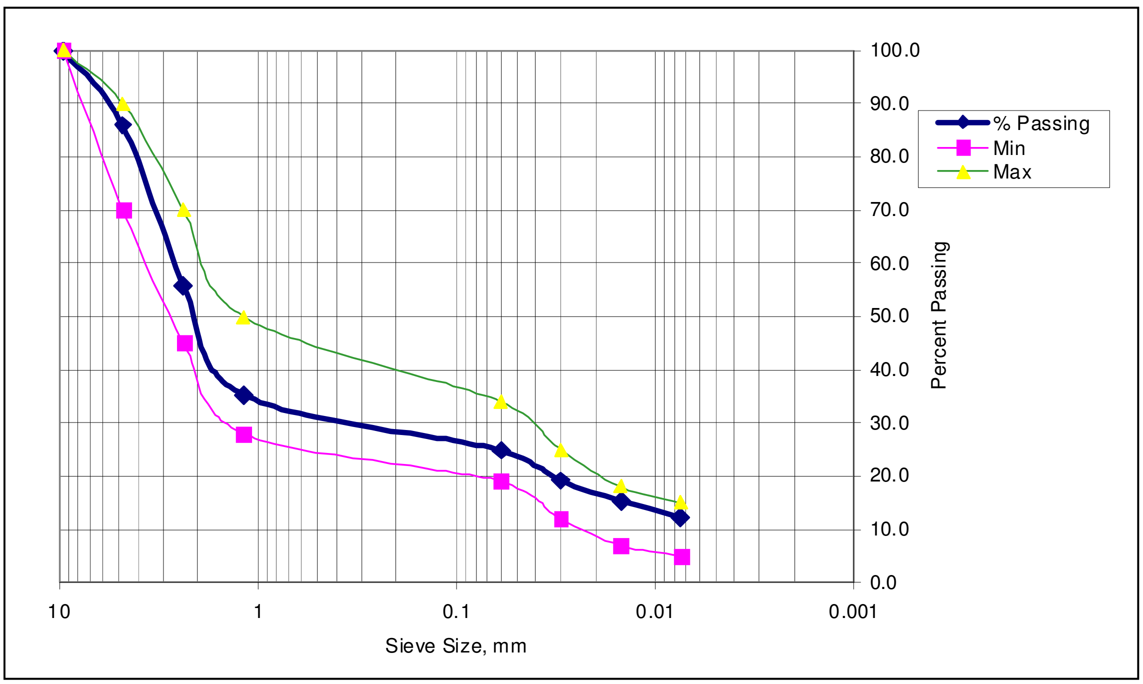
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-04

SIEVE ANALYSIS per AASHTO T27

1036.4	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
145.2	#4	4.75	86.0	70	90
457.6	#8	2.36	55.8	45	70
671.1	#16	1.18	35.2	28	50
778.9	#30	0.06	24.8	19	34
838.0	#50	0.03	19.1	12	25
876.8	#100	0.015	15.4	7	18
908.6	#200	0.0075	12.3	5	15



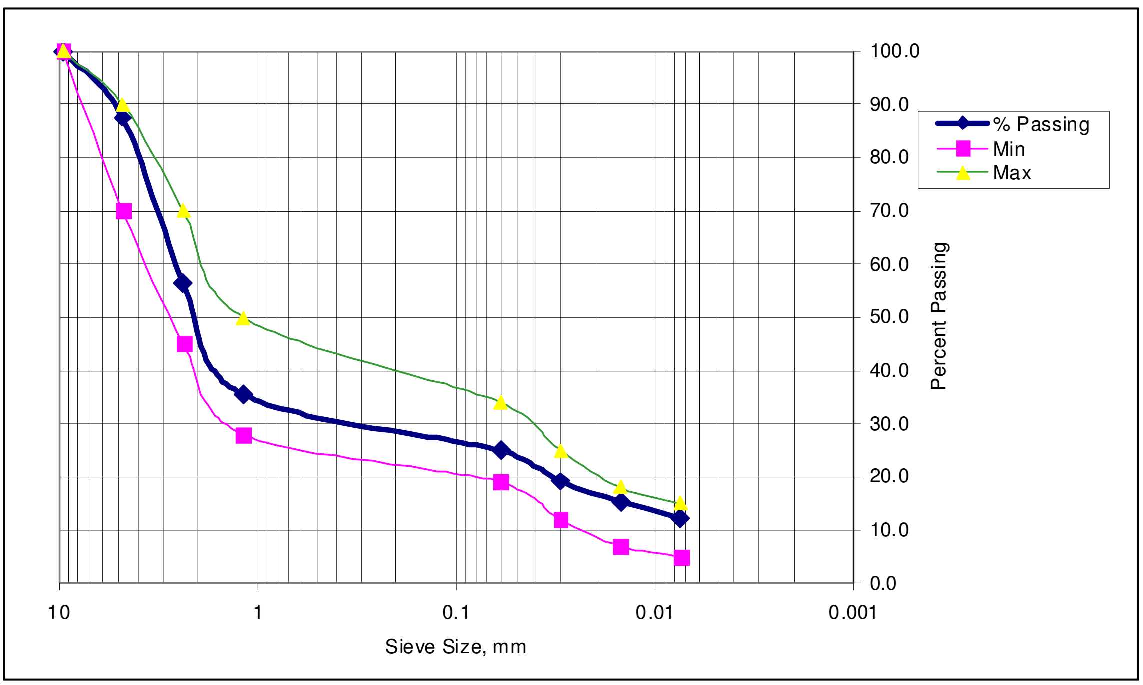
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-05

SIEVE ANALYSIS per AASHTO T27

1024.3 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
126.6	#4	4.75	87.6	70	90
446.5	#8	2.36	56.4	45	70
661.1	#16	1.18	35.5	28	50
769.1	#30	0.06	24.9	19	34
828.2	#50	0.03	19.1	12	25
866.3	#100	0.015	15.4	7	18
898.2	#200	0.0075	12.3	5	15



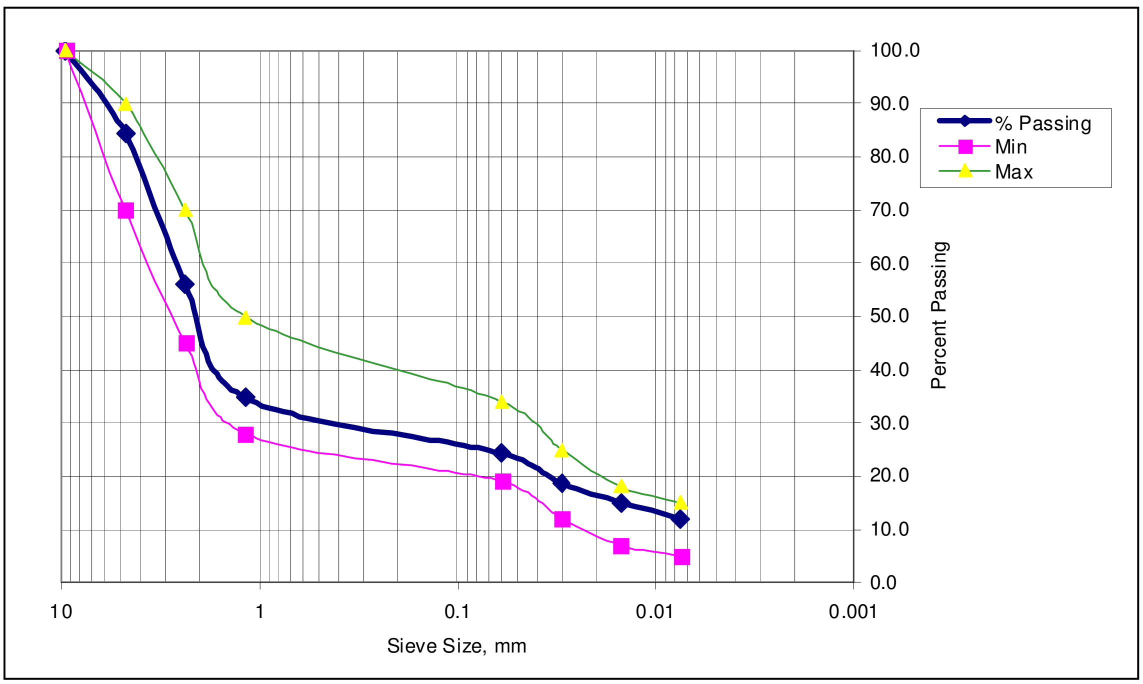
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-06

SIEVE ANALYSIS per AASHTO T27

608.2 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
95.5	#4	4.75	84.3	70	90
267.2	#8	2.36	56.1	45	70
396.9	#16	1.18	34.7	28	50
460.3	#30	0.06	24.3	19	34
494.6	#50	0.03	18.7	12	25
516.7	#100	0.015	15.0	7	18
535.5	#200	0.0075	12.0	5	15



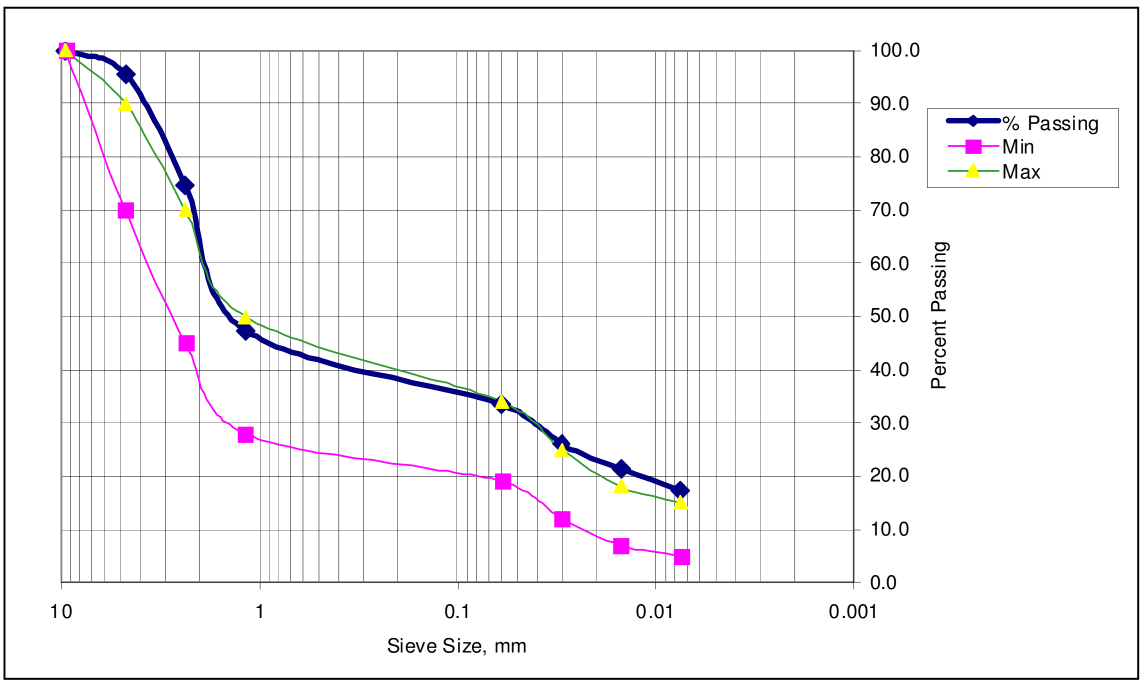
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-07

SIEVE ANALYSIS per AASHTO T27

513.6 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
22.4	#4	4.75	95.6	70	90
129.4	#8	2.36	74.8	45	70
270.2	#16	1.18	47.4	28	50
341.9	#30	0.06	33.4	19	34
380.4	#50	0.03	25.9	12	25
404.5	#100	0.015	21.2	7	18
425.2	#200	0.0075	17.2	5	15



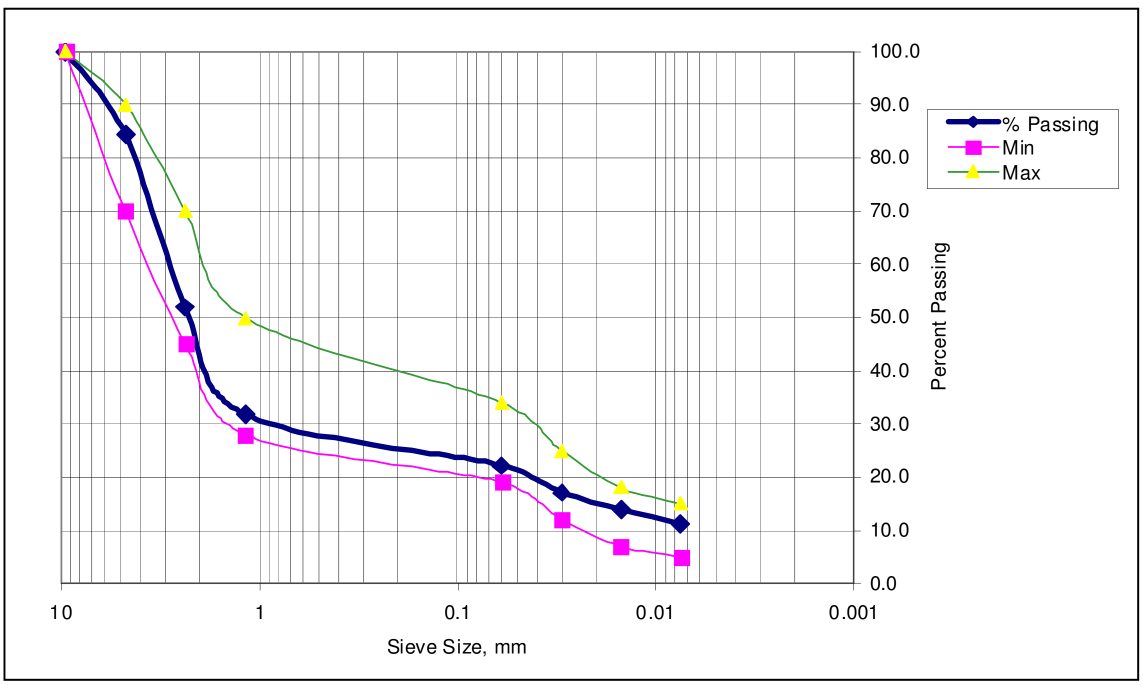
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-08

SIEVE ANALYSIS per AASHTO T27

643.3 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
99.8	#4	4.75	84.5	70	90
309.5	#8	2.36	51.9	45	70
438.5	#16	1.18	31.8	28	50
500.6	#30	0.06	22.2	19	34
533.3	#50	0.03	17.1	12	25
553.7	#100	0.015	13.9	7	18
571.2	#200	0.0075	11.2	5	15



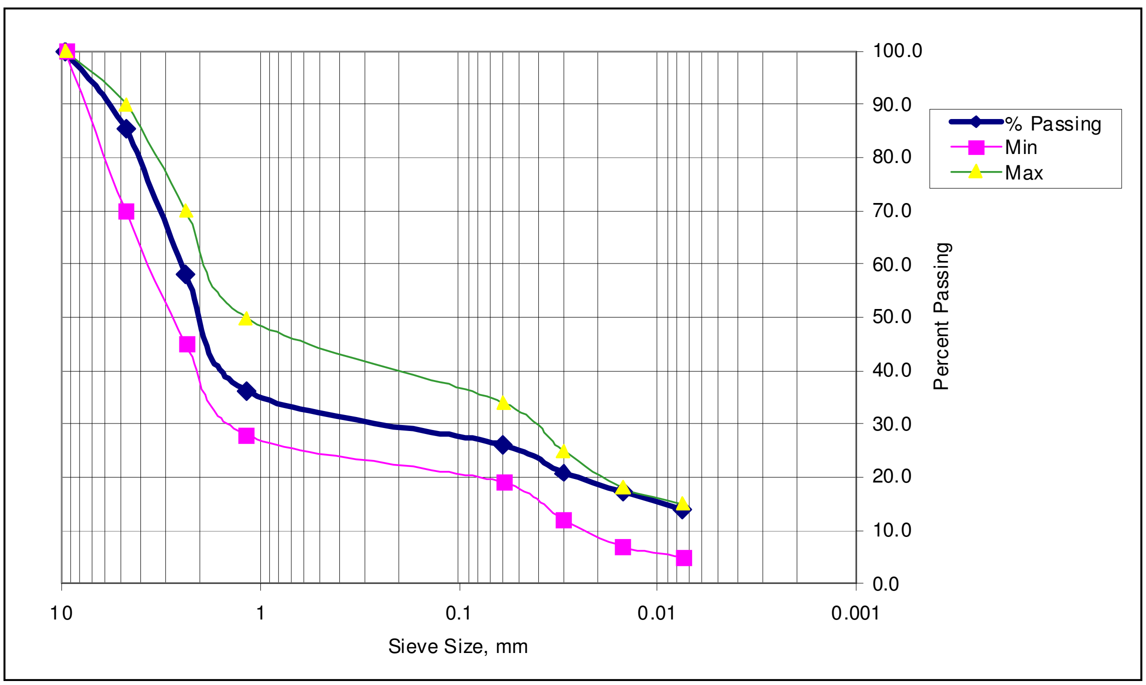
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-09

SIEVE ANALYSIS per AASHTO T27

522.9 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 ISSA Specifications Min	Max
0.0	3/8"	9.5	100.0	100	100
76.7	#4	4.75	85.3	70	90
219.0	#8	2.36	58.1	45	70
333.3	#16	1.18	36.3	28	50
386.5	#30	0.06	26.1	19	34
413.9	#50	0.03	20.8	12	25
432.2	#100	0.015	17.3	7	18
449.7	#200	0.0075	14.0	5	15



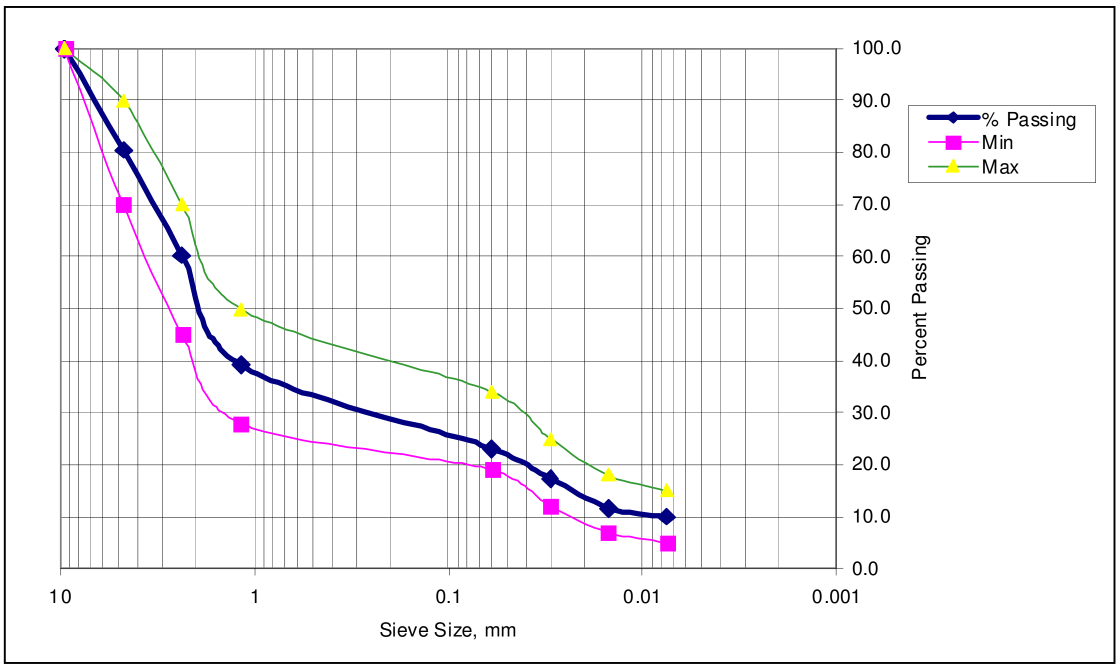
GRADATION ANALYSES FOR AGGREGATE A2

Source: Lopke (A2)
Aggregate: ISSA Type 3
Sampled ID: 2-10

SIEVE ANALYSIS per AASHTO T27

1007.8 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Type 3 Min	ISSA Specifications Max
0.0	3/8"	9.5	100.0	100	100
195.8	#4	4.75	80.6	70	90
400.3	#8	2.36	60.3	45	70
612.7	#16	1.18	39.2	28	50
774.2	#30	0.06	23.2	19	34
832.8	#50	0.03	17.4	12	25
890.0	#100	0.015	11.7	7	18
906.5	#200	0.0075	10.1	5	15



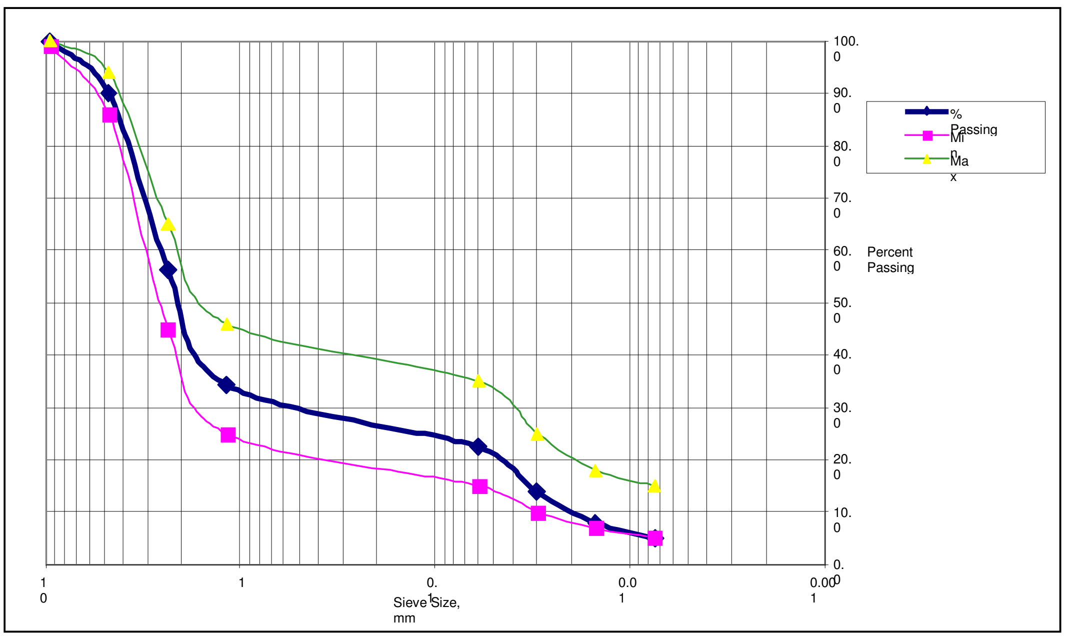
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-01

SIEVE ANALYSIS per AASHTO T27

1045.9	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
104.6	#4	4.75	90.0	86	94
458.1	#8	2.36	56.2	45	65
687.2	#16	1.18	34.3	25	46
811.6	#30	0.06	22.4	15	35
901.6	#50	0.03	13.8	10	25
963.3	#100	0.015	7.9	7	18
992.6	#200	0.0075	5.1	5	15



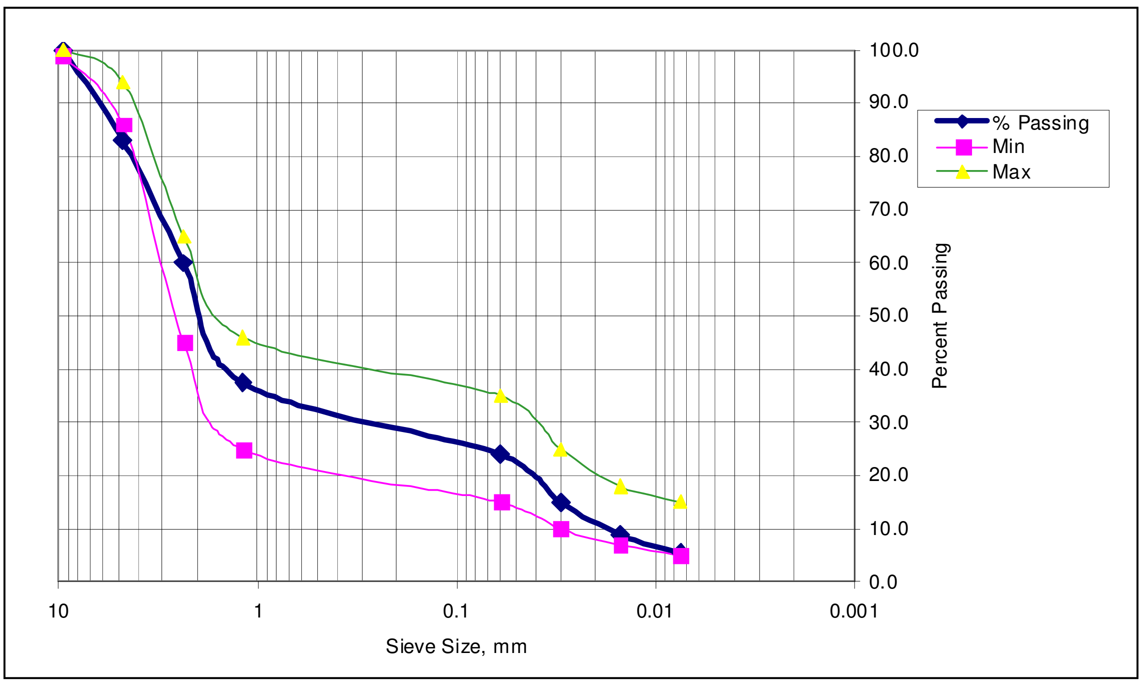
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-02

SIEVE ANALYSIS per AASHTO T27

523.5 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
88.8	#4	4.75	83.0	86	94
209.6	#8	2.36	60.0	45	65
327.6	#16	1.18	37.4	25	46
398.2	#30	0.06	23.9	15	35
444.6	#50	0.03	15.1	10	25
477.3	#100	0.015	8.8	7	18
494.9	#200	0.0075	5.5	5	15



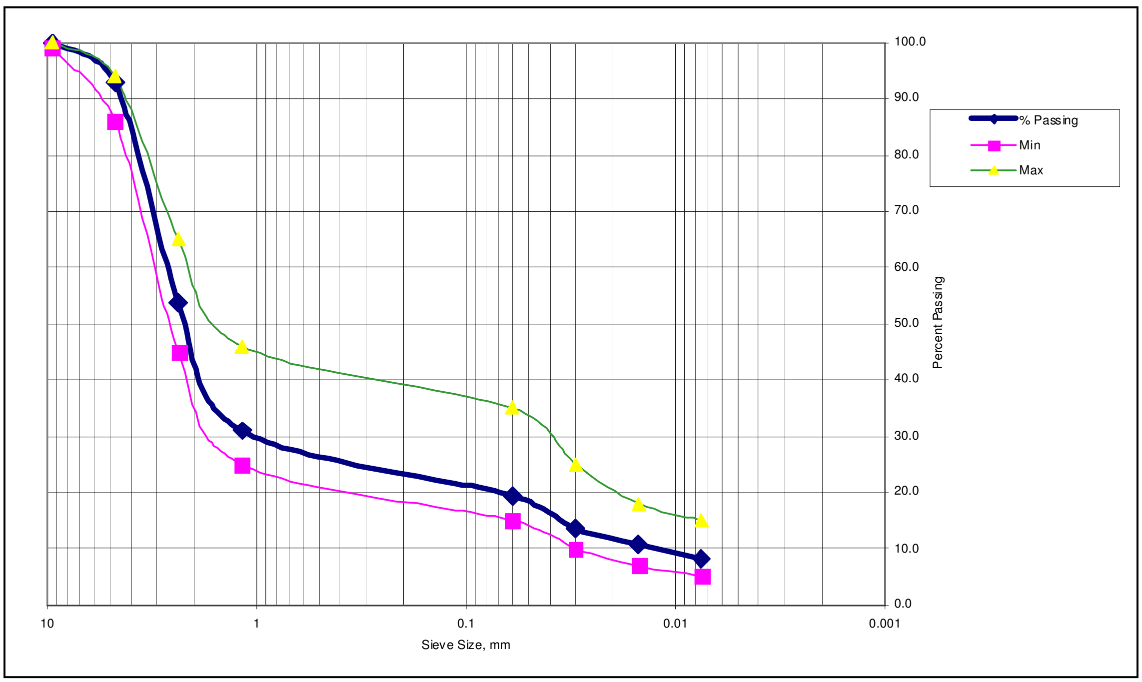
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-03

SIEVE ANALYSIS per AASHTO T27

500 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
35.7	#4	4.75	92.9	86	94
231.2	#8	2.36	53.8	45	65
345.3	#16	1.18	30.9	25	46
402.9	#30	0.06	19.4	15	35
432.6	#50	0.03	13.5	10	25
446.7	#100	0.015	10.7	7	18
458.9	#200	0.0075	8.2	5	15



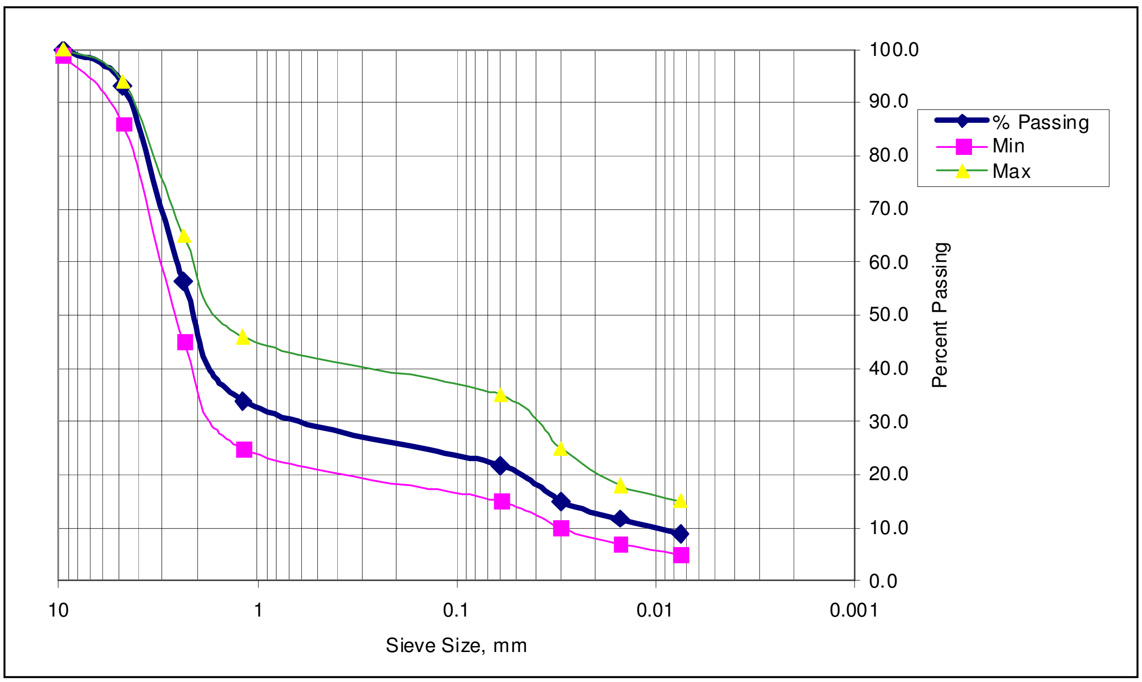
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-04

SIEVE ANALYSIS per AASHTO T27

500 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
34.0	#4	4.75	93.2	86	94
218.4	#8	2.36	56.3	45	65
330.4	#16	1.18	33.9	25	46
391.4	#30	0.06	21.7	15	35
425.1	#50	0.03	15.0	10	25
441.3	#100	0.015	11.7	7	18
454.8	#200	0.0075	9.0	5	15



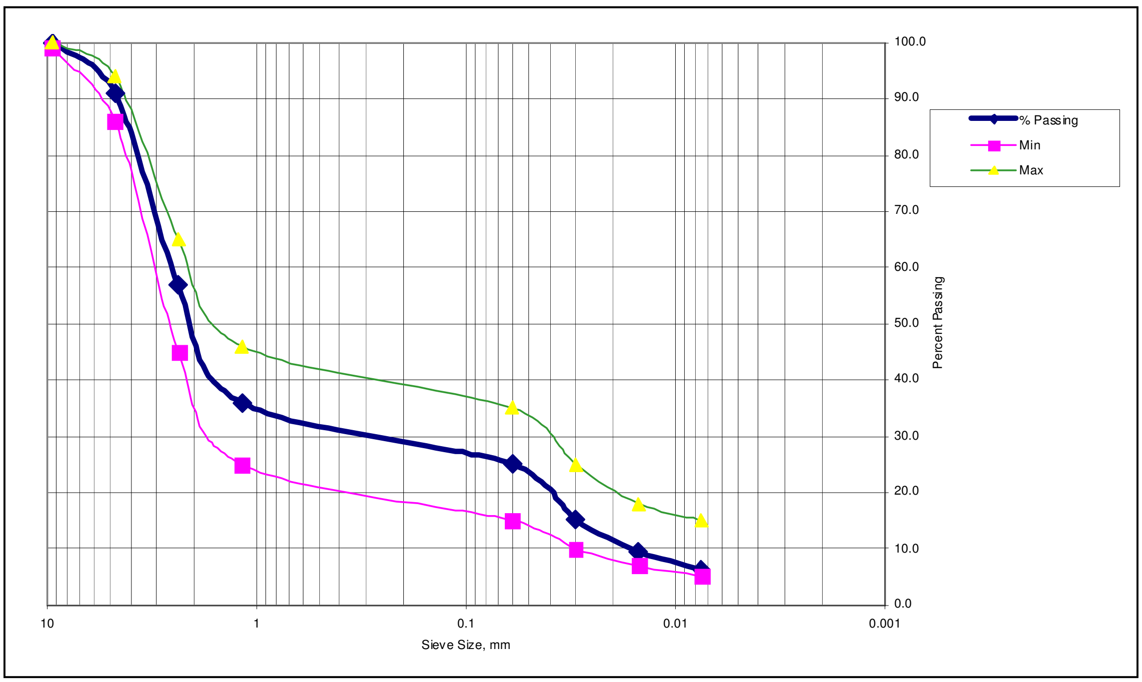
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-05

SIEVE ANALYSIS per AASHTO T27

567.7 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
51.1	#4	4.75	91.0	86	94
245.2	#8	2.36	56.8	45	65
363.9	#16	1.18	35.9	25	46
425.8	#30	0.06	25.0	15	35
481.4	#50	0.03	15.2	10	25
513.8	#100	0.015	9.5	7	18
531.9	#200	0.0075	6.3	5	15



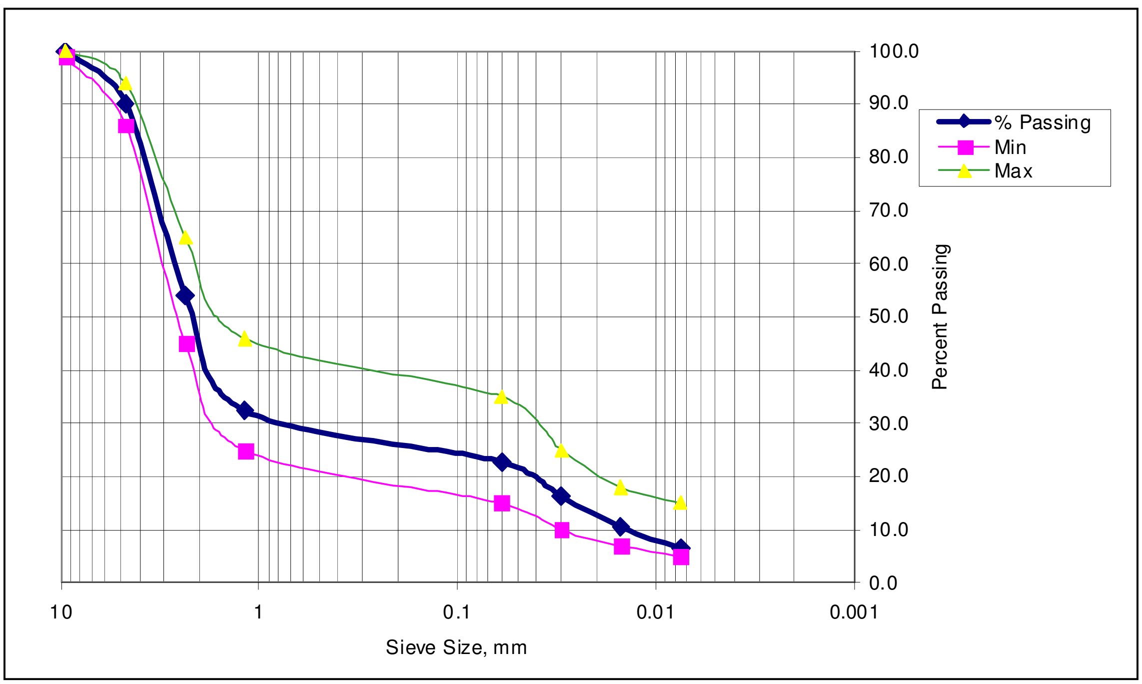
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-06

SIEVE ANALYSIS per AASHTO T27

500 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
49.0	#4	4.75	90.2	86	94
229.5	#8	2.36	54.1	45	65
338.0	#16	1.18	32.4	25	46
386.0	#30	0.06	22.8	15	35
418.5	#50	0.03	16.3	10	25
447.5	#100	0.015	10.5	7	18
467.5	#200	0.0075	6.5	5	15



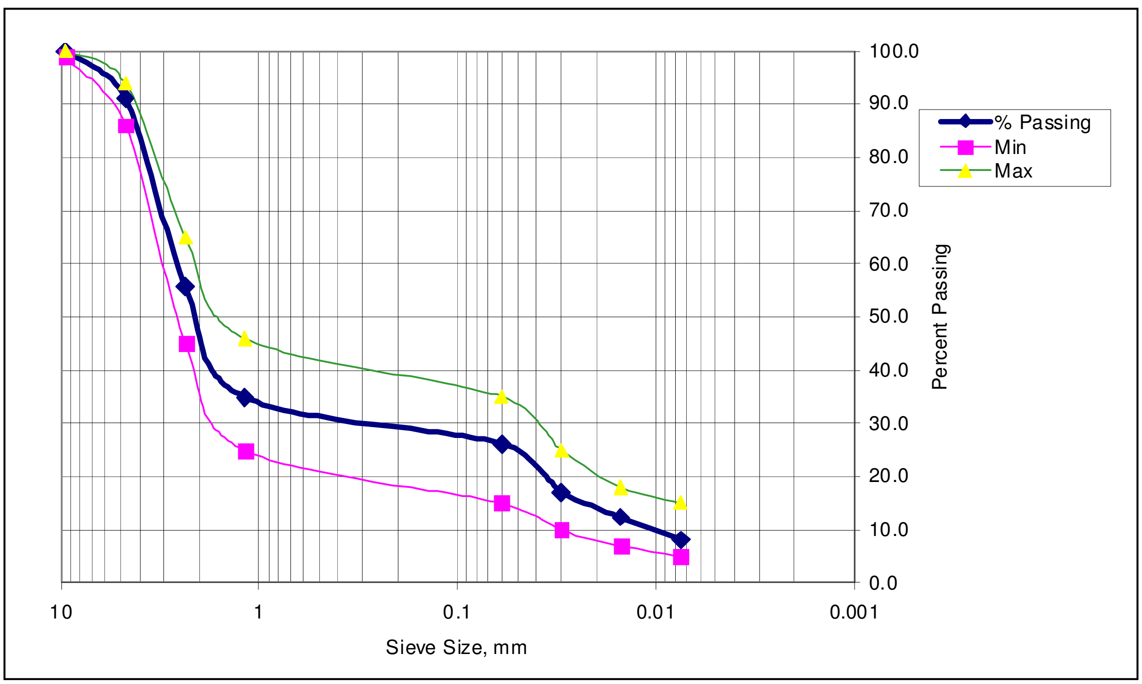
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-07

SIEVE ANALYSIS per AASHTO T27

510.1 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
45.9	#4	4.75	91.0	86	94
226.5	#8	2.36	55.6	45	65
332.1	#16	1.18	34.9	25	46
376.5	#30	0.06	26.2	15	35
422.9	#50	0.03	17.1	10	25
446.8	#100	0.015	12.4	7	18
468.8	#200	0.0075	8.1	5	15



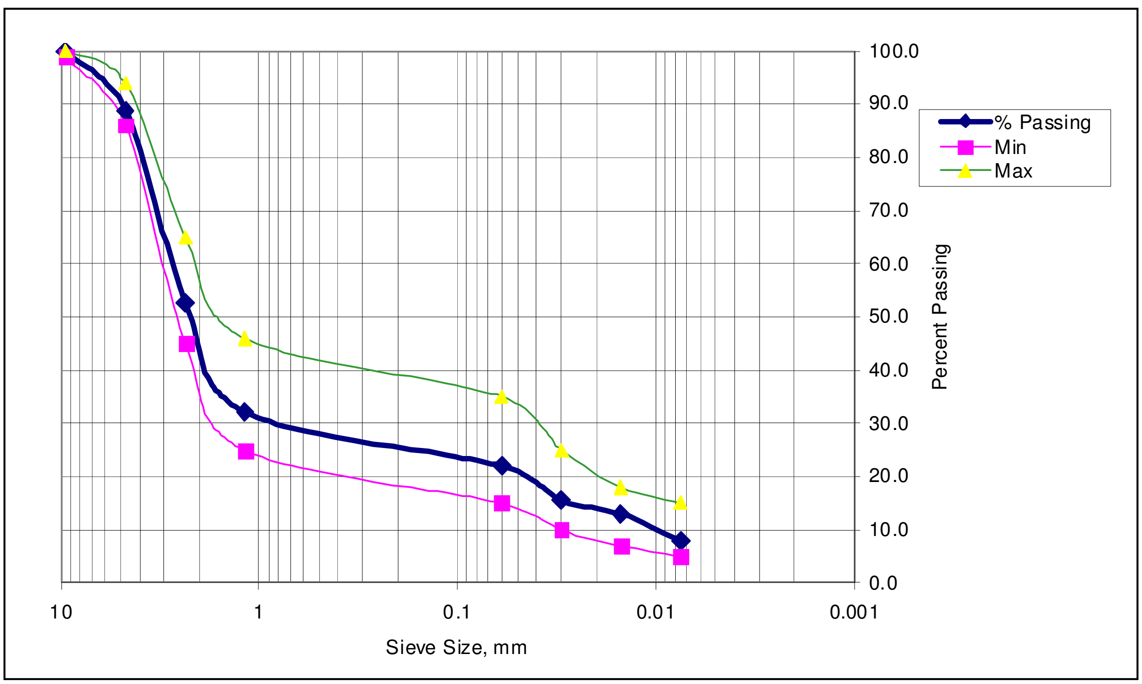
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-08

SIEVE ANALYSIS per AASHTO T27

1021.1 Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	100.0	99	100
113.3	#4	4.75	88.9	86	94
482.0	#8	2.36	52.8	45	65
692.3	#16	1.18	32.2	25	46
796.5	#30	0.06	22.0	15	35
862.9	#50	0.03	15.5	10	25
888.4	#100	0.015	13.0	7	18
941.5	#200	0.0075	7.8	5	15



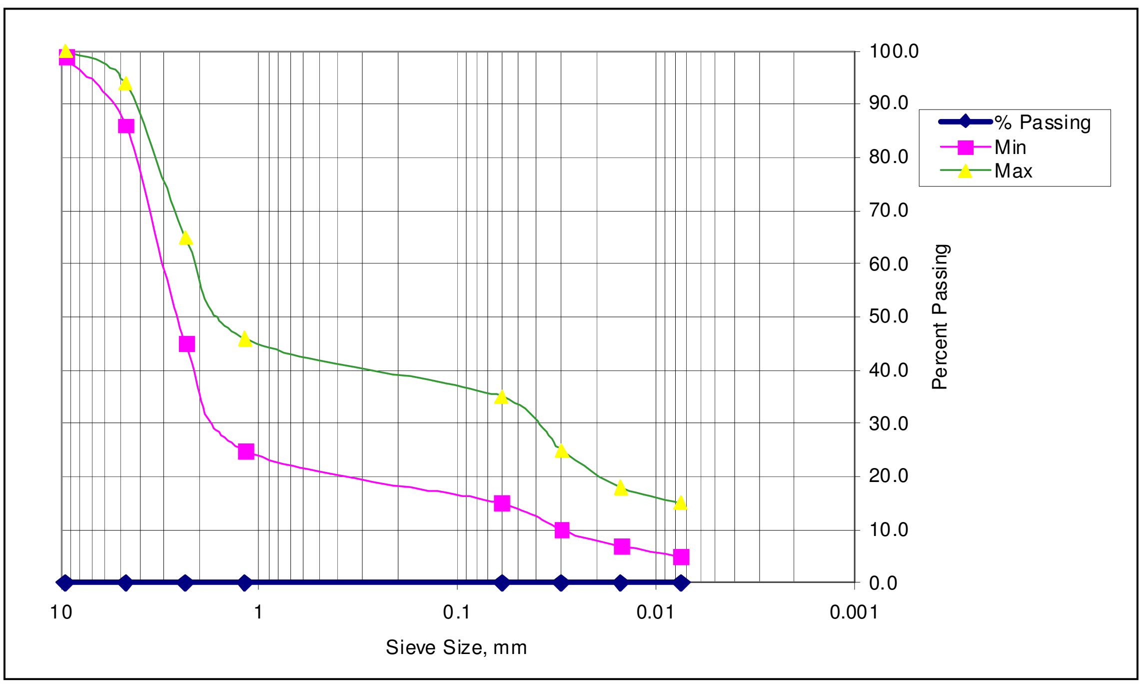
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-09

SIEVE ANALYSIS per AASHTO T27

0	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	#DIV/0!	99	100
0.0	#4	4.75	#DIV/0!	86	94
0.0	#8	2.36	#DIV/0!	45	65
0.0	#16	1.18	#DIV/0!	25	46
0.0	#30	0.06	#DIV/0!	15	35
0.0	#50	0.03	#DIV/0!	10	25
0.0	#100	0.015	#DIV/0!	7	18
0.0	#200	0.0075	#DIV/0!	5	15



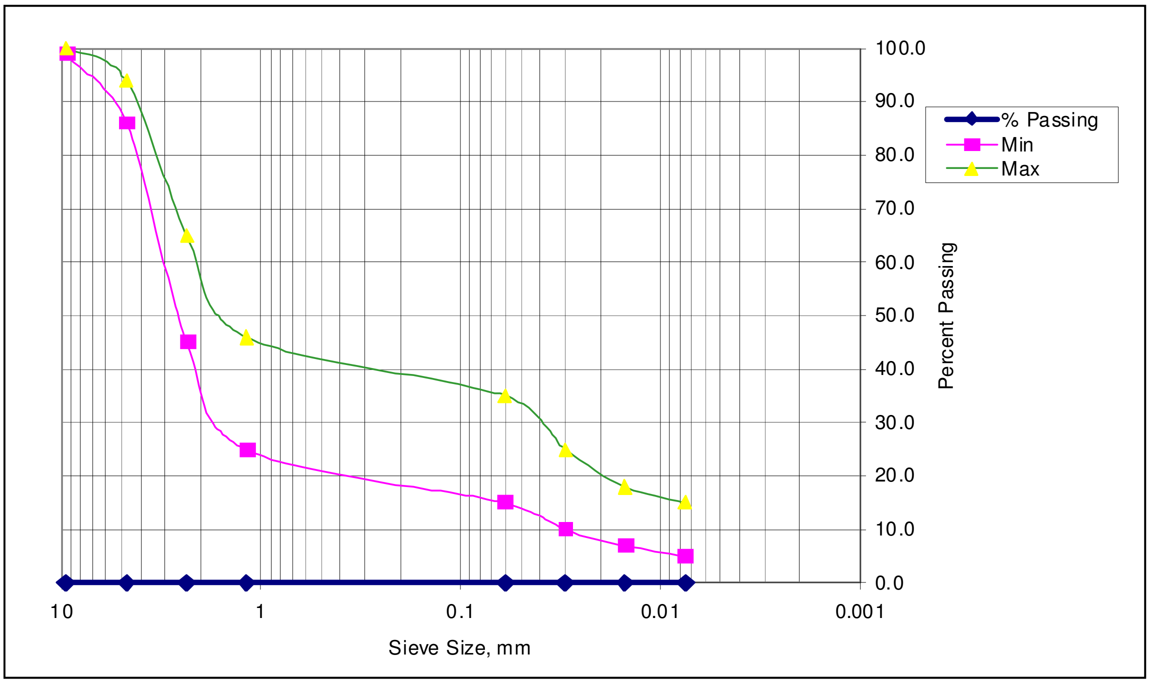
GRADATION ANALYSES FOR AGGREGATE A3

Source: Texas (A3)
Aggregate: Grade 2 Texas (between Type 2 & Type 3 ISSA specs)
Sampled ID: 3-10

SIEVE ANALYSIS per AASHTO T27

0	Dry Weight of Sample before #200 Wash, g

Cumulative Weight, g	Sieve Size	Sieve Size	Results % Passing	Grade 2, Texas specs Min	Max
0.0	3/8"	9.5	#DIV/0!	99	100
0.0	#4	4.75	#DIV/0!	86	94
0.0	#8	2.36	#DIV/0!	45	65
0.0	#16	1.18	#DIV/0!	25	46
0.0	#30	0.06	#DIV/0!	15	35
0.0	#50	0.03	#DIV/0!	10	25
0.0	#100	0.015	#DIV/0!	7	18
0.0	#200	0.0075	#DIV/0!	5	15



SODIUM SULFATE SOUNDNESS FOR AGGREGATES A1, A2, AND A3

Sodium Sulfate Soundness per AASHTO for Fine Aggregate Samples

CEL Number: 10-17749   Solution: Sodium
Aggregate: A1 (Table Mountain)   Solution: New

Initial Bulk Test Sample Size, g: 1021.7

FINE FRACTION

Sieve Size	Ind'l Wt Retained	Cum Wt Retained	Cum % Retained	Cum % Passing	Ind'l % Retained	check		To make grading equal to 100%	Weight of Fraction before test, g	% Passing designated sieve after test	Weighted Percentage Loss for Fine Fraction
	0.0	0.0	0.0	100.0	0.0			0.0			0.0
3/8"	0.0	0.0	0.0	100.0	0.0	0.0		0.0		0	0.0
#4	130.8	130.8	12.8	87.2	12.8	12.8		13.8	300.0	6.2	0.9
#8	232.9	363.7	35.6	64.4	23	22.8		24.6	100.0	4.9	1.2
#16	241.1	604.8	59.2	40.8	24	23.6		25.5	100.0	5.2	1.3
#30	141.0	745.8	73.0	27.0	14	13.8		14.9	100.1	4.3	0.6
#50	101.2	847.0	82.9	17.1	10	9.9		10.7	100.0	4.5	0.5
#100	49.0	896.0	87.7	12.3	5	4.8		5.2		0	0.0
#200	50.1	946.1	92.6	7.4	5	4.9		5.3		0	0.0
pan+wash	75.6		0.0			7.4	sum	100.0		sum=	5
Check:	1021.7				93	100.0					

(TOTAL final result reported to nearest whole number)

SODIUM SULFATE SOUNDNESS FOR AGGREGATES A1, A2, AND A3

Sodium Sulfate Soundness per AASHTO for Fine Aggregate Samples

CEL Number: 10-17749 Solution: Sodium
Aggregate: A2 (Lopke) Solution: Used

Initial Bulk Test Sample Size, g: 1012.9

FINE FRACTION

Sieve Size	Ind'l Wt Retained	Cum Wt Retained	Cum % Retained	Cum % Passing	Ind'l % Retained	check		To make grading equal to 100%	Weight of Fraction before test, g	% Passing designated sieve after test	Weighted Percentage Loss for Fine Fraction
	0.0	0.0	0.0	100.0	0.0			0.0			0.0
3/8"	0.0	0.0	0.0	100.0	0.0	0.0		0.0		0	0.0
#4	129.7	129.7	12.8	87.2	12.8	12.8		14.8	298.6	13.7	2.0
#8	195.4	325.1	32.1	67.9	19	19.3		22.4	100.0	9.2	2.1
#16	259.3	584.4	57.7	42.3	26	25.6		29.7	100.0	8.8	2.6
#30	136.8	721.2	71.2	28.8	14	13.5		15.7	100.0	8.8	1.4
#50	68.9	790.1	78.0	22.0	7	6.8		7.9	100.0	8.0	0.6
#100	43.5	833.6	82.3	17.7	4	4.3		5.0		0	0.0
#200	40.5	874.1	86.3	13.7	4	4.0		4.6		0	0.0
pan+wash	138.8		0.0			13.7	sum	100.0		sum=	9
Check:	1012.9				86	100.0					

(TOTAL final result reported to nearest whole number)

SODIUM SULFATE SOUNDNESS FOR AGGREGATES A1, A2, AND A3

Sodium Sulfate Soundness per AASHTO for Fine Aggregate Samples

CEL Number: 10-17749
Aggregate: A3 (Texas)
Solution: Sodium
Solution: Used

Initial Bulk Test Sample Size, g: 1045.9

FINE FRACTION

Sieve Size	Ind'l Wt Retained	Cum Wt Retained	Cum % Retained	Cum % Passing	Ind'l % Retained	check		To make grading equal to 100%	Weight of Fraction before test, g	% Passing designated sieve after test	Weighted Percentage Loss for Fine Fraction
	0.0	0.0	0.0	100.0	0.0			0.0			0.0
3/8"	0.0	0.0	0.0	100.0	0.0	0.0		0.0		0	0.0
#4	104.6	104.6	10.0	90.0	10.0	10.0		10.5	300.1	2.6	0.3
#8	353.5	458.1	43.8	56.2	34	33.8		35.6	100.0	3.7	1.3
#16	229.1	687.2	65.7	34.3	22	21.9		23.1	100.0	5.6	1.3
#30	124.4	811.6	77.6	22.4	12	11.9		12.5	100.0	5.2	0.7
#50	90.0	901.6	86.2	13.8	9	8.6		9.1	100.0	3.1	0.3
#100	61.7	963.3	92.1	7.9	6	5.9		6.2		0	0.0
#200	29.3	992.6	94.9	5.1	3	2.8		3.0		0	0.0
pan+wash	53.3		0.0			5.1	sum	100.0		sum=	4
Check:	1045.9				95	100.0					

(TOTAL final result reported to nearest whole number)

DURABILITY OF FINE AGGREGATE FOR A3

Durability of Fine Aggregate per Cal 229

CEL Number: 10-17749 Aggregate ID: A3 (Texas)

Sample: 3-01 Trial: 1

Soaking Time, Start:	10	minutes
Soaking Time, End:	0	10 +/- 1 min
Sedimentation, Start:	20	
Sedimentation, End:	0	at 20 min
Clay Reading, C:	5.2	
Sand Reading, S:	3.9	
Df (S/C)*100:	75.0	
Df to Round Up:	75	
Durability to Report:	75	

ABRASION LOSS BY AASHTO T-96 FOR AGGREGATES A1, A2, AND A3

Abrasion Loss by LA Rattler Machine per AASHTO T-96

CEL Number: 10-17749 Aggregate ID: A1 (Table Mountain)

Sieve Size Used:	#4 x #8	
Grading Used:	D	
Grading Wt to Use, g:	5000 +/- 10	
Initial Sample Wt, g:	5000.5	
Number of Spheres Used:	6	
Mass of Charges to Use, g:	2500 +/- 15	
Mass of Charges Used, g:	2508.5	
Wt of Sample After 500 Revs, g:	4103.8	Retained on #12
Percent Loss After 500 Revs:	18	

Abrasion Loss by LA Rattler Machine per AASHTO T-96

CEL Number: 10-17749 Aggregate ID: A2 (Lopke)

Sieve Size Used:	#4 x #8	
Grading Used:	D	
Grading Wt to Use, g:	5000 +/- 10	
Initial Sample Wt, g:	5000.2	
Number of Spheres Used:	6	
Mass of Charges to Use, g:	2500 +/- 15	
Mass of Charges Used, g:	2512.2	
Wt of Sample After 500 Revs, g:	3845.9	Retained on #12
Percent Loss After 500 Revs:	23	

Abrasion Loss by LA Rattler Machine per AASHTO T-96

CEL Number: 10-17749 Aggregate ID: A3 (Texas)

Sieve Size Used:	#4 x #8	
Grading Used:	D	
Grading Wt to Use, g:	5000 +/- 10	
Initial Sample Wt, g:	5001.8	
Number of Spheres Used:	6	
Mass of Charges to Use, g:	2500 +/- 15	
Mass of Charges Used, g:	2508.5	
Wt of Sample After 500 Revs, g:	3732.3	Retained on #12
Percent Loss After 500 Revs:	25	

SAND EQUIVALENT FOR AGGREGATES A1, AND A2

Sand Equivalent Value of Soils and Fine Aggregate per AASHTO T176

CEL Number: 10-17749

Aggregate: A1 (Table Mountain)

Sample# 1-01	Trial 1	Trial 2	Trial 3	
Soaking time: Start	0	3	6	minutes
Soaking time: End	10	13	16	10 +/- 1 min
Sedimentation: Start	1147	1435	1649	
Sedimentation: End	3147	3435	3649	@ 20 min
Clay reading, C	4.9	4.8	4.9	
Sand reading, S	4	3.9	3.9	
SE (S/C)*100	81.6	81.3	79.6	
SE to Round Up	82	81	80	
Average SE to Report	**81**			

Sample# 1-09	Trial 1	Trial 2	Trial 3	
Soaking time: Start	0	3	6	minutes
Soaking time: End	10	13	16	10 +/- 1 min
Sedimentation: Start	1158	1428	1652	
Sedimentation: End	3158	3428	3652	@ 20 min
Clay reading, C	4.9	4.7	5.1	
Sand reading, S	4.1	3.8	4.1	
SE (S/C)*100	83.7	80.9	80.4	
SE to Round Up	84	81	81	
Average SE to Report	**82**			

SAND EQUIVALENT FOR AGGREGATES A1, AND A2

Sand Equivalent Value of Soils and Fine Aggregate per AASHTO T176

CEL Number: 10-17749
Aggregate: A2 (Lopke)

Sample# 2-01	Trial 1	Trial 2	Trial 3	
Soaking time: start	0	3	6	minutes
Soaking time: end	10	13	16	10 +/- 1 min
Sedimentation: start	1210	1421	1630	
Sedimentation: end	3210	3421	3630	@ 20 min
Clay reading, C	6.8	6.7	6.7	
Sand reading, S	4.3	4.2	4.1	
SE (S/C)*100	63.2	62.7	61.2	
SE to round up	64	63	62	
Average SE to report	**63**			

Sample# 2-02	Trial 1	Trial 2	Trial 3	
Soaking time: start	0	3	6	minutes
Soaking time: end	10	13	16	10 +/- 1 min
Sedimentation: start	1201	1423	1638	
Sedimentation: end	3201	3423	3652	@ 20 min
Clay reading, C	6.9	6.8	7.0	
Sand reading, S	4.4	4.5	4.5	
SE (S/C)*100	63.8	66.2	64.3	
SE to round up	64	67	65	
Average SE to report	**66**			

Sample# 2-09	Trial 1	Trial 2	Trial 3	
Soaking time: start	0	3	6	minutes
Soaking time: end	10	13	16	10 +/- 1 min
Sedimentation: start	1226	1453	1654	
Sedimentation: end	3226	3453	3654	@ 20 min
Clay reading, C	6.8	6.9	7.1	
Sand reading, S	4.3	4.4	4.5	
SE (S/C)*100	63.2	63.8	63.4	
SE to round up	64	64	64	
Average SE to report	**64**			

SAND EQUIVALENT FOR AGGREGATES A1, AND A2

Sand Equivalent Value of Soils and Fine Aggregate per AASHTO T176

CEL Number: 10-17749
Aggregate: A1 (Table Mountain)

Sample# 1-01	Trial 1	Trial 2	Trial 3	
Soaking time: Start	0	3	6	minutes
Soaking time: End	10	13	16	10 +/- 1 min
Sedimentation: Start	1215	1422	1630	
Sedimentation: End	3215	3422	3630	@ 20 min
Clay reading, C	6.1	6.4	6.4	
Sand reading, S	4.4	4.5	4.6	
SE (S/C)*100	72.1	70.3	71.9	
SE to Round Up	73	71	72	
Average SE to Report	**72**			

Sample#	Trial 1	Trial 2	Trial 3	
Soaking time: Start	0	3	6	minutes
Soaking time: End	10	13	16	10 +/- 1 min
Sedimentation: Start				
Sedimentation: End				@ 20 min
Clay reading, C				
Sand reading, S				
SE (S/C)*100				
SE to Round Up				
Average SE to Report				

ABRASION LOSS BY ASTM D6928 FOR AGGREGATES A1, A2, AND A3

CEL#	10-17749	
Aggregate:	TABLE MOUNTAIN	
Abrasion Loss by Micro-Deval per ASTM D6928		
Sieve Size	Cumulative Wt of Sample, g	
3/8"	0.0	
1/4"	750.0	
#4	1501.6	a
Steel ball Wt, g:	4999.8	
Time Running, min:	95	
Wt of sample after test, g:	1414.3	b
% of Loss:	**5.8**	

CEL#	10-17749	
Aggregate:	A2-Lopke	
0		
Sieve Size	Cumulative Wt of Sample, g	
3/8"	0.0	
1/4"	277.0	
#4	1500.6	a
Steel ball Wt, g:	4999.8	
Time Running, min:	95	
Wt of sample after test, g:	1227.5	b
% of Loss:	**18.2**	

CEL#	10-17749	
Aggregate:	A3-Texas	
0		
Sieve Size	Cumulative Wt of Sample, g	
3/8"	0.0	
1/4"	180.3	
#4	1500.3	a
Steel ball Wt, g:	4999.8	
Time Running, min:	95	
Wt of sample after test, g:	1255	b
% of Loss:	**16.4**	

EMULSION TEST RESULTS FOR EMULSIONS E1

CEL# 10-17749

Source: Sem Materials

Material: Ralumac

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	62.6	61.8	64.6	
emulsion weight, g	40.1	40	40.1	C=Average
A: final total dry weight, g	87.7	87.5	90.5	Residue,%
Res, %	62.8	64.3	64.8	**63.9**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B]	start time @ 118°C:	6:15
	@30m, increase temp to 138°C:	6:45
	after 1.5h, stir and return to oven:	8:15
	complete after add'l 1.0h:	9:15

T59: Residue by Distillation

Tested By cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1	200
B'=Tare wt,g (still, lid, clamp, therm's, gasket)	3460.9
start time: 10:00 end time: 11:18 total time:	1:18
D'=Total final wt,g (tare & distilled sample)	3594.7
E'=Final sample wt, g=(D'-B')	133.8
C'=Residue, %= (E'/A')100 C'=	**66.9**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25

Time, s: 5

Load, g: 100

	Cup#1
Trial #1:	49
Trial #2:	50
Trial #3:	50
AVERAGE:	**50**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

Left side	Right Side
°C: 57.5	°C: 58

Softening Point to Report, °C: **57.8**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

EMULSION TEST RESULTS FOR EMULSIONS E1

CEL# 10-17749

Source: Sem Materials

Material: Ralumac verification testing

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	65.5	65	64.2	
emulsion weight, g	40	40	40.1	C=Average
A: final total dry weight, g	90.3	90.4	89.8	Residue,%
Res, %	62.0	63.5	64.0	**63.2**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B]	start time @ 118°C:	7:15
	@30m, increase temp to 138°C:	7:45
	after 1.5h, stir and return to oven:	9:15
	complete after add'l 1.0h:	10:15

T59: Residue by Distillation

Tested By cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1	not tested
B'=Tare wt,g (still, lid, clamp, therm's, gasket)	0
start time: end time: total time:	
D'=Total final wt,g (tare & distilled sample)	0
E'=Final sample wt, g=(D'-B')	0.0
C'=Residue, %= (E'/A')100 C'=	**#VALUE!**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25

Time, s: 5

Load, g: 100

	Cup#1
Trial #1:	52
Trial #2:	51
Trial #3:	49
AVERAGE:	**51**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

	Left side	Right Side
°C:	57.5	58.1

Softening Point to Report, °C: **57.8**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

EMULSION TEST RESULTS FOR EMULSIONS E1

CEL# 10-17749

Source: Sem Materials

Material: Ralumac verification testing

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	64.9	64	64.7	
emulsion weight, g	40	40	40	C=Average
A: final total dry weight, g	90.6	89.2	90.8	Residue,%
Res, %	64.3	63.0	65.3	**64.2**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B]	start time @ 118°C:	6:15
	@30m, increase temp to 138°C:	6:45
	after 1.5h, stir and return to oven:	8:15
	complete after add'l 1.0h:	9:15

T59: Residue by Distillation

Tested By cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1					not tested
B'=Tare wt,g (still, lid, clamp, therm's, gasket)					0
start time:		end time:		total time:	
D'=Total final wt,g (tare & distilled sample)					0
E'=Final sample wt, g=(D'-B')					0.0
C'=Residue, %= (E'/A')100				C'=	**#VALUE!**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25

Time, s: 5

Load, g: 100

	Cup#1
Trial #1:	46
Trial #2:	48
Trial #3:	47
AVERAGE:	**47**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

	Left side		Right Side
°C:	61	°C:	61.5

Softening Point to Report, °C: **61.3**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

EMULSION TEST RESULTS FOR EMULSIONS E2

CEL# 10-17749

Source: VSS Emultech

Material: PMCQS-1h

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	65.4	66.1	66.2	
emulsion weight, g	40	40	40.1	C=Average
A: final total dry weight, g	89.9	90.4	90.5	Residue,%
Res, %	61.3	60.8	60.8	**60.9**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B] start time @ 118°C:	5:30
@30m, increase temp to 138°C:	6:00
after 1.5h, stir and return to oven:	7:30
complete after add'l 1.0h:	8:30

T59: Residue by Distillation

Tested By cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1	200.1
B'=Tare wt,g (still, lid, clamp, therm's, gasket)	3461.4
start time: 9:45 end time: 10:55 total time:	1:10
D'=Total final wt,g (tare & distilled sample)	3587.3
E'=Final sample wt, g=(D'-B')	125.9
C'=Residue, %= (E'/A')100 C'=	**62.9**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25

Time, s: 5

Load, g: 100

	Cup#1
Trial #1:	73
Trial #2:	71
Trial #3:	74
AVERAGE:	**73**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

	Left side	Right Side
°C:	55	55.1

Softening Point to Report, °C: **55.1**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

EMULSION TEST RESULTS FOR EMULSIONS E2

CEL# 10-17749
Source: VSS Emultech
Material: PMCQS-1h

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	64.3	64.7	65.3	
emulsion weight, g	40.1	40	40	C=Average
A: final total dry weight, g	88.4	88.8	89.3	Residue,%
Res, %	60.3	60.3	60.0	**60.2**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B]	start time @ 118°C:	6:00
	@30m, increase temp to 138°C:	6:30
	after 1.5h, stir and return to oven:	8:00
	complete after add'l 1.0h:	9:00

T59: Residue by Distillation

Tested By cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1	not tested
B'=Tare wt,g (still, lid, clamp, therm's, gasket)	0
start time: end time: total time:	
D'=Total final wt,g (tare & distilled sample)	0
E'=Final sample wt, g=(D'-B')	0.0
C'=Residue, %= (E'/A')100 C'=	**#VALUE!**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25
Time, s: 5
Load, g: 100

	Cup#1
Trial #1:	85
Trial #2:	84
Trial #3:	85
AVERAGE:	**85**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

	Left side	Right Side
°C:	54.9	54

Softening Point to Report, °C: **54.5**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

EMULSION TEST RESULTS FOR EMULSIONS E3

CEL# 10-17749

Source: Ergon

Material: Micro emulsion

CTM 331: Residue by Evaporation

Tested By: lh

tare identification	1	2	3	
B: tare wt (beaker+rod), g	64.7	64.6	64.8	
emulsion weight, g	40	40	40	C=Average
A: final total dry weight, g	90.1	89.8	89.7	Residue,%
Res, %	63.5	63.0	62.3	**62.9**

emulsion weight = 39.9g or 40.0g or 40.1g

residue, % = 2.5[A-B] start time @ 118°C:	5:30
@30m, increase temp to 138°C:	6:00
after 1.5h, stir and return to oven:	7:30
complete after add'l 1.0h:	8:30

T59: Residue by Distillation

Tested By: cg

A'=Initial sample wt, g: 199.9 or 200.0 or 200.1	200.1
B'=Tare wt,g (still, lid, clamp, therm's, gasket)	3460.8
start time: 10:10 end time: 11:30 total time:	1:20
D'=Total final wt,g (tare & distilled sample)	3590
E'=Final sample wt, g=(D'-B')	129.2
C'=Residue, %= (E'/A')100 C'=	**64.6**

1. distillation time: 60 +/- 15 min

T49: Penetration of Bituminous Mate

Tested By: LH

Test temp, °C: 25

Time, s: 5

Load, g: 100

	Cup#1
Trial #1:	64
Trial #2:	65
Trial #3:	62
AVERAGE:	**64**

Report to the nearest whole unit the average of 3 penetrations whose values do not differ by more than the following:

Pen range:	0-49	50-149
Max difference b	2	4

highest & lowest penetration result

T53: Ring & Ball Softening Point

Tested By: LH

Liquid Bath Used: Boiled Distilled Water

	Left side	Right Side
°C:	58.5	58

Softening Point to Report, °C: **58.3**

1. Heat sample no more than 110°C above expected softening point within 2 hr max.
2. Pour sample into heated rings. Total time from this point not to exceed 240 min.
3. Cool, at ambient, for 30min. Trim excess w/heated spatula.
4. Assemble apparatus (w/steel balls at bottom); fill w/water to 105mm depth; return to refrig or ice bath for 15 min
5. Apply heat at 5°C/min. After first 3min, max. variation is +/-0.5°C
6. If the difference between the two temperatures exceeds 1°C (2°F), repeat the test.
7. When using a 15C or 15F thermometer (low temp range), then report to nearest 0.2°C (0.5°F)

AMT RESULTS FOR ALL MIXES

				Automated Mixing Test											
Mix:	M1	Agg:	Table Mtn		Emul:	Ralumac									
Trial #	Temp°C	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increas of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken	
1	25	0.5	8	0	10	300	1.5	24	0	30	n/a	n/a	n/a	>15 sec	
2	25	0	10	1	11	300	0	30	3	33	8.8	2:30	3:00	3:30	
3	25	0	12	1	11	300	0	36	3	33	8.8	3:45	6:15	7:30	
4	25	0	12	1	12	300	0	36	3	36	8.8	3:45	6:15	7:30	
5	25	0	12	1	12	300	0	36	3	36	8.8	5:00	7:30	8:45	
6	25	0	12	1	13	300	0	36	3	39	7.8	6:15	8:45	10:00	
7	25	0	12	1	14	300	0	36	3	42	7.5	6:15	8:45	10:00	
8	25	0	0	0	0	300	0	0	0	0					
Humidity= 50%															

						Automated Mixing Test									
Mix:	M2	Agg:	Table Mtn		Emul:	LMCQS-1h									
Trial #	Temp°C	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increas of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken	
1	25	0	14	1	11	300	0	42	3	33	9.5	2:30	8:15	9:00	
2	25	0	14	1	14	300	0	42	3	42	n/a	n/a	n/a	n/a	
3	25	0	14	1	14	300	0	42	3	42	9.5	8:45	n/a	10:00	*
4	25	0	12	1	15	300	0	36	3	45	8.8	10:00	n/a	10:00	**
5	25	0	13	0.5	12	300	0	39	1.5	36	9.5	5:00	8:45	10:00	***
6	25	0	12	0.5	12	300	0	36	1.5	36	9.5	3:45	7:30	8:45	****
7	25	0	12	1	11	300	0	36	3	33	9.5	3:45	7:30	8:00	
8	25	0	10	1	11	300	0	30	3	33	9.5	3:15	7:30	8:00	
Humidity= 50%															
					*	**aborted; LV; rocks interfering with stirrer**									
					**	**didn't break; stopped at 10 min**									
					***	**stopped at 10 min**									

AMT RESULTS FOR ALL MIXES

				Automated Mixing Test										
Mix:	M3	Agg:	Lopke		Emul:	Ralumac								
Trial #	Temp°C	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increas of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken
1	25	0	12	0	10	300	0	36	0	30	8.5	2:30	7:30	8:45
2	25	0.5	12	0	10	300	1.5	36	0	30	9	1:15	6:15	7:30
3	25	1	14	1	10	300	3	42	3	30	9	1:15	7:00	7:30
4	25	0	12	0	12	300	0	36	0	36	8.5	3:45	7:30	8:45
5	25	0.5	12	0	12	300	1.5	36	0	36	8	2:30	6:15	7:30
6	25	1	14	1	12	300	3	42	3	36	8	2:30	7:30	8:45
7	25	0	0	0	0	300	0	0	0	0				
8	25	0	0	0	0	300	0	0	0	0				
Humidity= 50%														

				Automated Mixing Test										
Mix:	M4	Agg:	Lopke		Emul:	LMCQS-1h								
Trial #	Temp°C	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increas of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken
1	25	1	16	0	11	300	3	48	0	33	7-8	8:15	>10	>10
2	25	1	14	0	11	300	3	42	0	33	8-9	6:15	>10	>10
3	25	1	12	0	11	300	3	36	0	33	9-10	5:00	>10	>10
4	25	1	10	0	11	300	3	30	0	33	2-3	6:15	>10	**>10***
4r	25	1	10	0	11	300	3	30	0	33	10-11	5:00	6:00	6:00
5	25	1	9	0.5	11	300	3	27	1.5	33	10	2:30	3:00	3:00
						300	0	0	0	0				
						300	0	0	0	0				
Humidity= 50%							*	**low torque b/c stirrer wasn't set low enough**						

AMT RESULTS FOR ALL MIXES

				Automated Mixing Test											
Mix:	M5	Agg:	Texas		Emul:	Ergon									
Trial #	Temp°C	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Aggregate, g	Cement, %	Water, %	Liquid Add, %:____	Emulsion, %	Mix Index: steady state torque	Mix Time: time where steady increas of torque begins	Spread Time: time where torque reaches 12 N-cm	Time when mix has broken	
1	25	0	9	0	12	300	0	27	0	36	7.2	2:30	5:00	7:30	
2	25	0.5	9	0	12	300	1.5	27	0	36	7.5	2:15	4:30	7:30	
3	25	0	9	0	10	300	0	27	0	30	8.5	2:30	4:30	6:15	
4	25	0.5	9	0	10	300	1.5	27	0	30	8.5	2:30	4:00	6:15	
5	25	0	10	0	10	300	0	30	0	30	9	2:30	5:00	7:30	
6	25	0.5	10	0	10	300	1.5	30	0	30	9	2:15	4:30	7:30	
7	25	0	11	0	8	300	0	33	0	24	8.5	2:15	5:00	7:30	
8	25	0.5	11	0	8	300	1.5	33	0	24	8.5	1:45	3:45	6:15	
Humidity= 50%															

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Table Mountain** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	12.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.00	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M1

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ___________		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1718.2	0:30	12:45	60	16	13:15	51	NO	1 min	61	16	1058.7	659.5
1716.8	0:30	13:00	60	16	13:30	51	YES	1 min	61	16	1114.5	602.3
1706.4	1:00	9:00	60	16	10:00	48	NO	1 min	61	16	1154.7	551.7
1732.6	1:00	8:30	60	16	9:30	50	YES	1 min	61	16	1291.6	441.0
1723.6	3:00	8:15	60	16	11:15	48	NO	1 min	60	16	1377.1	346.5
1728.1	3:00	8:00	60	16	11:00	51	YES	1 min	60	16	1184.7	543.4
1728.3	5:00	6:30	59	15	11:30	48	NO	1 hour	60	16	1344.6	383.7
1763.0	5:00	6:00	60	16	11:00	48	YES	1 hour	60	16	1549	214.0

CAT RESULTS FOR ALL MIXES

CEL#: 10-17749

Project Name: Slurry/Micro Mix Design

Project Name: Emulsion: **Ralumac**

Source: **Table Mountain** Source: Sem Materials

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 12.0

Additive mid-range target: 0.0 Additive: cement type 2

Additive mid-range target: 1.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M1

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ___________		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1777.2	0:30	12:00	60	16	12:30	90	NO	1 min	60	16	922.1	855.1
1752.3	0:30	12:15	61	16	12:45	89	YES	1 min	60	16	929.1	823.2
1762.8	1:00	9:45	60	16	10:45	88	NO	1 min	60	16	988.9	773.9
1785.0	1:00	9:35	60	16	10:35	88	YES	1 min	60	16	999.3	785.7
1742.9	3:00	8:15	59	15	11:15	88	NO	1 min	60	16	1113.9	629.0
1739.1	3:00	8:00	59	15	11:00	89	YES	1 min	59	15	1121.4	617.7
1756.8	5:00	5:45	60	16	10:45	90	NO	1 hour	60	16	1264.6	492.2
1759.2	5:00	5:30	60	16	10:30	90	YES	1 hour	60	16	1278.1	481.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Table Mountain** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	12.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M1

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other:		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1722.5	0:30	12:00	78	26	12:30	49	NO	1 min	78	26	1401.5	321.0
1743.3	0:30	12:15	78	26	12:45	49	YES	1 min	78	26	1439.5	303.8
1759.1	1:00	9:30	76	24	10:30	50	NO	1 min	77	25	1453.4	305.7
1749.5	1:00	9:15	76	24	10:15	50	YES	1 min	77	25	1466.1	283.4
1768.2	3:00	8:30	77	25	11:30	50	NO	1 min	77	25	1649.8	118.4
1740.0	3:00	8:00	77	25	11:00	50	YES	1 min	77	25	1664.7	75.3
1772.1	5:00	6:15	78	26	11:15	50	NO	1 hour	77	25	1758.2	13.9
1769.1	5:00	5:45	78	26	10:45	50	YES	1 hour	77	25	1758.9	10.2

CAT RESULTS FOR ALL MIXES

M1

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 | Emulsion: **Ralumac**

Source: **Table Mountain** | Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	12.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other:		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1724.3	0:30	12:00	76	24	12:30	90	NO	1 min	75	24	777.1	947.2
1751.9	0:30	12:15	75	24	12:45	90	YES	1 min	75	24	816.2	935.7
1711.6	1:00	9:45	77	25	11:45	89	NO	1 min	77	25	595.2	1116.4
1772.9	1:00	9:25	76	24	11:25	89	YES	1 min	73	23	857.1	915.8
1763.1	3:00	8:30	76	24	11:30	89	NO	1 min	76	24	913.6	849.5
1724.1	3:00	8:00	77	25	11:00	89	YES	1 min	74	23	1082	642.1
1770.4	5:00	6:15	78	26	11:15	88	NO	1 hour	74	23	895.4	875.0
1789.5	5:00	5:45	78	26	10:45	89	YES	1 hour	75	24	1266.3	523.2

CEL#: 10-17749

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Table Mountain** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	12.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M1

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ________		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1774.1	0:30	13:00	94	34	13:30	50	NO	1 min	94	34	1689.5	84.6
1777.8	0:30	12:50	95	35	13:20	49	YES	1 min	91	33	1680	97.8
1785.5	1:00	9:00	94	34	10:00	50	NO	1 min	91	33	1726.4	59.1
1815.9	1:00	8:30	94	34	9:30	49	YES	1 min	90	32	1776.9	39.0
1738.0	3:00	8:00	90	32	11:00	50	NO	1 min	94	34	1714.6	23.4
1750.3	3:00	7:30	94	34	10:30	50	YES	1 min	94	34	1717.1	33.2
1688.5	5:00	7:00	94	34	12:00	49	NO	1 hour	91	33	1686.5	2.0
1744.0	5:00	6:30	92	33	11:30	49	YES	1 hour	91	33	1741.6	2.4

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Table Mountain** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	12.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M1

Comments: binding between emulsion and rock looks poor

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ____________		
12.0	water	162.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1748.7	0:30	12:00	96	36	12:30	89	NO	1 min	96	36	1520.8	227.9
1729.9	0:30	12:15	96	36	12:45	89	YES	1 min	96	36	1512.1	217.8
1740.7	1:00	9:45	95	35	10:45	89	NO	1 min	95	35	1620.7	120.0
1766.2	1:00	9:35	95	35	10:35	89	YES	1 min	95	35	1653.8	112.4
1768.9	3:00	8:30	95	35	11:30	88	NO	1 min	95	35	1711.6	57.3
1754.6	3:00	8:00	95	35	11:00	89	YES	1 min	95	35	1690.5	64.1
1750.3	5:00	6:15	94	34	11:15	89	NO	1 hour	95	35	1721.5	28.8
1747.3	5:00	5:45	94	34	10:45	89	YES	1 hour	94	34	1721.8	25.5

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3		Emulsion:	**LMCQS-1h**	
Source: **Table Mtn**		Source:	VSS Emultech	
Emulsion mid-range target:	11.0			
Pre-wet water mid-range target:	14.0			
Additive mid-range target:	0.0	Additive:	cement type 2	
Additive mid-range target:	1.00	Additive:	alum.sulf.	
Additive mid-range target:		Additive:		
Additive mid-range target:		Additive:		

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

1

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ____________		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1777.6	0:30	11:45	61	16	12:15	49	Y	1 min	60	16	924.9	852.7
1755.4	0:30	11:30	60	16	12:00	49	NO	1 min	60	16	1082.8	672.6
1787.8	1:00	9:45	59	15	10:45	49	Y	1 min	60	16	1283.8	504.0
1749.4	1:00	9:30	59	15	10:30	49	NO	1 min	60	16	1295.9	453.5
1789.1	3:00	9:20	59	15	12:20	49	Y	1 min	60	16	1392.6	396.5
1801.0	3:00	9:00	59	15	12:00	50	NO	1 min	60	16	1477	324.0
1783.6	5:00	7:00	59	15	12:00	50	Y	1 hour	60	16	1571	212.6
1822.4	5:00	7:15	59	15	12:15	50	NO	1 hour	60	16	1480.4	342.0

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Table Mtn** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	14.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

2

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ______		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1637.8	0:30	11:35	59	15	12:05	89	Y	1 min	58	14	800.6	837.2
1640.6	0:30	11:25	59	15	11:55	89	NO	1 min	59	15	679.6	961.0
1577.6	1:00	8:20	59	15	9:20	901	Y	1 min	59	15	679.4	898.2
1634.2	1:00	8:00	58	14	9:00	90	NO	1 min	59	15	844.7	789.5
1701.5	3:00	7:00	60	16	10:00	91	Y	1 min	58	14	1450.5	251.0
1673.2	3:00	6:45	60	16	9:45	91	NO	1 min	59	15	1231.9	441.3
1753.2	5:00	6:15	59	15	11:15	90	Y	1 hour	58	14	1494.2	259.0
1710.4	5:00	6:00	59	15	11:00	90	NO	1 hour	59	15	1530.2	180.2

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Table Mtn** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	14.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

3

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other:		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature,°C	15	25	35
Temperature,°F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1730.3	0:30	11:35	78	26	12:05	52	Y	1 min	77	25	1176.9	553.4
1745.0	0:30	11:25	78	26	11:55	52	NO	1 min	77	25	1158.4	586.6
1752.7	1:00	8:25	77	25	9:25	52	Y	1 min	77	25	1240.8	511.9
1762.1	1:00	8:00	77	25	9:00	52	NO	1 min	77	25	1164.6	597.5
1760.8	3:00	7:00	77	25	10:00	51	Y	1 min	77	25	1225.2	535.6
1755.3	3:00	6:45	77	25	9:45	52	NO	1 min	77	25	1167.5	587.8
1759.3	5:00	6:15	77	25	11:15	54	Y	1 hour	77	25	1469.3	290.0
1748.4	5:00	6:00	77	25	11:00	54	NO	1 hour	77	25	1397.8	350.6

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 | Emulsion: **LMCQS-1h**

Source: **Table Mtn** | Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	14.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

4

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ________		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ________		

Curing Conditions:

Temperature,°C	15	25	35
Temperature,°F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1743.6	0:30	11:55	78	26	12:25	92	Y	1 min	79	26	1090	653.6
1752.8	0:30	12:10	78	26	12:40	92	NO	1 min	79	26	1114.7	638.1
1849.3	1:00	9:30	77	25	10:30	92	Y	1 min	79	26	1299.6	549.7
1868.1	1:00	8:20	77	25	9:20	92	NO	1 min	79	26	1432.6	435.5
1862.9	3:00	7:50	77	25	10:50	92	Y	1 min	79	26	1571.5	291.4
1877.5	3:00	7:15	77	25	10:15	92	NO	1 min	79	26	1562.3	315.2
1857.1	5:00	6:00	77	25	11:00	92	Y	1 hour	79	26	1718.8	138.3
1899.4	5:00	5:40	77	25	10:40	92	NO	1 hour	79	26	1762.6	136.8

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Table Mtn** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	14.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

5

Comments: tests 1-4 done on 10/05; tests 5-8 done on 10/04

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other: ________		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1790.4	0:30	10:35	96	36	11:05	48	Y	1 min	91	33	1332	458.4
1792.2	0:30	10:20	96	36	10:50	48	NO	1 min	92	33	1396.6	395.6
1756.0	1:00	9:45	95	35	10:45	49	Y	1 min	93	34	1360	396.0
1760.1	1:00	9:30	95	35	10:30	49	NO	1 min	92	33	1379.3	380.8
1781.4	3:00	7:15	93	34	10:15	49	Y	1 min	93	34	1544.9	236.5
1769.5	3:00	7:00	93	34	10:00	49	NO	1 min	93	34	1539.6	229.9
1788.5	5:00	6:00	92	33	11:00	49	Y	1 hour	93	34	1592.1	196.4
1748.6	5:00	5:45	92	33	10:45	49	NO	1 hour	93	34	1530.5	218.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Table Mtn** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	14.0		
Additive mid-range target:	0.0	Additive:	cement type 2
Additive mid-range target:	1.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M2

6

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.0	cement / lime	0.0	cement
	Other:		
14.0	water	189.0	water
1.0	alum.sulf.	13.5	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1749.9	0:30	12:00	91	33	12:30	88	Y	1 min	88	31	934.1	815.8
1776.9	0:30	12:15	91	33	12:45	88	NO	1 min	88	31	1177.2	599.7
1786.1	1:00	9:15	92	33	10:15	88	Y	1 min	87	31	1180	606.1
1797.3	1:00	9:00	92	33	10:00	88	NO	1 min	87	31	1174.1	623.2
1734.1	3:00	7:35	93	34	10:35	89	Y	1 min	88	31	1121.5	612.6
1716.3	3:00	7:20	93	34	10:20	89	NO	1 min	88	31	1172.3	544.0
1773.9	5:00	6:15	93	34	11:15	89	Y	1 hour	88	31	1539.6	234.3
1739.4	5:00	6:00	93	34	11:00	89	NO	1 hour	88	31	1388.3	351.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Lopke** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	15.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

1

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1798.0	0:30	12:10	62	17	12:40	49	Y	1 min	61	16	1451.9	346.1
1784.4	0:30	12:05	61	16	12:35	49	NO	1 min	60	16	1451.2	333.2
1715.9	1:00	11:30	60	16	12:30	49	Y	1 min	60	16	1425.9	290.0
1760.9	1:00	11:10	60	16	12:10	49	NO	1 min	60	16	1442.2	318.7
1755.0	3:00	7:30	60	16	10:30	49	Y	1 min	60	16	1419.1	335.9
1794.1	3:00	7:00	60	16	10:00	49	NO	1 min	60	16	1478.4	315.7
1691.7	5:00	6:15	60	16	11:15	49	Y	1 hour	60	16	1434.1	257.6
1736.2	5:00	6:00	60	16	11:00	49	NO	1 hour	60	16	1454.1	282.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 | Emulsion: **Ralumac**

Source: **Lopke** | Source: Sem Materials

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 15.0

Additive mid-range target: 0.5 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

2

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ______		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1826.7	0:30	12:25	58	14	12:55	88	Y	1 min	57	14	1367.3	459.4
1826.5	0:30	12:10	58	14	12:40	88	NO	1 min	57	14	1346.5	480.0
1816.5	1:00	9:15	58	14	10:15	88	Y	1 min	56	13	1389.7	426.8
1813.9	1:00	9:00	58	14	10:00	87	NO	1 min	57	14	1378.4	435.5
1740.6	3:00	8:00	58	14	11:00	88	Y	1 min	57	14	1369.4	371.2
1774.6	3:00	7:40	59	15	10:40	87	NO	1 min	57	14	1380	394.6
1760.6	5:00	7:20	59	15	12:20	88	Y	1 hour	57	14	1477.1	283.5
1760.7	5:00	7:00	59	15	12:00	88	NO	1 hour	57	14	1482.8	277.9

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Lopke** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	15.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

3

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ____________		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1762.4	0:30	12:55	78	26	13:25	49	Y	1 min	78	26	1523.9	238.5
1738.1	0:30	12:40	78	26	13:10	49	NO	1 min	78	26	1481	257.1
1683.4	1:00	9:15	77	25	10:15	49	Y	1 min	78	26	1434.2	249.2
1762.8	1:00	9:00	77	25	10:00	50	NO	1 min	77	25	1426.5	336.3
1785.4	3:00	8:00	78	26	11:00	50	Y	1 min	77	25	1556.4	229.0
1736.7	3:00	7:40	77	25	10:40	50	NO	1 min	77	25	1474.1	262.6
1755.5	5:00	7:20	77	25	12:20	50	Y	1 hour	78	26	1538.6	216.9
1743.9	5:00	7:00	77	25	12:00	51	NO	1 hour	78	26	1517.9	226.0

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Lopke** — Source: Sem Materials

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 15.0

Additive mid-range target: 0.5 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: ______ Additive: ______

Additive mid-range target: ______ Additive: ______

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

4

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ______		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1874.3	0:30	8:00	79	26	8:30	92	Y	1 min	74	23	1604.1	270.2
1889.6	0:30	7:40	77	25	8:10	91	NO	1 min	74	23	1640.5	249.1
1853.2	1:00	7:15	78	26	8:15	92	Y	1 min	75	24	1629.6	223.6
1830.2	1:00	7:00	77	25	8:00	91	NO	1 min	75	24	1549.1	281.1
1766.6	3:00	9:10	78	26	12:10	92	Y	1 min	76	24	1512.9	253.7
1756.2	3:00	9:00	79	26	12:00	92	NO	1 min	76	24	1515.8	240.4
1712.1	5:00	6:30	78	26	11:30	91	Y	1 hour	76	24	1409.5	302.6
1790.4	5:00	6:15	79	26	11:15	91	NO	1 hour	76	24	1554.3	236.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate:	Type 3	Emulsion:	**Ralumac**
Source:	**Lopke**	Source:	Sem Materials
Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	15.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

5

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ___________		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1742.5	0:30	11:15	91	33	11:45	50	Y	1 min	93	34	1569	173.5
1736.4	0:30	11:00	91	33	11:30	51	NO	1 min	92	33	1611.9	124.5
1759.6	1:00	8:15	91	33	9:15	49	Y	1 min	92	33	1599.4	160.2
1737.7	1:00	7:45	92	33	8:45	49	NO	1 min	92	33	1613.5	124.2
1730.1	3:00	7:00	92	33	10:00	49	Y	1 min	92	33	1646.2	83.9
1743.8	3:00	6:45	92	33	9:45	49	NO	1 min	93	34	1686.2	57.6
1723.5	5:00	5:45	91	33	10:45	50	Y	1 hour	92	33	1666.9	56.6
1694.2	5:00	5:30	92	33	10:30	50	NO	1 hour	92	33	1634.5	59.7

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **Ralumac**

Source: **Lopke** — Source: Sem Materials

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	15.0		
Additive mid-range target:	0.5	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M3

6

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
0.5	cement / lime	6.8	cement
	Other: ___________		
15.0	water	202.5	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1766.7	0:30	12:10	94	34	12:40	91	Y	1 min	92	33	1575.1	191.6
1766.3	0:30	12:05	92	33	12:35	90	NO	1 min	93	34	1560.7	205.6
1756.5	1:00	11:30	92	33	12:30	90	Y	1 min	91	33	1569.3	187.2
1743.7	1:00	11:10	93	34	12:10	91	NO	1 min	90	32	1578.3	165.4
1749.6	3:00	7:30	92	33	10:30	90	Y	1 min	90	32	1658.5	91.1
1774.6	3:00	7:00	92	33	10:00	90	NO	1 min	90	32	1697.2	77.4
1760.5	5:00	6:15	91	33	11:15	91	Y	1 hour	89	32	1699	61.5
1762.6	5:00	6:00	91	33	11:00	91	NO	1 hour	90	32	1709.9	52.7

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Lopke** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

1

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ______		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1841.0	0:30	15:05	60	16	15:35	49	Y	1 min	61	16	1266	575.0
1794.9	0:30	14:55	58	14	15:25	51	NO	1 min	61	16	1421.1	373.8
1806.2	1:00	13:50	60	16	14:50	48	Y	1 min	62	17	1419.5	386.7
1789.7	1:00	13:20	59	15	14:20	48	NO	1 min	61	16	1438.2	351.5
1796.8	3:00	10:00	59	15	13:00	49	Y	1 min	60	16	1394.9	401.9
1799.4	3:00	10:45	60	16	13:45	50	NO	1 min	60	16	1419.5	379.9
1826.3	5:00	5:30	61	16	10:30	50	Y	1 hour	60	16	1452.6	373.7
1830.3	5:00	5:45	61	16	10:45	50	NO	1 hour	60	16	1401.6	428.7

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3

Source: **Lopke**

Emulsion: **LMCQS-1h**

Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

2

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1758.2	0:30	11:20	59	15	11:50	88	Y	1 min	62	17	1075.5	682.7
1761.8	0:30	11:10	59	15	11:40	88	NO	1 min	62	17	1107.4	654.4
1764.6	1:00	7:55	57	14	8:55	88	Y	1 min	61	16	1262.7	501.9
1750.0	1:00	7:40	57	14	8:40	87	NO	1 min	62	17	1230.7	519.3
1760.2	3:00	7:30	57	14	10:30	88	Y	1 min	62	17	1304.4	455.8
1755.6	3:00	7:05	57	14	10:05	87	NO	1 min	61	16	1320.6	435.0
1785.1	5:00	6:30	57	14	11:30	89	Y	1 hour	61	16	1358	427.1
1761.5	5:00	6:15	57	14	11:15	89	NO	1 hour	60	16	1323.3	438.2

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3

Source: **Lopke**

Emulsion: **LMCQS-1h**

Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

3

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____________		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1740.2	0:30	12:10	78	26	12:40	48	Y	1 min	79	26	1423.5	316.7
1763.8	0:30	12:05	78	26	12:35	48	NO	1 min	79	26	1465.4	298.4
1766.4	1:00	11:30	78	26	12:30	48	Y	1 min	79	26	1464.9	301.5
1784.1	1:00	11:10	78	26	12:10	48	NO	1 min	79	26	1437	347.1
1760.6	3:00	7:30	77	25	10:30	49	Y	1 min	79	26	1576.2	184.4
1750.8	3:00	7:00	77	25	10:00	49	NO	1 min	79	26	1466.2	284.6
1748.6	5:00	6:15	77	25	11:15	50	Y	1 hour	78	26	1532.4	216.2
1766.0	5:00	6:00	77	25	11:00	50	NO	1 hour	78	26	1508.6	257.4

CEL#: 10-17749

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3

Source: **Lopke**

Emulsion: **LMCQS-1h**

Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

4

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ______		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1831.2	0:30	12:10	77	25	12:40	88	Y	1 min	75	24	1365.1	466.1
1796.8	0:30	11:45	77	25	12:15	88	NO	1 min	75	24	1325	471.8
1843.1	1:00	9:15	78	26	10:15	89	Y	1 min	75	24	1442.5	400.6
1833.1	1:00	9:00	77	25	10:00	89	NO	1 min	75	24	1418.5	414.6
1841.8	3:00	7:45	77	25	10:45	90	Y	1 min	74	23	1526	315.8
1822.4	3:00	7:25	77	25	10:25	88	NO	1 min	74	23	1525.5	296.9
1845.7	5:00	6:30	77	25	11:30	88	Y	1 hour	74	23	1598	247.7
1811.4	5:00	6:15	76	24	11:15	89	NO	1 hour	74	23	1587.7	223.7

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 | Emulsion: **LMCQS-1h**

Source: **Lopke** | Source: VSS Emultech

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

5

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1768.1	0:30	12:55	95	35	13:25	50	Y	1 min	94	34	1514.2	253.9
1764.4	0:30	12:40	95	35	13:10	50	NO	1 min	93	34	1536.9	227.5
1755.9	1:00	9:15	93	34	10:15	51	Y	1 min	93	34	1553.3	202.6
1740.9	1:00	9:00	92	33	10:00	51	NO	1 min	93	34	1522.5	218.4
1755.8	3:00	8:00	92	33	11:00	52	Y	1 min	93	34	1593.4	162.4
1784.2	3:00	7:40	92	33	10:40	52	NO	1 min	93	34	1604.9	179.3
1761.7	5:00	7:20	92	33	12:20	52	Y	1 hour	93	34	1623.6	138.1
1743.0	5:00	7:00	92	33	12:00	52	NO	1 hour	93	34	1597.9	145.1

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 3 — Emulsion: **LMCQS-1h**

Source: **Lopke** — Source: VSS Emultech

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M4

6

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ___________		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1749.2	0:30	11:10	93	34	11:40	91	Y	1 min	96	36	1443.5	305.7
1757.9	0:30	11:00	93	34	11:30	91	NO	1 min	96	36	1476.7	281.2
1784.0	1:00	7:45	92	33	8:45	89	Y	1 min	94	34	1533.6	250.4
1756.3	1:00	7:30	92	33	8:30	89	NO	1 min	94	34	1487.8	268.5
1766.6	3:00	7:20	92	33	10:20	89	Y	1 min	94	34	1547.8	218.8
1754.8	3:00	7:00	92	33	10:00	89	NO	1 min	93	34	1542.1	212.7
1765.2	5:00	6:30	92	33	11:30	91	Y	1 hour	93	34	1579.9	185.3
1760.6	5:00	6:15	92	33	11:15	91	NO	1 hour	93	34	1593.3	167.3

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.00	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

1

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ______		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ______		

Curing Conditions:

Temperature, ℃	15	25	35
Temperature, ℉	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1755.2	0:30	12:30	61	16	13:00	51	Y	1 min	61	16	973	782.2
1764.8	0:30	12:45	61	16	13:15	51	NO	1 min	61	16	1003.4	761.4
1747.3	1:00	8:25	60	16	9:25	52	Y	1 min	61	16	1035.3	712.0
1787.8	1:00	8:00	60	16	9:00	52	NO	1 min	61	16	1091.5	696.3
1745.8	3:00	7:00	58	14	10:00	52	Y	1 min	59	15	1513.1	232.7
1722.3	3:00	6:45	58	14	9:45	52	NO	1 min	59	15	1446.9	275.4
1766.6	5:00	6:15	58	14	11:15	52	Y	1 hour	59	15	1582.5	184.1
1748.9	5:00	6:00	58	14	11:00	52	NO	1 hour	59	15	1553	195.9

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

2

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other:		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1717.4	0:30	12:45	59	15	13:15	92	Y	1 min	59	15	925.5	791.9
1667.8	0:30	12:35	59	15	13:05	91	NO	1 min	59	15	980.2	687.6
1756.0	1:00	8:15	58	14	9:15	91	Y	1 min	58	14	1374.5	381.5
1693.5	1:00	8:00	58	14	9:00	92	NO	1 min	59	15	1261.8	431.7
1767.1	3:00	7:05	58	14	10:05	89	Y	1 min	58	14	1499.7	267.4
1699.3	3:00	6:50	58	14	9:50	89	NO	1 min	59	15	1431.3	268.0
1688.1	5:00	6:20	60	16	11:20	92	Y	1 hour	59	15	1517.7	170.4
1760.8	5:00	6:00	58	14	11:00	89	NO	1 hour	59	15	1591	169.8

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

3

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other:		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other:		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1796.7	0:30	12:10	79	26	12:40	49	Y	1 min	74	23	1468.1	328.6
1761.7	0:30	12:00	79	26	12:30	49	NO	1 min	74	23	1481	280.7
1711.1	1:00	10:10	77	25	11:10	50	Y	1 min	74	23	1573.6	137.5
1762.9	1:00	9:50	77	25	10:50	50	NO	1 min	74	23	1610.5	152.4
1785.4	3:00	8:00	77	25	11:00	50	Y	1 min	74	23	1708.3	77.1
1781.4	3:00	7:45	77	25	10:45	50	NO	1 min	74	23	1716.1	65.3
1761.4	5:00	6:05	76	24	11:05	52	Y	1 hour	74	23	1681.8	79.6
1773.5	5:00	6:20	77	25	11:20	52	NO	1 hour	74	23	1710.5	63.0

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target: 11.0

Pre-wet water mid-range target: 16.0

Additive mid-range target: 1.0 Additive: cement type 2

Additive mid-range target: 0.0 Additive: alum.sulf.

Additive mid-range target: Additive:

Additive mid-range target: Additive:

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

4

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ___________		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature,℃	15	25	35
Temperature,℉	59	77	95

Humidity, %	50	90

Soaking period before testing	1 minute	1 hour

Compaction w/ roller immediately before testing	yes	no

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp ℉	Temp ℃	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1723.9	0:30	12:30	78	26	13:00	89	Y	1 min	76	24	1382.3	341.6
1733.5	0:30	12:45	78	26	13:15	90	NO	1 min	76	24	1382.7	350.8
1701.8	1:00	10:00	77	25	11:00	90	Y	1 min	76	24	1447.8	254.0
1679.4	1:00	9:50	77	25	10:50	90	NO	1 min	76	24	1376.5	302.9
1729.4	3:00	8:10	77	25	11:10	90	Y	1 min	76	24	1579	150.4
1715.8	3:00	7:45	77	25	10:45	90	NO	1 min	75	24	1560.1	155.7
1744.9	5:00	6:05	77	25	11:05	90	Y	1 hour	76	24	1646.9	98.0
1730.3	5:00	6:20	77	25	11:20	90	NO	1 hour	76	24	1619.7	110.6

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

5

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ____		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ____		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1732.6	0:30	13:00	96	36	13:30	49	Y	1 min	95	35	1681.9	50.7
1748.5	0:30	13:15	95	35	13:45	49	NO	1 min	95	35	1689	59.5
1736.8	1:00	9:45	95	35	10:45	50	Y	1 min	95	35	1692.4	44.4
1761.6	1:00	9:30	95	35	10:30	50	NO	1 min	95	35	1714.7	46.9
1766.9	3:00	7:20	95	35	10:20	50	Y	1 min	95	35	1762	4.9
1754.9	3:00	7:00	95	35	10:00	50	NO	1 min	95	35	1749.7	5.2
1737.1	5:00	6:00	95	35	11:00	50	Y	1 hour	95	35	1735.7	1.4
1752.4	5:00	6:15	95	35	11:15	50	NO	1 hour	95	35	1751.3	1.1

CAT RESULTS FOR ALL MIXES

CEL#: **10-17749**

Project Name: Slurry/Micro Mix Design

Aggregate: Type 2 / 3 — Emulsion: **Micro**

Source: **Texas Delta** — Source: Ergon

Emulsion mid-range target:	11.0		
Pre-wet water mid-range target:	16.0		
Additive mid-range target:	1.0	Additive:	cement type 2
Additive mid-range target:	0.0	Additive:	alum.sulf.
Additive mid-range target:		Additive:	
Additive mid-range target:		Additive:	

1)apply tack coat to disc and break emulsion
2)record weight of specimen after cure, before soaking
3)cover test specimen with water
4)abrade for 60 sec
5)rinse debris with 1000ml of water
6)carefully pat dry with towel
7)record weight after test

M5

6

Comments:

%	material	Cohes.Abrasion w/wheels weights,g	
--	aggregate	1350.0	agg
1.0	cement / lime	13.5	cement
	Other: ___________		
16.0	water	216.0	water
0.0	alum.sulf.	0.0	alum.sulf.
11.0	*emulsion (target)*	148.5	emulsion
	Other: ___________		

Curing Conditions:

Temperature, °C	15	25	35
Temperature, °F	59	77	95
Humidity, %	50	90	
Soaking period before testing	1 minute	1 hour	
Compaction w/ roller immediately before testing	yes	no	

A Original Wt, g	Cure Time minutes	Start Clock Time	Temp °F	Temp °C	End Clock Time	Humidity	Rolled @ end of cure yes / no	Soaking Period before test	Temp of SOAK water	Temp of SOAK water	B Final Wt, g	C=A-B Loss Wt, g
1748.8	0:30	12:30	94	34	13:00	89	Y	1 min	95	35	1670.9	77.9
1736.5	0:30	12:45	94	34	13:15	90	NO	1 min	95	35	1650.9	85.6
1717.8	1:00	8:25	94	34	9:25	90	Y	1 min	94	34	1667.8	50.0
1760.2	1:00	8:00	94	34	9:00	90	NO	1 min	94	34	1715.5	44.7
1762.8	3:00	7:00	94	34	10:00	90	Y	1 min	94	34	1751.5	11.3
1744.4	3:00	6:45	94	34	9:45	90	NO	1 min	94	34	1735.3	9.1
1738.4	5:00	6:15	93	34	11:15	90	Y	1 hour	94	34	1738	0.4
1751.4	5:00	6:00	93	34	11:00	90	NO	1 hour	94	34	1750.3	1.1

CAT RESULTS FOR ALL MIXES

Aggregates:

A1	Table Mountain (ISSA Type III)	
A2	Lopke Gravel Products (ISSA Type III)	
A3	Unknown: Texas	Texas

Emulsions:

E1	Koch Ralumac Polymer Modified LMCQS-1h, VSS	
E2	Emultech	
E3	Unknown:	Ergon

Mixes:

M1	A1+E1
M2	A1+E2
M3	A2+E1
M4	A2+E2
M5	A3+E3, Unknown

ACT RESULTS FOR ALL MIXES

TEST RESULTS			Mix	M1		M2		M3		M4		M5	
			Auto/Man	AUTOMATIC		AUTOMATIC		AUTOMATIC		AUTOMATIC		AUTOMATIC	
	Temp.		*Replicates*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Humidity	('F)	('C)	Curing(min)	TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01	
50%	50	10	15	1.8 N	2.1 N	1.3 N	1.6 N	3.5 N	4.5 N	2.8 N	2.5 N	4.0 N	6.1 N
50%	50	10	30	2.1 N	2.3 N	1.9 N	2.0 N	4.9 N	5.0 N	3.6 N	2.8 N	5.0 N	4.7 N
50%	50	10	60	3.1 N	3.9 N	1.6 N	1.9 N	4.7 N	5.8 N	3.4 N	3.8 N	4.3 N	4.2 N
50%	50	10	90	2.7 N	3.2 N	2.1 N	1.6 N	7.2 N	8.5 N	3.3 N	3.0 N	3.0 N	4.9 N
50%	50	10	120	3.1 N	3.4 N	2.4 N	1.9 N	8.5 N	8.8 N	4.6 N	2.8 N	4.1 N	4.2 N
50%	50	10	180	4.9 N	4.9 N	2.3 N	2.1 N	8.9 NS	8.9 NS	4.5 N	6.9 N	5.6 N	5.2 N
50%	50	10	240	5.9 N	6.5 N	4.2 N	3.0 N	9.9 SS	9.5 S	11.9 SS	12.0 S	6.8 N	6.0 N
50%	77	25	15	2.5 N	3.3 N	1.9 N	1.3 N	8.8 N	8.0 N	3.1 N	2.7 N	4.7 N	5.5 N
50%	77	25	30	4.5 N	3.8 N	1.6 N	2.1 N	11.5 N	11.0 N	4.6 N	5.2 N	7.0 N	6.1 N
50%	77	25	60	7.2 N	4.3 N	2.4 N	2.2 N	9.4 S	9.9 NS	5.2 N	4.8 N	4.9 N	6.3 N
50%	77	25	90	8.6 NS	9.8 NS	3.9 N	3.8 N	13.1 S	11.1 S	6.0 N	5.9 N	7.6 N	7.7 N
50%	77	25	120	8.6 S	9.4 S	3.9 N	3.4 N	12.6 SS	11.0 SS	7.3 N	9.7 N	8.4 NS	9.8 NS
50%	77	25	180	11.9 SS	10.3 SS	5.5 N	4.9 N	17.7 SS	13.1 SS	8.1 S	10.0 S	6.6 S	11.2 S
50%	77	25	240	10.9 SS	11.8 SS	6.9 S	6.3 S	9.9 SS	15.8 SS	11.8 SS	9.5 SS	9.7 SS	12.8 SS
50%	95	35	15	2.2 N	2.0 N	3.0 N	3.1 N	8.2 N	7.6 N	3.1 N	3.1 N	6.3 NS	6.9 NS
50%	95	35	30	3.4 N	4.0 N	5.2 N	3.7 N	9.2 N	8.8 N	4.7 N	3.2 N	7.6 NS	9.6 NS
50%	95	35	60	3.9 N	4.3 N	5.3 N	5.2 N	10.2 NS	9.8 N	4.1 N	5.0 N	8.9 NS	8.0 NS
50%	95	35	90	6.6 N	6.2 N	8.1 NS	6.2 NS	12.0 S	13.3 S	5.6 N	3.8 N	9.6 NS	15.3 NS
50%	95	35	120	6.8 NS	9.0 NS	10.2 NS	8.0 NS	11.1 SS	10.1 SS	8.2 NS	8.8 NS	10.9 NS	10.1 S
50%	95	35	180	13.9 S	14.2 S	15.0 S	13.6 S	11.1 SS	9.7 SS	11.4 S	11.8 S	10.2 S	8.4 S
50%	95	35	240	14.4 SS	13.5 SS	12.7 SS	13.7 SS	16.5 SS	13.8 SS	12.7 SS	12.4 SS	13.5 SS	11.3 SS
90%	50	10	15	1.8 N	3.7 N	2.2 N	1.1 N	3.7 N	2.1 N	2.1 N	3.1 N	6.6 N	5.1 N
90%	50	10	30	2.8 N	2.1 N	1.8 N	1.8 N	3.6 N	3.1 N	2.7 N	2.2 N	5.2 N	4.6 N
90%	50	10	60	2.7 N	2.4 N	1.6 N	2.0 N	7.4 N	5.4 N	3.3 N	3.2 N	5.7 N	6.5 N
90%	50	10	90	3.9 N	4.2 N	1.3 N	1.8 N	8.0 N	8.0 N	3.4 N	2.1 N	4.6 N	5.1 N
90%	50	10	120	2.7 N	4.1 N	1.3 N	2.0 N	8.3 NS	8.3 N	2.8 N	2.9 N	3.6 N	6.2 N
90%	50	10	180	4.2 N	3.7 N	1.5 N	2.6 N	10.2 NS	10.9 NS	2.9 N	4.7 N	4.6 N	4.2 N
90%	50	10	240	6.9 N	6.8 N	2.9 N	1.6 N	8.6 SS	7.6 SS	3.6 N	4.6 N	5.7 N	5.1 N
90%	77	25	15	1.8 N	2.0 N	2.1 N	2.4 N	6.7 N	6.6 N	4.2 N	3.8 N	5.4 N	7.9 N
90%	77	25	30	2.8 N	2.2 N	1.7 N	1.5 N	7.6 N	7.6 N	3.7 N	3.6 N	7.0 N	6.7 N
90%	77	25	60	2.3 N	2.2 N	2.8 N	2.3 N	8.2 NS	8.7 NS	3.4 N	5.5 N	6.9 N	8.4 N
90%	77	25	90	2.2 N	2.0 N	2.1 N	2.7 N	11.7 S	10.8 S	5.8 N	5.8 N	7.8 N	8.7 N
90%	77	25	120	2.2 N	2.1 N	2.9 N	4.1 N	10.6 S	9.9 SS	5.3 N	6.2 N	8.2 N	6.8 N
90%	77	25	180	3.2 N	1.8 N	6.5 N	9.6 N	10.6 S	9.2 S	8.8 N	6.8 N	9.6 N	8.1 N
90%	77	25	240	3.5 N	3.4 N	10.6 NS	11.9 NS	10.5 SS	9.6 SS	11.5 N	7.9 N	7.9 NS	9.8 NS
90%	95	35	15	3.0 N	3.2 N	1.6 N	2.1 N	5.5 N	6.0 N	3.9 N	3.3 N	6.9 N	7.3 N
90%	95	35	30	2.0 N	2.7 N	2.5 N	1.9 N	5.3 N	7.1 N	4.1 N	3.5 N	7.3 N	6.7 N
90%	95	35	60	2.8 N	2.7 N	3.0 N	2.2 N	8.2 S	6.5 S	5.0 N	5.7 N	7.0 N	8.2 N
90%	95	35	90	4.2 N	5.6 N	3.8 N	3.9 N	5.6 SS	6.0 SS	4.6 N	4.6 N	8.0 N	7.2 N
90%	95	35	120	5.4 N	7.1 N	5.1 N	5.8 N	15.7 SS	14.4 SS	4.8 N	5.6 N	8.5 N	8.0 N
90%	95	35	180	10.4 NS	13.1 NS	6.1 N	5.7 N	11.9 SS	9.9 SS	4.4 N	6.0 N	9.2 N	7.8 N
90%	95	35	240	16.9 S	15.9 S	8.0 N	9.0 N	12.8 SS	15.8 SS	8.6 N	11.4 N	10.0 NS	11.7 NS

ACT RESULTS FOR ALL MIXES

TEST RESULTS			Mix	M1		M2		M3		M4		M5	
			Auto/Man	MANUAL		MANUAL		MANUAL		MANUAL		MANUAL	
	Temp.		***Replicates***	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Humidity	**('F)**	**('C)**	**Curing(min)**	ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910	
50%	50	10	15										
50%	50	10	30										
50%	50	10	60										
50%	50	10	90										
50%	50	10	120										
50%	50	10	180										
50%	50	10	240										
50%	77	25	15					15.0 N	14.0 N	10.0 N	11.0 N		
50%	77	25	30					16.0 N	15.0 NS	12.0 N	13.0 N		
50%	77	25	60					19.0 S	17.0 S	13.0 N	14.0 N		
50%	77	25	90					20.0 S	21.0 S	17.0 N	17.0 N		
50%	77	25	120					21.0 SS	21.0 SS	18.0 N	18.0 N		
50%	77	25	180					22.0 SS	23.0 SS	22.0 S	23.0 S		
50%	77	25	240					24.0 SS	24.0 SS	28.0 SS	26.0 SS		
50%	95	35	15									15.0 NS	16.0 NS
50%	95	35	30									19.0 NS	20.0 NS
50%	95	35	60									20.0 NS	21.0 NS
50%	95	35	90									20.0 NS	21.0 NS
50%	95	35	120									23.0 S	22.0 S
50%	95	35	180									23.0 SS	23.0 SS
50%	95	35	240									25.0 SS	26.0 SS
90%	50	10	15										
90%	50	10	30										
90%	50	10	60										
90%	50	10	90										
90%	50	10	120										
90%	50	10	180										
90%	50	10	240										
90%	77	25	15			7.0 N	9.0 N						
90%	77	25	30			9.0 N	9.0 N						
90%	77	25	60			11.0 N	9.0 N						
90%	77	25	90			12.0 N	10.0 N						
90%	77	25	120			12.0 N	12.0 N						
90%	77	25	180			14.0 NS	15.0 NS						
90%	77	25	240			16.0 NS	17.0 NS						
90%	95	35	15										
90%	95	35	30										
90%	95	35	60										
90%	95	35	90										
90%	95	35	120										
90%	95	35	180										
90%	95	35	240										

ACT RESULTS FOR ALL MIXES

Parameter	Units	Values		Test No.			
		High (H)	Low (L)	1	2	3	4
1. Cure Temp	C	2	-2	L	L	H	H
2. Cure Time	min	3	-3	L	H	L	H
3. Cure Humidity	%	10	-10	H	L	L	H

MACTEC

Asphalt Classification Summary

Client: Pooled Fund Study	MACTEC Job No.: 5016-03-0007
Project Name: Automated Cohesion Testing Asphalt Products Testing	Date Reported: 05-08-2008
	Material: PMCQS-1h
	Source: SemMaterials, L.P.

	Project No.:		NP		
	Sample ID.:		NP		
	MACTEC Lab No.:		830440		
	Date Received:		04-14-2008		
	Sample Date:		NP		
	Sample Type:		Concentrate		
Tests on Emulsions	Test Method	Spec			
Saybolt Furol Viscosity, (77°F), s	AASHTO T59	15-90	44		
Sieve Test, %	AASTHO T59	0.3 max.	0.01		
Storage Stability,24 hr.	AASHTO T59	1.0 max.	0.86		
Residue by Evaporation, %	CTM 331	57 min.	62.7		
Particle Charge	AASHTO T59	positive	positive		
Tests on Residue from Evaporation	CTM 331				
Penetration, (77°F), 100g, 5s, dmm	AASHTO T49	40-90	45		
Ductility, (77°F), 5cm/min,mm	AASHTO T51	400 min.	660		
Torsional Recovery, %	CTM 332	18 min.	21.8		

Remarks:

Reviewed By: [signature]
Sam W. Huddleston, Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

MACTEC
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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	79086
Project No.:	--	Date Received:	07-27-2007
Material Source:	np	Report Date:	01-15-2008
Material Supplier:	Table Mountain	Material:	Type III Slurry Sand

Gradation		
Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	89	
#4 / 4.75 mm	72	70-90
#8 / 2.36 mm	*41	45-70
#10 / 2.00 mm	36	
#16 / 1.18 mm	*25	28-50
#30 / 600 µm	*16	19-34
#40 /425 µm	13	
#50 / 300 µm	*10	12-25
#100 / 150 µm	7	7-18
#200 / 75 µm	*4.8	5-15

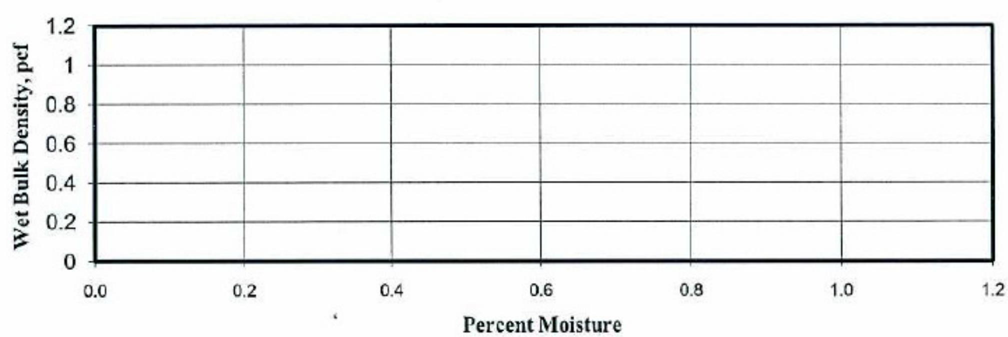
Sand Equivalent Test		
Test Method: ASTM D2419		Spec
SE Value:	85	45 Min.

Sulfate Soundness (source)		
Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

L.A. Abrasion (source)		
Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect	
Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf

Bulking Effect of Mineral Aggregate



**: Does not meet Project Specifications*
Specifications reference ISSA A105/A143
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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	79087
Project No.:	--	Date Received:	07-27-2007
Material Source:	np	Report Date:	01-15-2008
Material Supplier:	Lopke	Material:	Type III Slurry Sand

Gradation

Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	99	
#4 / 4.75 mm	*96	70-90
#8 / 2.36 mm	*76	45-70
#10 / 2.00 mm	68	
#16 / 1.18 mm	49	28-50
#30 / 600 µm	34	19-34
#40 /425 µm	30	
#50 / 300 µm	*26	12-25
#100 / 150 µm	*21	7-18
#200 / 75 µm	*17.2	5-15

Sand Equivalent Test

Test Method: ASTM D2419		Spec
SE Value:	*37	45 Min.

Sulfate Soundness (source)

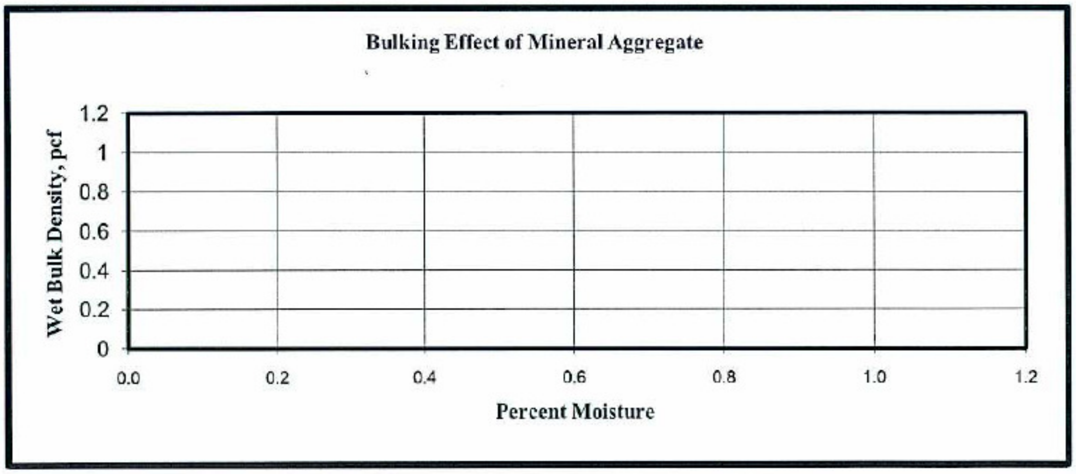
Test Method: AASHTO T104	(%)	Spec
Coarse:		
Fine:		

L.A. Abrasion (source)

Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect

Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf



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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

MACTEC

Asphalt Classification Summary

Client: Pooled Fund Study	MACTEC Job No.: 5016-03-0007
Project Name: Automated Cohesion Testing	Date Reported: 05-08-2008
Asphalt Products Testing	Material: CSS-1P
	Source: Ergon, Waco Texas

	Project No.:		NP		
	Sample ID.:		Tank 308		
	MACTEC Lab No.:		79726		
	Date Received:		11-19-2007		
	Sample Date:		11-13-2007		
	Sample Type:		Concentrate		
Tests on Emulsions	Test Method	Spec			
Saybolt Furol Viscosity, (77°F), s	AASHTO T59	15-90	16		
Sieve Test, %	AASTHO T59	0.3 max.	0.01		
Storage Stability,24 hr.	AASHTO T59	1.0 max.	0.42		
Residue by Evaporation, %	CTM 331	57 min.	67.7		
Particle Charge	AASHTO T59	positive	positive		
Tests on Residue from Evaporation	CTM 331				
Penetration, (77°F), 100g, 5s, dmm	AASHTO T49	40-90	61		
Ductility, (77°F), 5cm/min,mm	AASHTO T51	400 min.	410		
Torsional Recovery, %	CTM 332	18 min.	20.3		

Remarks:

Reviewed By: [signature]
Sam W. Huddleston, Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	79753
Project No.:	--	Date Received:	11-27-2007
Material Source:	Waco, Texas	Report Date:	01-15-2008
Material Supplier:	Delta Materials, Gr. 2	Material:	Type II Slurry Sand

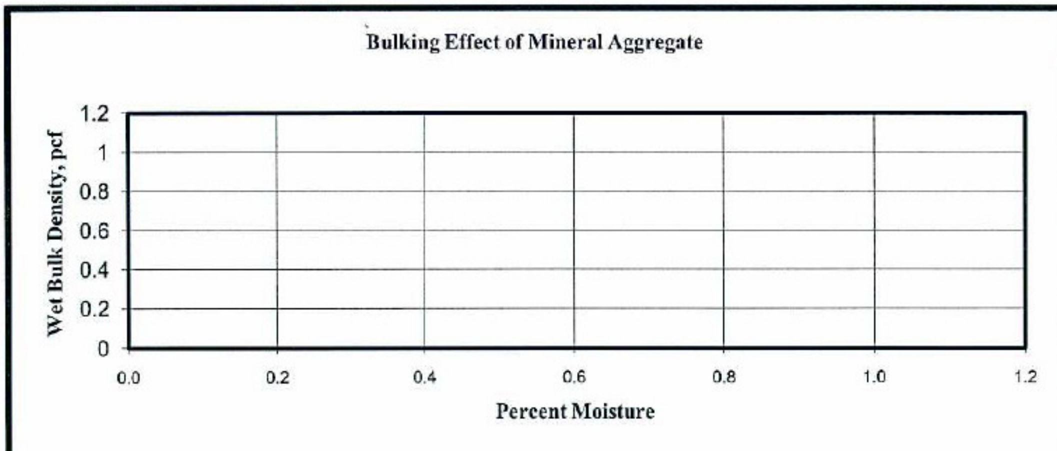
Gradation		
Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	99	
#4 / 4.75 mm	*89	90-100
#8 / 2.36 mm	*53	65-90
#10 / 2.00 mm	46	
#16 / 1.18 mm	*32	45-70
#30 / 600 µm	*22	30-50
#40 /425 µm	18	
#50 / 300 µm	*15	18-30
#100 / 150 µm	13	10-21
#200 / 75 µm	7.8	5-15

Sand Equivalent Test		
Test Method: ASTM D2419		Spec
SE Value:	63	45 Min.

Sulfate Soundness (source)		
Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

L.A. Abrasion (source)		
Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect	
Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf



**: Does not meet Project Specifications*
Specifications reference ISSA A105/A143
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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	79753
Project No.:	--	Date Received:	11-27-2007
Material Source:	Waco, Texas	Report Date:	01-15-2008
Material Supplier:	Delta Materials, Gr. 2	Material:	Type II Slurry Sand

Gradation

Test Method: ASTM C136, C117		Txdot
Screen Size	% Retained	Spec
1/2" / 12.5 mm		0
3/8"/ 9.5 mm	0	0-1
1/4" / 6.3 mm	1	
#4 / 4.75 mm	11	6-14
#8 / 2.36 mm	47	35-55
#10 / 2.00 mm	54	
#16 / 1.18 mm	68	54-75
#30 / 600 µm	78	65-85
#40 /425 µm	82	
#50 / 300 µm	85	75-90
#100 / 150 µm	87	82-93
#200 / 75 µm	92.2	85-95

Sand Equivalent Test

Test Method: ASTM D2419		Spec
SE Value:	63	45 Min.

Sulfate Soundness (source)

Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

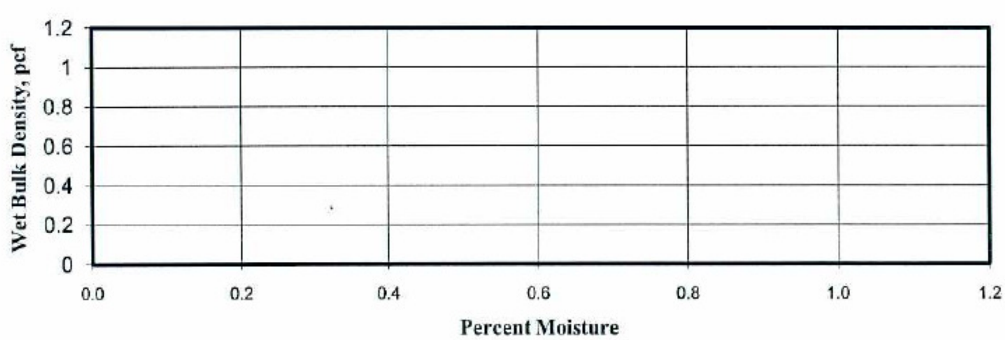
L.A. Abrasion (source)

Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect

Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf

Bulking Effect of Mineral Aggregate



Specifications reference TxDOT 2004
Standard Specifications

Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	830152
Project No.:	--	Date Received:	02-12-2008
Material Source:	np	Report Date:	02-18-2008
Material Supplier:	Lopke	Material:	Type III Slurry Sand

Gradation

Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	99	
#4 / 4.75 mm	87	70-90
#8 / 2.36 mm	55	45-70
#10 / 2.00 mm	48	
#16 / 1.18 mm	34	28-50
#30 / 600 μm	24	19-34
#40 /425 μm	21	
#50 / 300 μm	18	12-25
#100 / 150 μm	15	7-18
#200 / 75 μm	11.9	5-15

Sand Equivalent Test

Test Method: ASTM D2419		Spec
SE Value:	*43	45 Min.

Sulfate Soundness (source)

Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

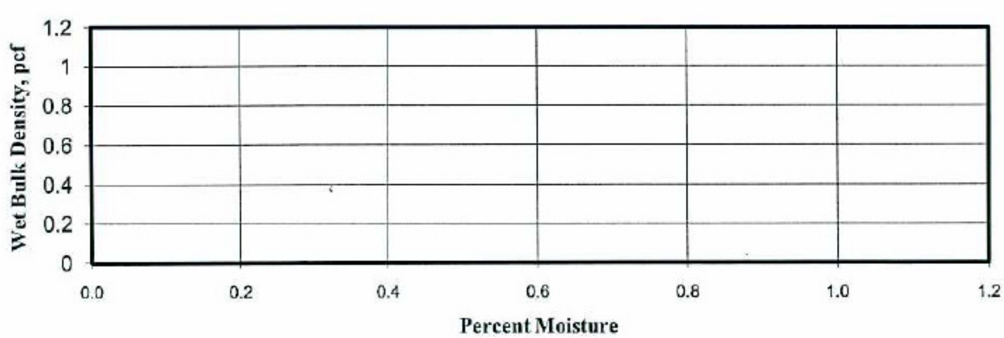
L.A. Abrasion (source)

Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect

Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf

Bulking Effect of Mineral Aggregate



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Specifications reference ISSA A105/A143
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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	830257
Project No.:	--	Date Received:	03-06-2008
Material Source:	np	Report Date:	05-08-2008
Material Supplier:	Lopke	Material:	Type III Slurry Sand

Gradation		
Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	99	
#4 / 4.75 mm	85	70-90
#8 / 2.36 mm	55	45-70
#10 / 2.00 mm	53	
#16 / 1.18 mm	35	28-50
#30 / 600 µm	22	19-34
#40 /425 µm	20	
#50 / 300 µm	19	12-25
#100 / 150 µm	15	7-18
#200 / 75 µm	11.7	5-15

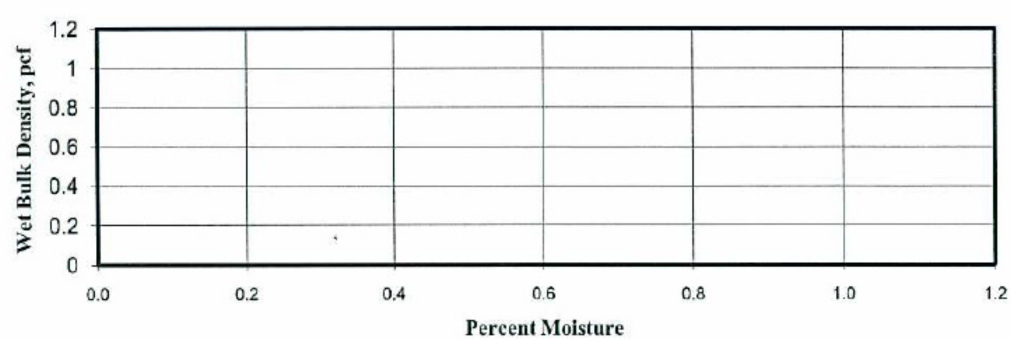
Sand Equivalent Test		
Test Method: ASTM D2419		Spec
SE Value:	47	45 Min.

Sulfate Soundness (source)		
Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

L.A. Abrasion (source)		
Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect	
Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf

Bulking Effect of Mineral Aggregate



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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

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Mineral Aggregate Summary

Client:	Pooled Fund Study	MACTEC Job No.:	5016-03-0007
Project Name:	Asphalt Testing Services	Lab No.:	830359
Project No.:	--	Date Received:	03-27-2008
Material Source:	np	Report Date:	05-08-2008
Material Supplier:	Table Mountain	Material:	Type III Slurry Sand

Gradation		
Test Method: ASTM C136, C117		ISSA
Screen Size	% Passing	Spec
1/2" / 12.5 mm		
3/8"/ 9.5 mm	100	100
1/4" / 6.3 mm	100	
#4 / 4.75 mm	87	70-90
#8 / 2.36 mm	67	45-70
#10 / 2.00 mm	64	
#16 / 1.18 mm	45	28-50
#30 / 600 µm	30	19-34
#40 /425 µm	25	
#50 / 300 µm	19	12-25
#100 / 150 µm	13	7-18
#200 / 75 µm	9.1	5-15

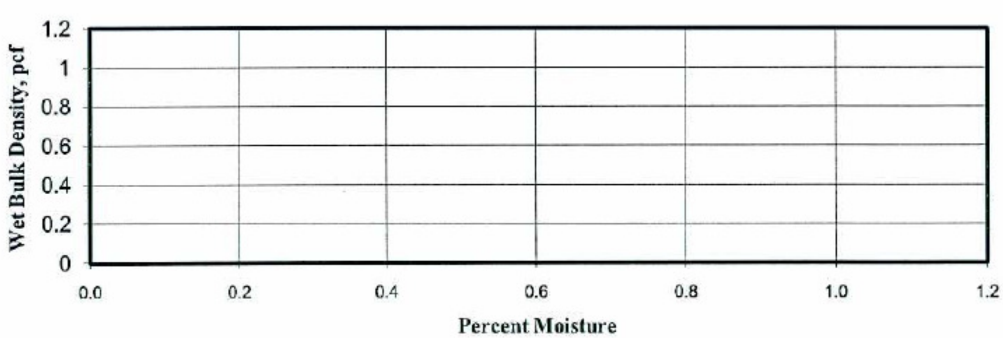
Sand Equivalent Test		
Test Method: ASTM D2419		Spec
SE Value:	79	45 Min.

Sulfate Soundness (source)		
Test Method: AASHTO T104		
	(%)	Spec
Coarse:		
Fine:		

L.A. Abrasion (source)		
Test Method: ASTM C131		
Method:	% Loss	Spec
100 Rev (%)		
500 Rev (%)		

Bulking Effect	
Test Method: ASTM C29	
Moisture Content	Wet Bulk Density, pcf

Bulking Effect of Mineral Aggregate



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Reviewed By:
Sam W. Huddleston
Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

ACT RESULTS FOR ALL MIXES

MACTEC

Asphalt Classification Summary

Client: Pooled Fund Study	MACTEC Job No.: 5016-03-0007
Project Name: Automated Cohesion Testing	Date Reported: 05-08-2008
Asphalt Products Testing	Material: Ralumac
	Source: SemMaterials, L.P.

	Project No.:		NP		
	Sample ID.:		NP		
	MACTEC Lab No.:		830420		
	Date Received:		04-08-2008		
	Sample Date:		04-02-2008		
	Sample Type:		Concentrate		
Tests on Emulsions	Test Method	Spec			
Saybolt Furol Viscosity, (77°F), s	AASHTO T59	15-90	28		
Sieve Test, %	AASTHO T59	0.3 max.	0.10		
Storage Stability,24 hr.	AASHTO T59	1.0 max.	0.58		
Residue by Evaporation, %	CTM 331	57 min.	64.5		
Particle Charge	AASHTO T59	positive	positive		
Tests on Residue from Evaporation	CTM 331				
Penetration, (77°F), 100g, 5s, dmm	AASHTO T49	40-90	84		
Ductility, (77°F), 5cm/min,mm	AASHTO T51	400 min.	866		
Torsional Recovery, %	CTM 332	18 min.	19.2		

Remarks:

Reviewed By:

Sam W. Huddleston, Bituminous Laboratory Manager

3630 East Wier Avenue * Phoenix, Arizona 85040 * Telephone: (602) 437-0250

ACT RESULTS FOR ALL MIXES

TEST RESULTS		Mix	M1		M2		M3		M4		M5	
		Auto/Man	AUTOMATIC		AUTOMATIC		AUTOMATIC		AUTOMATIC		AUTOMATIC	
		Replicates	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Humidity	Temp. ('C)	Curing(min)	TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01		TEMPLE 2047-01	
50%	10	15	1.8 N	2.1 N	1.3 N	1.6 N	3.5 N	4.5 N	2.8 N	2.5 N	4.0 N	6.1 N
50%	10	30	2.1 N	2.3 N	1.9 N	2.0 N	4.9 N	5.0 N	3.6 N	2.8 N	5.0 N	4.7 N
50%	10	60	3.1 N	3.9 N	1.6 N	1.9 N	4.7 N	5.8 N	3.4 N	3.8 N	4.3 N	4.2 N
50%	10	90	2.7 N	3.2 N	2.1 N	1.6 N	7.2 N	8.5 N	3.3 N	3.0 N	3.0 N	4.9 N
50%	10	120	3.1 N	3.4 N	2.4 N	1.9 N	8.5 N	8.8 N	4.6 N	2.8 N	4.1 N	4.2 N
50%	10	180	4.9 N	4.9 N	2.3 N	2.1 N	8.9 NS	8.9 NS	4.5 N	6.9 N	5.6 N	5.2 N
50%	10	240	5.9 N	6.5 N	4.2 N	3.0 N	9.9 SS	9.5 S	11.9 SS	12.0 S	6.8 N	6.0 N
50%	25	15	2.5 N	3.3 N	1.9 N	1.3 N	8.8 N	8.0 N	3.1 N	2.7 N	4.7 N	5.5 N
50%	25	30	4.5 N	3.8 N	1.6 N	2.1 N	11.5 N	11.0 N	4.6 N	5.2 N	7.0 N	6.1 N
50%	25	60	7.2 N	4.3 N	2.4 N	2.2 N	9.4 S	9.9 NS	5.2 N	4.8 N	4.9 N	6.3 N
50%	25	90	8.6 NS	9.8 NS	3.9 N	3.8 N	13.1 S	11.1 S	6.0 N	5.9 N	7.6 N	7.7 N
50%	25	120	8.6 S	9.4 S	3.9 N	3.4 N	12.6 SS	11.0 SS	7.3 N	9.7 N	8.4 NS	9.8 NS
50%	25	180	11.9 SS	10.3 SS	5.5 N	4.9 N	17.7 SS	13.1 SS	8.1 S	10.0 S	6.6 S	11.2 S
50%	25	240	10.9 SS	11.8 SS	6.9 S	6.3 S	9.9 SS	15.8 SS	11.8 SS	9.5 SS	9.7 SS	12.8 SS
50%	35	15	2.2 N	2.0 N	3.0 N	3.1 N	8.2 N	7.6 N	3.1 N	3.1 N	6.3 NS	6.9 NS
50%	35	30	3.4 N	4.0 N	5.2 N	3.7 N	9.2 N	8.8 N	4.7 N	3.2 N	7.6 NS	9.6 NS
50%	35	60	3.9 N	4.3 N	5.3 N	5.2 N	10.2 NS	9.8 N	4.1 N	5.0 N	8.9 NS	8.0 NS
50%	35	90	6.6 N	6.2 N	8.1 NS	6.2 NS	12.0 S	13.3 S	5.6 N	3.8 N	9.6 NS	15.3 NS
50%	35	120	6.8 NS	9.0 NS	10.2 NS	8.0 NS	11.1 SS	10.1 SS	8.2 NS	8.8 NS	10.9 NS	10.1 S
50%	35	180	13.9 S	14.2 S	15.0 S	13.6 S	11.1 SS	9.7 SS	11.4 S	11.8 S	10.2 S	8.4 S
50%	35	240	14.4 SS	13.5 SS	12.7 SS	13.7 SS	16.5 SS	13.8 SS	12.7 SS	12.4 SS	13.5 SS	11.3 SS
90%	10	15	1.8 N	3.7 N	2.2 N	1.1 N	3.7 N	2.1 N	2.1 N	3.1 N	6.6 N	5.1 N
90%	10	30	2.8 N	2.1 N	1.8 N	1.8 N	3.6 N	3.1 N	2.7 N	2.2 N	5.2 N	4.6 N
90%	10	60	2.7 N	2.4 N	1.6 N	2.0 N	7.4 N	5.4 N	3.3 N	3.2 N	5.7 N	6.5 N
90%	10	90	3.9 N	4.2 N	1.3 N	1.8 N	8.0 N	8.0 N	3.4 N	2.1 N	4.6 N	5.1 N
90%	10	120	2.7 N	4.1 N	1.3 N	2.0 N	8.3 NS	8.3 N	2.8 N	2.9 N	3.6 N	6.2 N
90%	10	180	4.2 N	3.7 N	1.5 N	2.6 N	10.2 NS	10.9 NS	2.9 N	4.7 N	4.6 N	4.2 N
90%	10	240	6.9 N	6.8 N	2.9 N	1.6 N	8.6 SS	7.6 SS	3.6 N	4.6 N	5.7 N	5.1 N
90%	25	15	1.8 N	2.0 N	2.1 N	2.4 N	6.7 N	6.6 N	4.2 N	3.8 N	5.4 N	7.9 N
90%	25	30	2.8 N	2.2 N	1.7 N	1.5 N	7.6 N	7.6 N	3.7 N	3.6 N	7.0 N	6.7 N
90%	25	60	2.3 N	2.2 N	2.8 N	2.3 N	8.2 NS	8.7 NS	3.4 N	5.5 N	6.9 N	8.4 N
90%	25	90	2.2 N	2.0 N	2.1 N	2.7 N	11.7 S	10.8 S	5.8 N	5.8 N	7.8 N	8.7 N
90%	25	120	2.2 N	2.1 N	2.9 N	4.1 N	10.6 S	9.9 SS	5.3 N	6.2 N	8.2 N	6.8 N
90%	25	180	3.2 N	1.8 N	6.5 N	9.6 N	10.6 S	9.2 S	8.8 N	6.8 N	9.6 N	8.1 N
90%	25	240	3.5 N	3.4 N	10.6 NS	11.9 NS	10.5 SS	9.6 SS	11.5 N	7.9 N	7.9 NS	9.8 NS
90%	35	15	3.0 N	3.2 N	1.6 N	2.1 N	5.5 N	6.0 N	3.9 N	3.3 N	6.9 N	7.3 N
90%	35	30	2.0 N	2.7 N	2.5 N	1.9 N	5.3 N	7.1 N	4.1 N	3.5 N	7.3 N	6.7 N
90%	35	60	2.8 N	2.7 N	3.0 N	2.2 N	8.2 S	6.5 S	5.0 N	5.7 N	7.0 N	8.2 N
90%	35	90	4.2 N	5.6 N	3.8 N	3.9 N	5.6 SS	6.0 SS	4.6 N	4.6 N	8.0 N	7.2 N
90%	35	120	5.4 N	7.1 N	5.1 N	5.8 N	15.7 SS	14.4 SS	4.8 N	5.6 N	8.5 N	8.0 N
90%	35	180	10.4 NS	13.1 NS	6.1 N	5.7 N	11.9 SS	9.9 SS	4.4 N	6.0 N	9.2 N	7.8 N
90%	35	240	16.9 S	15.9 S	8.0 N	9.0 N	12.8 SS	15.8 SS	8.6 N	11.4 N	10.0 NS	11.7 NS

ACT RESULTS FOR ALL MIXES

TEST RESULTS		Mix	M1		M2		M3		M4		M5	
		Auto/Man	MANUAL		MANUAL		MANUAL		MANUAL		MANUAL	
		Replicates	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Humidity	Temp. ('C)	Curing(min)	ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910		ALPHA Labs 3910	
50%	10	15										
50%	10	30										
50%	10	60										
50%	10	90										
50%	10	120										
50%	10	180										
50%	10	240										
50%	25	15					15.0 N	14.0 N	10.0 N	11.0 N		
50%	25	30					16.0 N	15.0 NS	12.0 N	13.0 N		
50%	25	60					19.0 S	17.0 S	13.0 N	14.0 N		
50%	25	90					20.0 S	21.0 S	17.0 N	17.0 N		
50%	25	120					21.0 SS	21.0 SS	18.0 N	18.0 N		
50%	25	180					22.0 SS	23.0 SS	22.0 S	23.0 S		
50%	25	240					24.0 SS	24.0 SS	28.0 SS	26.0 SS		
50%	35	15									15.0 NS	16.0 NS
50%	35	30									19.0 NS	20.0 NS
50%	35	60									20.0 NS	21.0 NS
50%	35	90									20.0 NS	21.0 NS
50%	35	120									23.0 S	22.0 S
50%	35	180									23.0 SS	23.0 SS
50%	35	240									25.0 SS	26.0 SS
90%	10	15										
90%	10	30										
90%	10	60										
90%	10	90										
90%	10	120										
90%	10	180										
90%	10	240										
90%	25	15			7.0 N	9.0 N						
90%	25	30			9.0 N	9.0 N						
90%	25	60			11.0 N	9.0 N						
90%	25	90			12.0 N	10.0 N						
90%	25	120			12.0 N	12.0 N						
90%	25	180			14.0 NS	15.0 NS						
90%	25	240			16.0 NS	17.0 NS						
90%	35	15										
90%	35	30										
90%	35	60										
90%	35	90										
90%	35	120										
90%	35	180										
90%	35	240										

ACT RESULTS FOR ALL MIXES

Parameter	Units	Values		Test No.			
		High (H)	Low (L)	1	2	3	4
1. Cure Temp	C	2	-2	L	L	H	H
2. Cure Time	min	3	-3	L	H	L	H
3. Cure Humidity	%	10	-10	H	L	L	H

APPENDIX F UPDATED WORK PLAN FOR PHASE III

1.0 PHASE III OBJECTIVE

The objectives of Phase III is to actually use mix designs in accordance with the procedures outlined in this report on projects identified by the states supporting this study. Attempts will be made to place these mixes in a variety of environmental and traffic conditions.

2.0 GUIDELINES AND SPECIFICATIONS

It was first estimated that by the end of Phase II, the work plan would be considered to be essentially final. Due to the cancellation of the project, additional research is anticipated before final guidelines and specifications can be produced. Much of the Reference Manual, 1.5-day training course and the “tailgate” training are near completion. This chapter describes what has been done and what remains to be done on the phase.

3.0 PURPOSE OF PHASE III STUDY

The purpose of Phase III is to validate that mixes designed in the laboratory, using the new and revised procedures as outlined in Phase II, can actually be built in the field. This chapter presents the proposed Work Plan to complete the following tasks, as outlined in the original proposal:

- *Develop guidelines and specifications for the proper use of slurry and micro-surfacing.*
- *Develop a workshop training program that includes a pre-construction module to educate and inform agency, contractor, and material supplier personnel of the new design procedures and constructability issues.*
- *Construct and monitor pilot projects for the validation effort.*
- *Revise the procedures or the training program based on test section field performance.*
- *Prepare a Final Report documenting all the activities throughout the project.*

4.0 TASK 1: DEVELOPMENT OF GUIDELINES/SPECIFICATIONS

During this phase of the work, the project team will develop guidelines that can be used by both contractor and agency personnel that will aid them in the proper selection of projects and the appropriate use of these treatments. For example, the guidelines for proper project selection will address issues such as type and condition of the existing pavement. These treatments are not effective if placed on pavements in poor to bad condition. Additionally, the project team will address the differences between the S3 systems and provide guidance where each will meet expected performance expectations. For example, if quick return to traffic and friction are important functional characteristics desired by the agency, the use of a high traffic mixture may be preferred over a low traffic one.

The guidelines will also address constructability issues that need to be considered during the placement of these techniques. This will include mixing, wetting, and adhesion at the placement site as well as techniques to preclude segregation of the mix and homogenous spreading of the mix over the pavement surface.

Guidance will be provided to both agency and contractor personnel regarding the things to evaluate for proper curing characteristics of the emulsion. It is also important that identification be made of those characteristics that are of utmost importance in assuring the long-term performance of the mix. This will be dependent on the quality and reproducibility of the mix design and the condition of the existing pavement.

The team will develop the necessary specifications for S3 mixes. Work on this effort has already begun. Working with existing specifications from agencies that have a great deal of experience with these systems as a starting point, we will include the new test methods and other appropriate sections in the specifications that we prepare.

5.0 TASK 2: DEVELOPMENT OF THE TRAINING PROGRAM

Under this task, the Fugro team will develop a comprehensive training program as the principal aid in the implementation of the new slurry/micro-surfacing mix design procedure. The program will include two primary training elements:

- A 1.5-day course designed to educate State highway agency personnel (at several levels), contractor personnel, and material suppliers on the technology and overall application of the new mix design procedure.
- A 1-hour presentation module that can be used to appraise inspectors and contractor personnel of the required new/improved construction procedures that have come about as a result of the new mix design procedure. We refer to this effort as a "tailgate" training package.

These two components will be treated as separate, but complementary, sets of training materials. A more detailed discussion of the development plans for each is provided below.

5.1 Slurry/Micro-Surfacing Mix Design Training Course

The training course to be developed under this effort will be designed to provide basic training on the development and application of the new mix design procedure. The training materials, as discussed in greater detail below, will include a Reference Manual, a set of training course visual aids (in electronic format), and an Instructor's Guide. The course will be designed for presentation over a 1.5-day period and will include two workshops. In developing the workshops, the goal will be to incorporate "hands-on" exercises that not only advance the learning, but help generate some enthusiasm and interaction among the participants, as well.

The materials for this course will be developed to be compatible with National Highway Institute's (NHI's) Guidelines for Training Materials because the NHI has set the standard for training materials.

5.2.1 Reference Manual

This manual will be a detailed, stand-alone document that covers all the key aspects of the new mix design procedure. It will be referenced throughout the course to help familiarize the participants with the contents and improve its use as a technical resource. Table F-1 provides an outline of the manual as it is currently envisioned.

Technical leadership for this effort will be supplied by Jim Moulthrop. The key staff that will participate in its development include Glynn Holleran, Dragos Andrei, Steven Seeds, and David Peshkin.

Table F.1: Draft Outline for Reference Manual

Section	Title/Description
1	Introduction • Background • Slurry/Micro-Surfacing Overview • Objectives and Scope of Manual
2	Project Selection Criteria
3	Pre-Construction Requirements
4	Specifications
5	Mix Design Criteria • Binder Requirements • Aggregate Requirements • Blending Requirements
6	Test Methods and Procedures • Framework • Mechanisms • Significance of Test Variables • Protocols
7	Construction Considerations and Limitations • Project Geometry • Weather Limitations
8	Construction Operations • Surface Preparation • Equipment and Calibration Requirements • Mix Design Verification • Stockpile Management • Troubleshooting • Inspection and Workmanship Requirements
9	QC/QA Requirements • Pre-Construction and Construction Testing Requirements • Frequency and Type of Test
10	Troubleshooting
-	References
-	Appendices • Test Methods • Specifications

5.2.2 Visual aids

Visual aids are required to present the training course material in a clear, consistent, and organized fashion. They will be prepared in electronic format using Microsoft PowerPoint®. This is a standard tool for NHI training courses and is very effective for both preparation and presentation of visual aids. Where appropriate, animation will be included in certain slide images to either emphasize certain points or provide an additional aid in understanding the message. Video clips of certain processes will also be included where they can provide the most benefit.

The organization of the course will closely follow that of the Reference Manual. Each section of the report will be translated into a training module with a presentation length ranging from 20 to 90 minutes, depending on the topic (see preliminary agenda in Table F-2). In addition, two workshops will be prepared. A hands-on workshop involving the use of the different types of laboratory equipment will developed for conduct on the afternoon of the first day of training. The second workshop will be prepared in a game format (such as Jeopardy) to test learning and emphasize key points relative to the slurry/micro-surfacing construction process. It will be conducted during the morning of the second day of training.

Table F.2: Preliminary Agenda for 1.5 Day Training Course

Day		Module	Title
1	AM	1	Course Overview
		2	Introduction to Slurry/Micro-Surfacing
		3	Project Selection Criteria
		4	Preconstruction Requirements
		5	Mix Design Criteria
	PM	6	Test Methods and Procedures
		7	Laboratory/Mix Design Workshop
2	AM	8	Construction Considerations and Limitations
		9	Construction Operations
		10	QC/QA Requirements
		11	Construction Workshop
		12	Summary and Closing Remarks

5.2.3 Instructor's Guide

The Instructor's Guide will be developed to provide detailed assistance to the instructor for the successful presentation of the training course. It will contain the following information:

- General Introduction (title page, table of contents, general course information, learning objectives, description of target audience, assumed course prerequisites, class schedule, key technical references, and sources of additional information).
- General Training Course Set-Up and Wrap-Up Procedures (preparatory activities, host agency interactions, room set-up, and pre- and post-workshop housekeeping items).
- Annotated Outline by Session (including learning objectives, key discussion points, answers to typical questions, time allotments, areas to reduce if time becomes an issue, copies of visual aids with annotations, and associated workshops or other learning evaluation/application methods).

David Peshkin will take the lead in developing the visual aids and the Instructor's Guide. Development assistance will be provided by Steve Seeds and Dragos Andrei. Jim Moulthrop will serve in both an advisory and review capacity.

5.3. PRE-JOB TRAINING MODULE

It is anticipated that this project will result in several significant modifications to the slurry/micro-surfacing construction processes as well as mix design procedures. Consequently, the purpose of this effort is to develop a pre-job training module, which will include a section on project safety, so that the "must know" information can be shared with agency and contractor personnel. This information will be extracted from the Reference Manual and a stand-alone document prepared for presentation and discussion during a meeting (similar to a pre-construction meeting) that will be held prior to the beginning of a slurry surfacing or micro-surfacing project. In addition, an easy to use, pocketsize guidebook will be prepared so that both agency and contractor personnel can take it into the field.

Jim Moulthrop will oversee and participate heavily in this effort. He will be assisted by Dragos Andrei and David Peshkin.

5.4 TASK 3: CONSTRUCTION OF PILOT PROJECTS FOR FIELD VALIDATION OF DESIGN PROCEDURES

The purpose of this work plan is to develop guidelines for the construction and evaluation of test sections for the validation of slurry seal and micro-surfacing mix design procedures. These guidelines indicate the type of equipment used and evaluation of the construction of test sections. A factorial for the determination of the site locations including test section layout has also been developed. Finally, a monitoring plan has been developed to determine constructability, and both short-term and long-term performance of the test sections.

The LTPP program developed a study to determine the long-term performance of various maintenance treatments.(1) Seven States participated in the construction of these test sections. The layout of these sections along with their site selection provided valuable information for the economical evaluation of the test sections. A similar plan is proposed for the validation of the slurry and micro-surfacing mix design procedure.

Fortunately, there has been widespread support for this study, which includes agencies from the States noted in Chapter 1. It is hoped that additional States may add their support before the conclusion of this study. These States provide a diverse set of climatic conditions ideally suited for this study. Their support in sponsoring and constructing test sections for slurry surfacing and micro-surfacing will greatly benefit this study.

5.4.1 Identification of Test Sections

5.4.1.1 Site Selection

Many factors affect the performance of slurry seal and micro-surfacing projects. These include climate, traffic, and condition of the existing pavement prior to the application, workmanship, and the mix design. A matrix factorial considering each of these variables has been developed and is noted in Table F-3. Consideration was given to the cost of constructing these test sections during the development of this factorial. It is important to consider each of the factors affecting performance to provide the team with the proper information to perform a validation of the procedures.

Table F.3: Site Selection Matrix Factorial

Traffic	Surface Type	Climatic Region			
		Wet-Freeze	Wet-No Freeze	Dry-Freeze	Dry-No Freeze
High >25,000 ADT <10 m ESALS**	HMAC	*(1,2)	*(1,2)	*(1,2)	*(1,2)
	PCC				
Moderate >10,000<25,000 ADT >4<10 m ESALS	HMAC	*(1,2)	*(1,2)	*(1,2)	*(1,2)
	PCC				

*1-Coarse
*2-Coarse (rut, or level-up)
**Equivalent Single Axle Load

An examination of the site conditions prior to selection must be conducted to insure uniformity among the test sections. The first step is to insure that the site is long enough to accommodate the number and length of test sections to be included in the site. Particular attention to entrance and exit ramps should be taken to insure uniform traffic among the test sections. It is preferable that the agencies avoid roadways that have sharp turns and super elevation in order to mitigate the interaction of the tire and the pavement between different test sections. It is recommended that the test sections be located on a relatively straight roadway with uniform vertical grade. The existing condition of the pavement (surface distress) should also be determined. It is recommended to select pavements with little or no distress. However, sites with limited distress will be accepted as long as the site has uniform conditions (raveling, bleeding, transverse cracks, etc.). Distress surveys using the LTPP Distress Identification Manual (DIM) shall be conducted on all sites prior to placement of the treatments to document the pavement condition.[2] This manual contains survey sheets and specific instructions on conducting these types of distress surveys.

Ride quality has been shown to impact the rate of deterioration of pavements. It is recommended that the surface of the pavement be smooth and provide an excellent ride level to reduce the effects this may have on individual sections within a test site. As a target, the existing surface should have a prorated IRI of less than 100 inches per mile (2540 mm per 1609.3 m) as measured by a calibrated profiler.

A site will be required in each of the four climatic regions. The current project States provide this diversity of climate regions. The four climatic regions used by the LTPP program were Wet-Freeze, Wet-No-Freeze, Dry-Freeze, and Dry-No-Freeze. These regions were determined by the amount of average annual precipitation and duration of freezing temperatures during an average year. The type of climate has a significant impact on the selection of the mix. In warm and dry climates, the rate of evaporation is greater and slow setting emulsions are desired. The opposite is true of wet and cold climates. The rate of curing can be altered by the amount of water, cement, emulsion, and set control chemicals. The four climatic regions will provide an opportunity to apply different mix designs using the new recommended procedures.

The effects of traffic also have an impact on the rate of deterioration. Traffic loadings may be determined in many different ways; unfortunately, there is no consistent national traffic loading reporting scheme. Many States do not utilize a consistent traffic loading procedure. The most prevalent way to express traffic loadings is the Equivalent Single Axle Load (ESAL), which is based on Average Daily Traffic, Percent Trucks, Truck Factors, and other conditions. Another way is to express traffic applications as Average Daily Traffic (ADT) with a certain percentage of trucks. Other States use a Traffic Index based on ESAL values. Slurry seals and micro-surfacing are preventive maintenance treatments and are not used as enhancements to the structural capacity of the pavement. Because ESAL values are used primarily for the structural design of pavements and utilize an ADT and percent trucks, the expression of ADT and percent trucks is recommended to express traffic applications.

Table F-3 presents the recommended matrix factorial for site selection. The amount of traffic for the factorial has been divided into two levels: high and moderate. The high traffic level ranges from 25,000 ADT and above (>10 Million ESALs). The moderate traffic level ranges from 10,000 ADT to 25,000 ADT (approximately 4-10 Million ESALs over 20 years with 10 percent trucks).

The variation of the type of subgrade soil and base materials (and their properties) between different sites will have an effect on the structural performance of the roadway. The costs associated with sampling and testing these materials at each site location is considered prohibitive. This would also burden the participating State Departments of Transportation with additional responsibilities. Therefore, this sort of sampling and testing will not be undertaken.

The primary focus of this study will be on the constructability of the recommended mix-designs and their performance compared to existing mix design procedures or various maintenance treatments. It is not recommended that subgrade soil and base types be included in the site selection. These treatments will be placed within the same site location and the structure should be approximately the same. If changes in pavement type or structural design are identified, the site should be adjusted to eliminate the presence of multiple pavement structures. The structural capacity of the pavement is important in determining the life span of the pavement. It is recommended that only those sites with sufficient remaining life (five years) be used for this study. This should prevent the need for maintenance and rehabilitation activities prior to completing the study.

5.4.2 Test Section Layout

The section layout will depend on the number of test sections desired for the study. As a minimum, the sections should include a control section without treatment and a slurry seal or micro-surfacing test section. This will provide validation of the constructability of the recommended mix design as well as the effect of the treatment on extending the existing pavement's life. However, this type of experiment does not allow a comparison of the improvement of the recommended mix design to existing mix designs or other treatments. Multiple treatment sections (e.g., slurry seal and micro-surfacing systems with different binders) along with the control are recommended to obtain the amount of information necessary for a complete evaluation and validation.

Multiple test sections using micro-surfacing may be placed using different types of polymers (e.g., natural rubber, synthetic rubber latex [SBR], or various combinations). It is recommended that a section using the ISSA design procedure be placed along with one of the recommended design procedures to determine the long-term performance of each type of mix design. The number of treated sections will depend on the results of the Phase II study and the desire of States to include supplemental sections to evaluate additional materials/treatments. Each treatment will be placed according to the construction guidelines described in this work plan. The recommended length of the test sections will be determined by the project team with approval from the panel and will be a minimum of 500 feet (152 m) and a maximum of 1000 feet (305 m). The length of each test section will remain constant for each site in this study.

5.4.3 Construction Guidelines

The construction guidelines to be developed are intended to insure proper placement of the material. Direct discussions between the teams, the contractor, and the participating State agency will be held prior to construction and will be part of the training program outlined in Section 4.3. This interaction is critically important for developing the participants' necessary understanding of the objectives of the experiment and the need for cooperation in adhering, as much as possible, to the requirements outlined in this report.

Many of the problems encountered with slurry seal and micro-surfacing can be attributed to improper placement of the material. These problems include the field conditions at the time of placement (i.e., wet surface, debris present, and temperature). The LTPP program was able to use of the same crew and equipment in the SPS-3 studies: HMAC Maintenance Treatments. It would be preferable for the same crew, equipment, and materials (aggregate and emulsion) to be used to apply all treatments in this project in order to reduce the impact of variation between treatment locations. However, due to the extreme effort of mobilizing the same crew and equipment to each State, this is cost prohibitive.

To account for the variables represented by differing crews and equipment, documentation on the type of equipment and source of materials is recommended to record the potential impacts these may have on the performance of the treatment. The project team has provided a plan, discussed below. Forms to obtain data on the lay down procedures are provided in Appendix G.

5.4.3.1 Pre-Construction

All cracks that are greater than 0.25 inches wide (6 mm) should be sealed prior to application of the treatment. It is not anticipated that patching will be required because of the pre-qualifying condition of the test sites. If patching is required, it must be performed prior to the distress survey. The site conditions prior to construction will be recorded and will include the following:

- Pavement Distress using the LTPP DIM(2)
- Type of Surface Material and Construction History (age)
- ADT and Percent Trucks
- Climate
- QA Procedures Developed in Task 1
- Calibration of Equipment

Prior to construction, the pavement must be in a dry condition and free of debris.

5.4.3.2 Construction

The following construction guidelines must be followed:

- The treatment mix design can be placed only after the contractor has satisfactorily demonstrated proper placement procedures on non-test section locations.
- All transverse construction joints must be placed outside the test sections (e.g., within the transitions between test sections).

The distance between the transition areas must be sufficient to allow changes in materials during construction. The distance is required to accommodate changes in material type in a manner that will reduce the influence on the properties of the finished pavement. Each test section will have a minimum of 100 feet (30.5 m) before and after the monitored length to provide sufficient production to develop consistency after changes in materials.

The mixture for the treatment will be documented using the forms in Appendix G, which include the type and quantities (rates) for each of the following:

- Polymer-modified emulsified asphalt cement
- Well-graded crushed mineral aggregate
- Mineral filler (normally portland cement or lime)
- Water
- Other mixing aid additives (normally emulsifying agents)

The project team shall provide the mix design information to the contractor and agency prior to the beginning of the project.

The equipment used for the application of the treatment shall also be documented using the forms in Appendix G, which will contain the following information:

- Type of paving equipment (continuous, truck-mounted)
- Type of spreader box

The breaking and curing rates of the treatment will be collected and entered on the Equipment Form provided in Appendix G.

An agency that desires to participate, but finds it necessary to deviate from some of the guidelines described in the report, should review these deviations with the research team. The team will assess the implications of these deviations on the study objectives. If the implications of the non-compliance appear minimal, the deviations will be accepted; if the implications appear to represent a major impact, the team will suggest alternatives for consideration by the participating agency.

5.4.3.3 Post-Construction

It is recommended that the test sections be allowed to cure properly prior to the application of traffic loadings to prevent premature damage. Evaluations of the test sections will be conducted immediately after construction, prior to opening the site to traffic one month after construction, and one year after construction. It is important that the sections be marked with tape, paint, or placards to identify the test sections. It is also recommended that the exact section locations be obtained using Geographical Positioning Systems (GPS), route, milepost, or other reference information. A section identification code will be developed to identify individual sections in the study. The evaluations of these test sections will be described in detail in the following sections.

5.5 PAVEMENT EVALUATION

Each pavement evaluation before, immediately after, and one year after construction, will consist of a detailed survey of the existing pavement distress using the LTPP DIM. The post construction surveys will also include comments of any abrasion, delamination, drag marks by the spreader box, wash boarding, and measurements of surface texture and noise. Segregation and flushing are identified in the LTPP DIM.

A survey form has been provided in Appendix G that summarizes the distress information obtained from the field. The amount of rutting will be measured with a 6 feet (1.8 m) straight edge every 50 feet (15.2 m) within the test section. If a high-speed profiler is used having five or more sensors to obtain ride quality information, the rutting will be obtained from this information. The texture will be determined using sand patch or other accepted test procedures. After the test section is open to traffic, the noise level will be determined from a safe distance from the pavement edge (edge of shoulder) if the agency has this type of equipment available.

If subgrade and base properties are still desired by the agencies, then a sampling and testing plan will be developed to accommodate the collection of these data. Structural testing using a Falling Weight Deflectometer (FWD) may also be considered to determine the variability of the pavement structure throughout each of the test sites to determine the remaining service life or to identify if there are underlying structural problems. An evaluation of the costs associated with this additional data collection effort should be considered by the agency before adopting this effort because it is beyond the scope of this project.

5.5.1 Revision of Procedures and Training Programs

Based on the feedback from participants in the training modules and the contractor and agency personnel involved with the construction and evaluation of the pilot projects, adjustments will be made (where necessary) to the guidelines, specifications, and training programs to make them clearer and more “user friendly.”

5.6 REFERENCES

1. SPS-3 Construction Report, SHRP Contract H-101, Brent Rauhut Engineering, SHRP Southern Region Coordination Office, Strategic Highway Research Program, Federal Highway Administration, Washington, DC, January 1991.

2. *Distress Identification Manual for the Long-Term Pavement Performance Program*, FHWA-RD-03-031, Federal Highway Administration, Washington, DC, June 2003.