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16. Abstract

Limestone Rock Asphalt (LRA) mixtures have been produced and placed for several decades using specification requirements currently listed under DMS 9210. Several districts have had placement issues and premature failures at the beginning of 2010. These issues and failures have been attributed to material properties. Requirements for DMS 9210 have not changed for several years and need to be evaluated to possibly produce a higher quality material to reduce the occurrence of premature failures and to minimize placement issues. The objectives of the study are to (1) evaluate specification requirements of Item 330 and DMS 9210, (2) conduct field evaluations and lab testing to determine workability and acceptability as stockpile material for use as needed in pavement maintenance, and (3) consider improvements to the specification requirements to ensure an acceptable and workable stockpile material for up to 6 months.

The Hveem stability was determined to be a good indicator of rutting resistance of LRA but it does not indicate when a mix is too dry and susceptible to raveling. The Cantabro test was able to identify dry mixtures with insufficient flux oil as well as poor quality flux oil.

A Cantabro loss of 15 percent maximum is being proposed as a new specification test and limit.

17. Key Words
Asphalt, Pavements, Maintenance, Cold Mix, Patching Mix, Limestone Rock Asphalt

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IMPROVING DMS 9210 REQUIREMENTS FOR LIMESTONE ROCK ASPHALT – FINAL REPORT

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The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objectives of this report.

ACKNOWLEDGMENTS

The author would like to acknowledge the significant contribution of TxDOT personnel in the work documented in this report:

- Mr. John Bohuslav of the San Antonio District for working with four districts and the General Services Division to procure materials from both suppliers and for providing overall guidance to the researchers.
- District personnel who provided test section locations, constructed test patches, sampled materials for researchers, and monitored performance of the patches.
  - Mr. John Bohuslav, San Antonio District and Mr. Homer Bermea, Uvalde Maintenance.
  - Ms. Darlene Goehl, Bryan District and Mr. Carl Schroeder, Navasota Maintenance.
  - Mr. Darwin Lankford, Childress District.
  - Mr. Lance Simmons and Mr. Doug Reiter, Atlanta District.

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BACKGROUND

BACKGROUND AND OBJECTIVES

Limestone rock asphalt (LRA) is a relatively porous stone permeated with a very hard natural asphalt. The material is found in very large deposits in the southwest corner of Uvalde County and extending into Kinney County. LRA is quarried with the aid of explosives, which create tremendous piles of rubble, including very large boulders. The boulders are passed through a series of primary and secondary crushers, and screened to standard grading requirements.

For Type I LRA mixtures, the limestone rock asphalt aggregate is blended with varying amounts of flux oil, water, and additives to produce a series of cold-mix, cold-laid paving materials. Type II LRA mixtures consist of a blend of native LRA aggregate, virgin aggregates, fluxing material, additives, and water. Since the aggregate contains natural bitumen, the amount of additional asphaltic binder required to produce a quality paving mixture is significantly reduced.

Flux oils are used to soften the hard native asphalt contained in the pores of the limestone. These softened native asphalts together with the asphalt cement contained in the flux oils act as the binder and impart the engineering properties required for the limestone rock asphalts to perform as roadway surfacing and base materials.

Limestone Rock Asphalt (LRA) mixtures have been produced and placed for several decades using specification requirements currently listed under DMS 9210, and Standard Specification Item 330. Several districts had placement issues and premature failures at the beginning of 2010. Most of the reported problems were regarding the material being too dry and raveling prematurely.

TxDOT initiated a study with Texas A&M Transportation Institute (TTI) in 2011 with the following objectives:

- Evaluate specification requirements of Item 330 and DMS 9210.
- Conduct field evaluations and lab testing to determine workability and acceptability as stockpile material for use as needed in pavement maintenance.
- Consider improvements to the specification requirements to ensure an acceptable and workable stockpile material for up to 6 months.

To accomplish these objectives, a 2-year work plan was initiated. Report 0-6686-1 detailed the findings of the Phase I or first year's research effort and the second year's effort (Phase II) will be documented here. Also included in this report (Chapter 2) is a summary of the findings from Report 0-6686-1.

LRA USE

LRA is considered a very important material used by TxDOT forces for various types of roadway maintenance including blade-on level-up, edge repair, thin overlay paving, and base repair. Its cost is significantly less than conventional hot mix and the ability to stockpile it and use it at ambient temperature makes it very versatile. Its use seems to be more predominant in the southern districts (closest to where it is produced in Uvalde); however, it is used statewide as shown in Figure 1 through Figure 3.

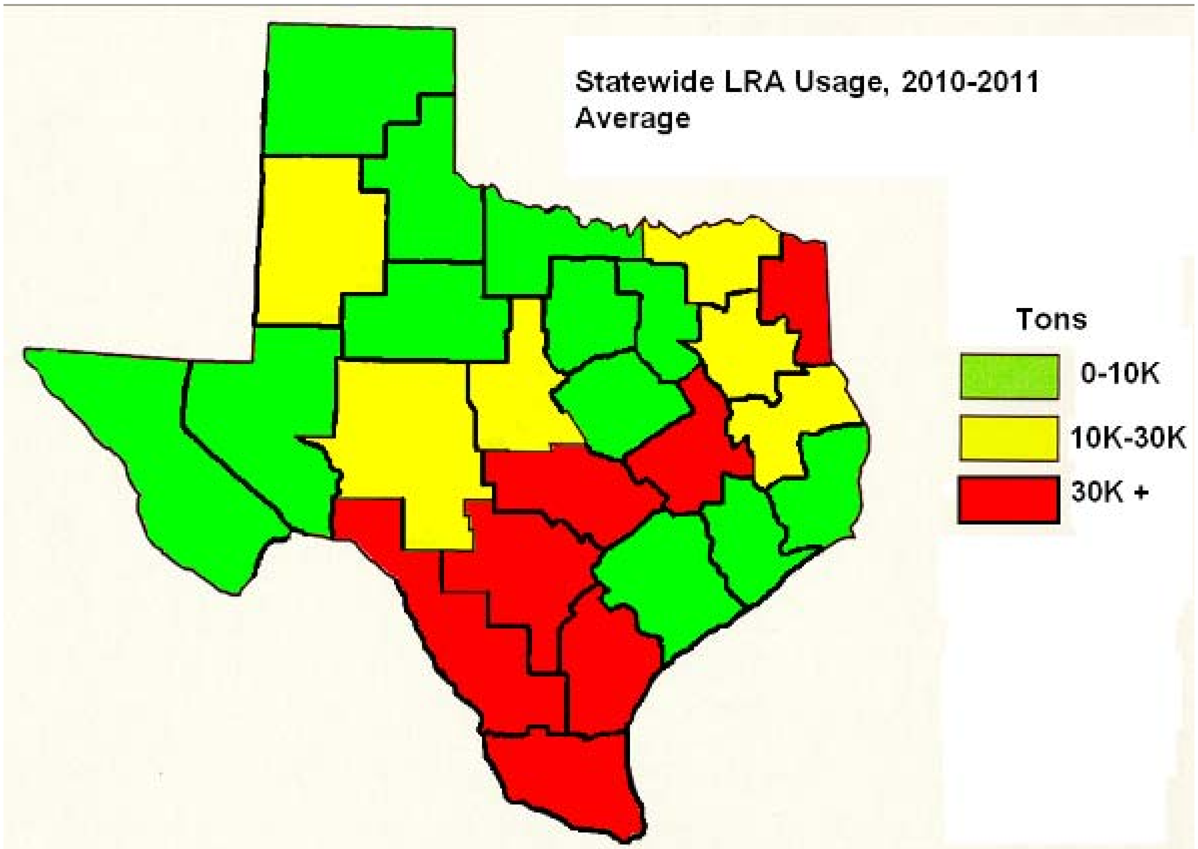


Figure 1. Statewide LRA Usage, FY 2010–2011 Average (as Purchased through Smartbuy).

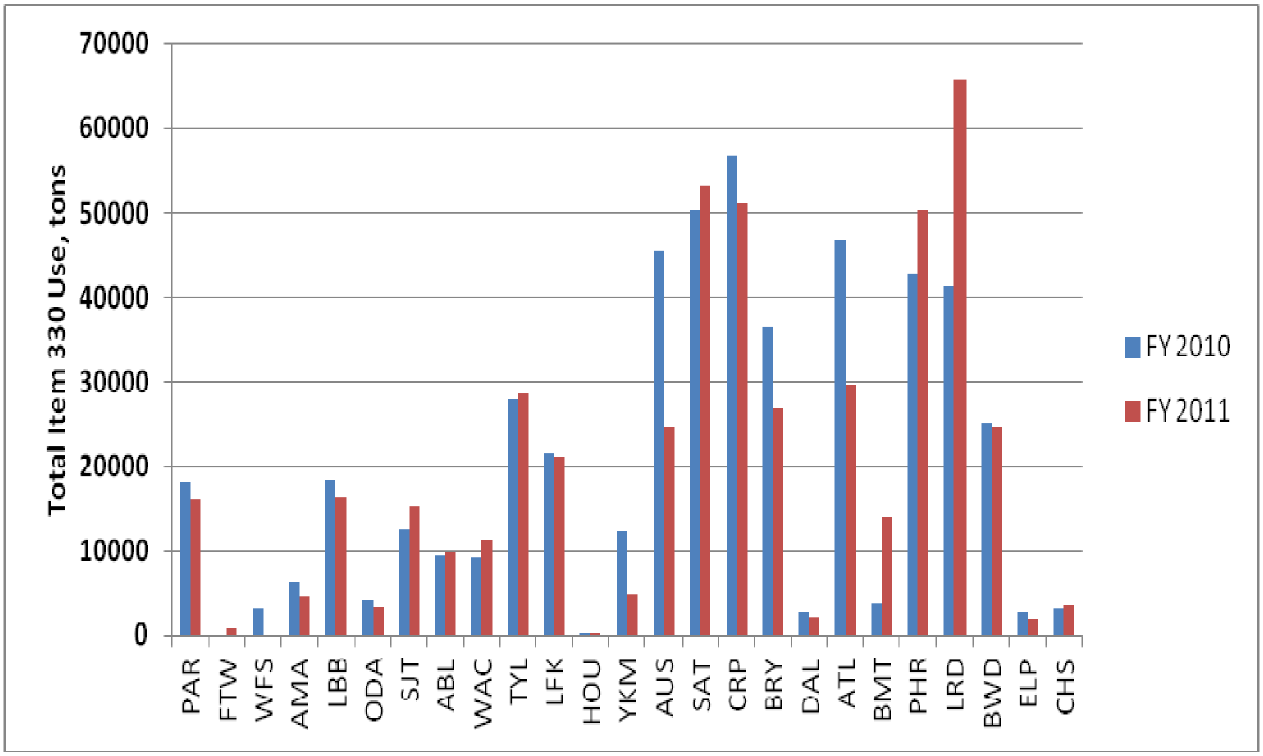


Figure 2. District Use of LRA in FY 2010 and 2011 (as Purchased through Smartbuy).

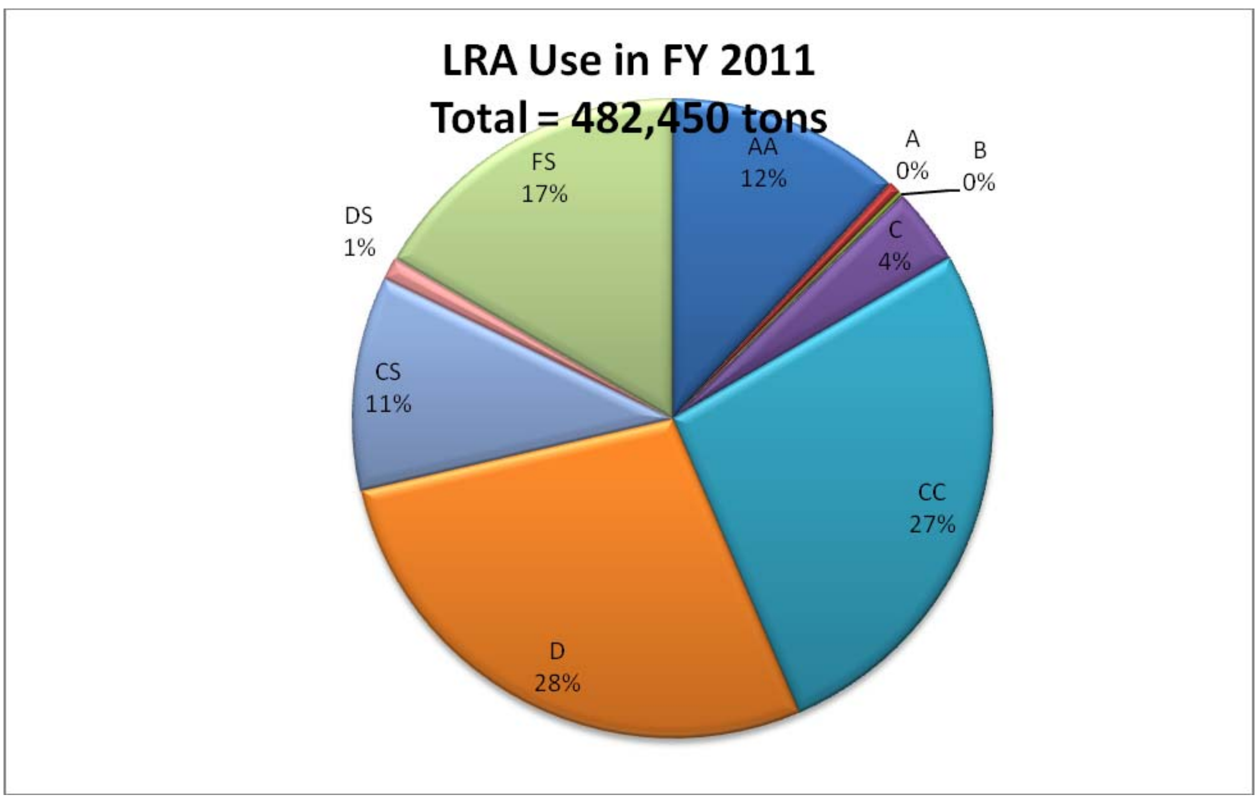


Figure 3. Use of LRA in FY 2011 by Item 330 Type.

CHAPTER 2
SUMMARY OF PHASE I RESEARCH

OBJECTIVES

The Phase I research effort as documented in more detail in Report 0-6686-1 focused on answering the following questions:

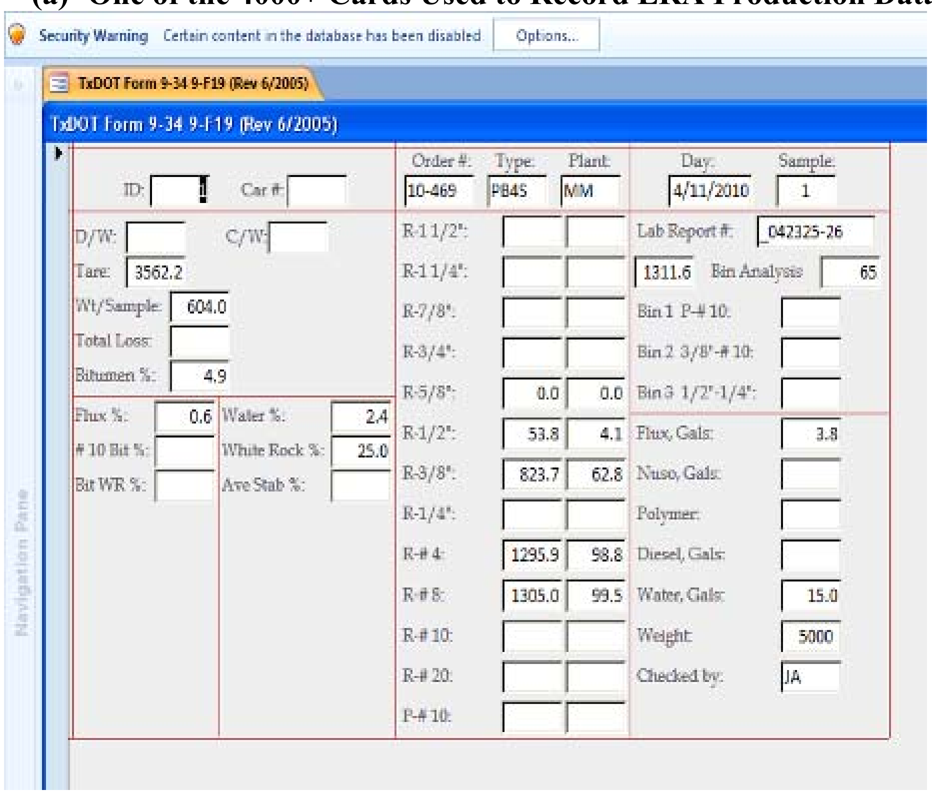
- What was the cause of LRA failures in 2010?
- Why did TxDOT not detect the problem?
- Does the problem still exist?
- How can TxDOT avoid the problem in the future?

PHASE I ACCOMPLISHMENTS

The following is a summary of the work performed in Phase I to answer the above questions.

- Reviewed production facilities, processes, and field labs at Uvalde.
- Obtained production test reports from field lab. Wrote a software program, entered, and analyzed data from 4000 handwritten test reports spanning a 3 year period (2009 through 2011). See Figure 4.
- Worked with TxDOT to obtain shipments of materials from Martin Marietta and Vulcan to be sent to four different districts (Figure 5).
  - San Antonio.
  - Childress.
  - Bryan.
  - Atlanta.
- Worked with each district to place, document construction and monitor performance of test sections placed in both winter and spring (total of 28). See Figure 6.
- Obtained samples of material from all 16 stockpiles for the lab testing program (Figure 7).
- Conducted the following lab tests from the field-sampled stockpiles:
  - Workability Test.
  - Hveem Stability.
  - Hamburg – Standard Method (wet).
  - Hamburg (dry).
  - Cantabro.
  - Indirect Tensile Strength (dry).
  - Indirect Tensile Strength (wet).
  - Wet ball (as a modified Cantabro).
  - Asphalt Content.
  - Sieve Analysis.
  - DSR test on extracted and recovered asphalt.
  - Water and light hydrocarbon volatiles determination.
  - Theoretical max gravity.

(a) One of the 4000+ Cards Used to Record LRA Production Data.



(b) Screen Display of Microsoft Access Program Used by Researchers to Enter Card Data for Processing and Summarizing Trends in Production Data.

Figure 4. Example of Production Data and Analysis Process.

(a) San Antonio District – Uvalde Maintenance.

(b) Atlanta District – Jefferson Maintenance.
Figure 5. Four Stockpiles of Material (Two per Supplier) Shipped to Four Districts.

(a) San Antonio District **(b) Bryan District**

(c) Atlanta District **(d) Childress District**

Figure 6. Test Section Construction in Four TxDOT Districts.

Figure 7. Five Buckets of Each of the Four Stockpiles per District Were Sampled for Further Lab Testing at TTI.

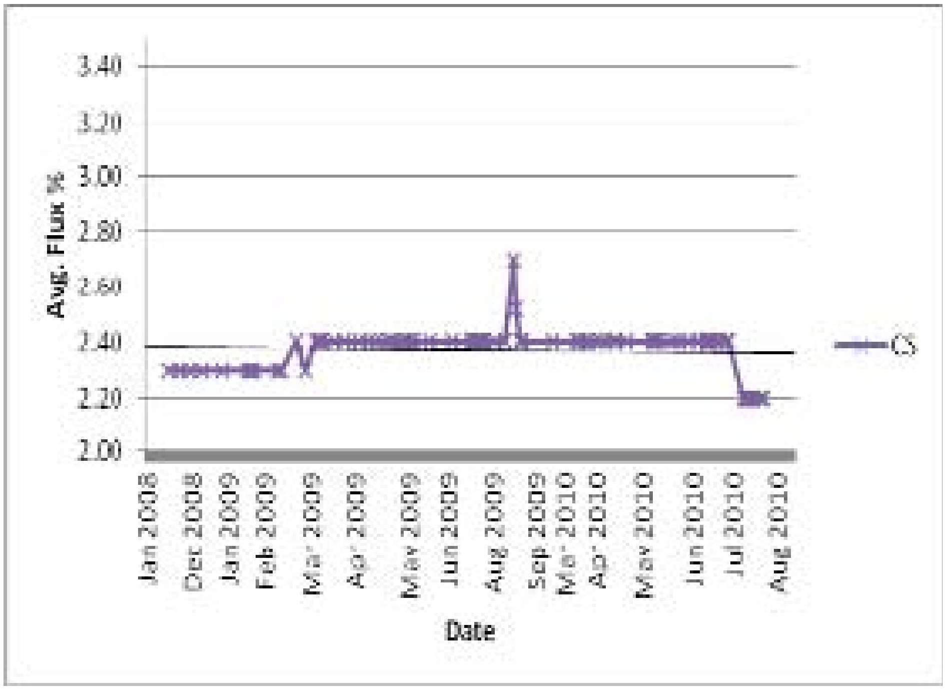
SUMMARY OF PHASE I FINDINGS

What Was the Cause of the 2010 Failures?

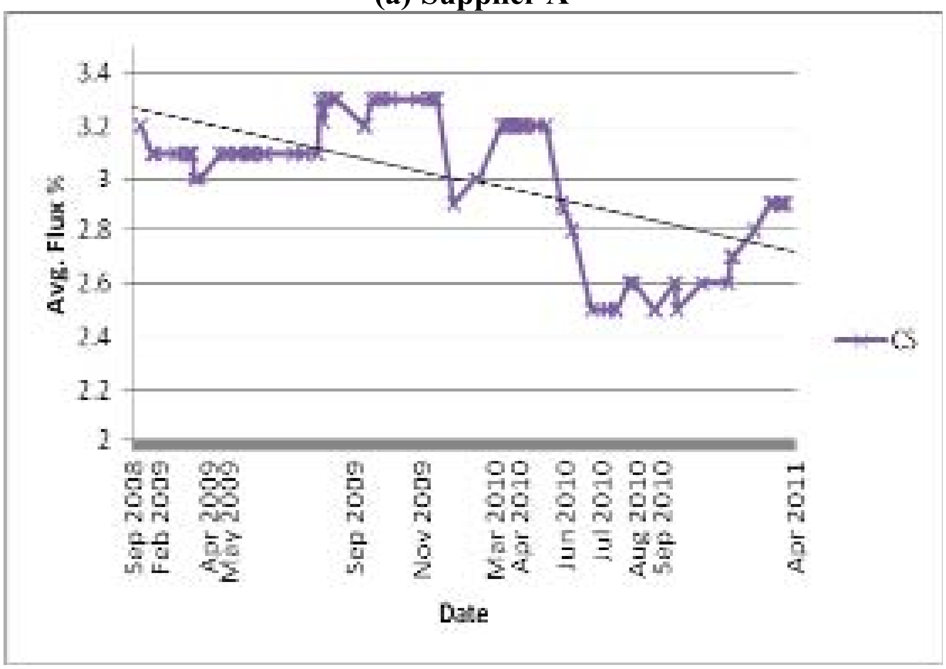
TTI processed and graphed the production data from the data cards from 2009 through 2011 and the main conclusion from this was that one of the suppliers was altering the production process by making significant changes to the amount and possible type of flux oil. This variation in flux oil was noted for all of the LRA mixture types coming from this supplier during the time-frame in question. An example of the difference in the two suppliers is shown in Figure 8 for LRA Type CS.

Why Did TxDOT Not Detect the Problem?

- All of the materials passed current specification requirements.
- Hveem stability detects mixes, which are prone to rutting but cannot identify a mix that is too dry and prone to raveling (Figure 9).
- TxDOT needs a new performance-related test and specification requirement to identify mixes, which are too dry and susceptible to raveling.

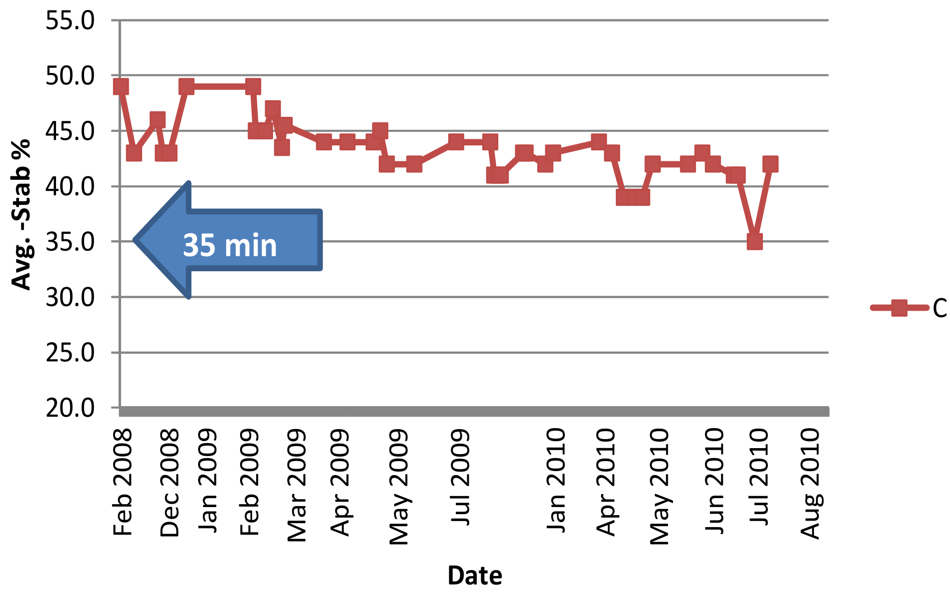


(a) Supplier A

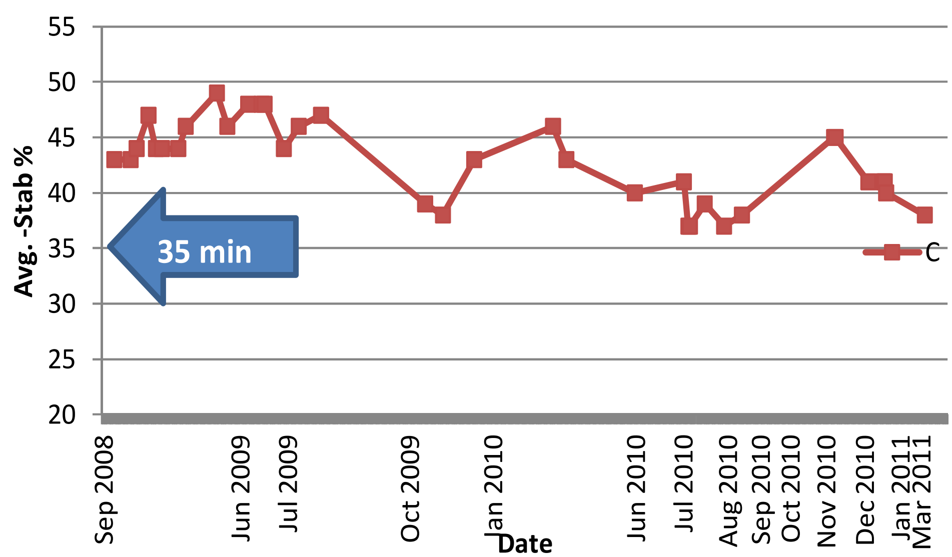


(b) Supplier B

Figure 8. Item 330, Type CS Mixture Production Data, Average Flux Oil Content, % by Wt.



Supplier A



Supplier B

Figure 9. Item 330 Type C, Mixture Production Data, Hveem Stability, %.

Does the Problem Still Exist?

- No performance problems were identified throughout 2011 and 2012.
- Twenty-eight test sections were constructed in four districts, fall 2011 and spring 2012 construction.
    - Martin Marietta D.
    - Martin Marietta DS.
    - Vulcan D.
    - Vulcan DS.
- All exhibited minor raveling in day 1.
- No major performance problems after 12+ months in service (see Figure 10).
- District survey in fall 2012 identified no new field performance problems.

(a) Age One Day

(b) Age Six Months

Figure 10. Uvalde Test Patches Typical of Acceptable Performance in All Test Sections.

How Can TxDOT Avoid Problems in the Future?

Conclusions from the Phase I research effort were:

- Failures in 2010 most likely caused by variations in the type and amount of flux oil.
- The current Hveem Stability test did not catch the dry mixes.
- New materials placed in 2011 and 2012 were better. No problems encountered.
- *A new test and specification is needed to identify and disqualify dry, raveling-susceptible LRA mixes*.

From preliminary work in Phase 1 three tests appeared to have potential as predictors of LRA performance:

- Cantabro Test.
- Indirect Tensile Strength Test.
- Modified Wet Ball Mill test.

These are standard TxDOT tests.

CHAPTER 3
PHASE II RESEARCH EFFORT

A laboratory test plan was conducted in Phase II to evaluate the effects of flux oil type and quantity as measured with different performance tests. Tests were conducted on Type C and D LRA mixes. The following performance tests were included in the evaluation:

- Hveem stability.
- Cantabro loss.
- Indirect tensile strength.
- Modified wet ball.

Flux oil types included those obtained from each material supplier (Martin Marietta and Vulcan Materials) in addition to three others obtained from various asphalt suppliers. To measure the effects in the laboratory of a flux known to be of a poor quality, used motor oil was included in the experiment.

It was initially hoped that the wet ball mill equipment could be used (similar in nature to the Cantabro test but on a small scale) as a potential specification parameter. Numerous tests were conducted on dry and wet conditioned samples; however, the wet ball mill equipment could never induce enough damage to the specimens to be conclusive. This equipment is shown in Figure 11.

Indirect tensile strength testing consistently showed decreasing strength with increasing flux oil content but did not seem to distinguish between good and bad flux oils (Figure 13 and Figure 14). The Cantabro Test equipment is shown in Figure 15. A Texas Gyratory sample is shown before and after Cantabro in Figure 16. Additional Cantabro-tested specimens are shown in Figure 17 showing that the specimen experiences more loss in material as flux oil content decreases (as expected).

Figure 11. Inside of Wet Ball Mill Drum.

Figure 12. Texas Gyratory Specimen of LRA before and after Tumbling in Wet Ball Mill Machine.

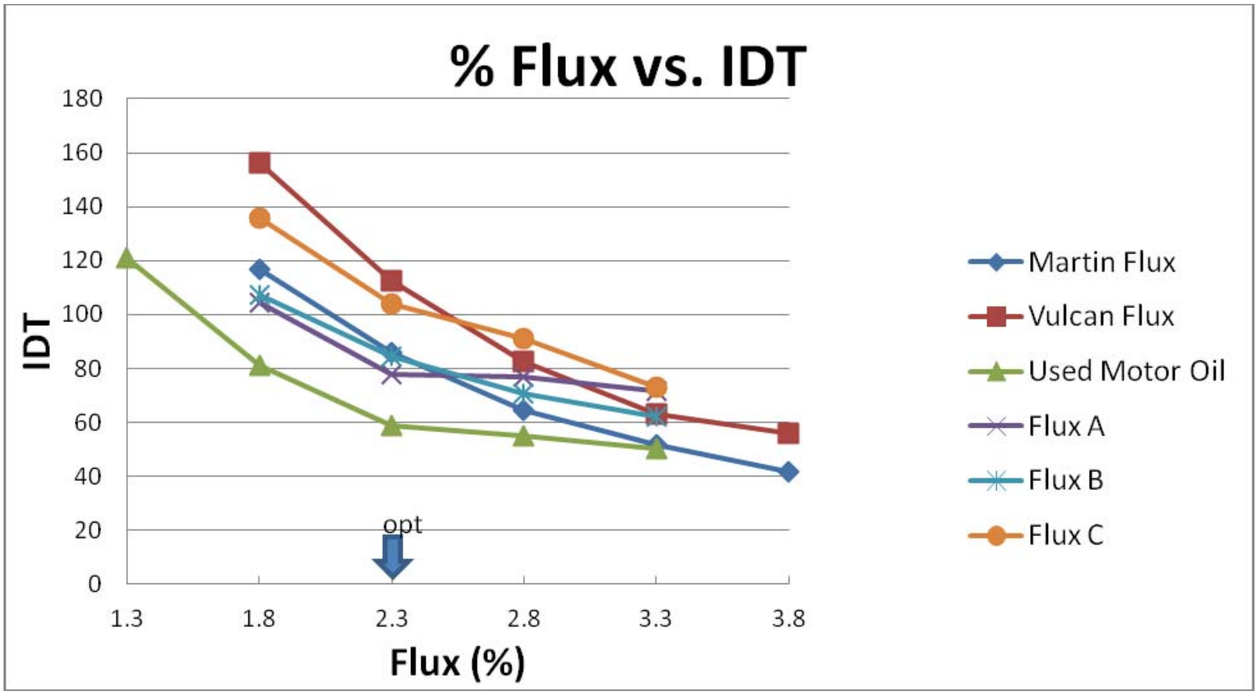


Figure 13. Indirect Tensile Strength at Different Flux Oil Contents.

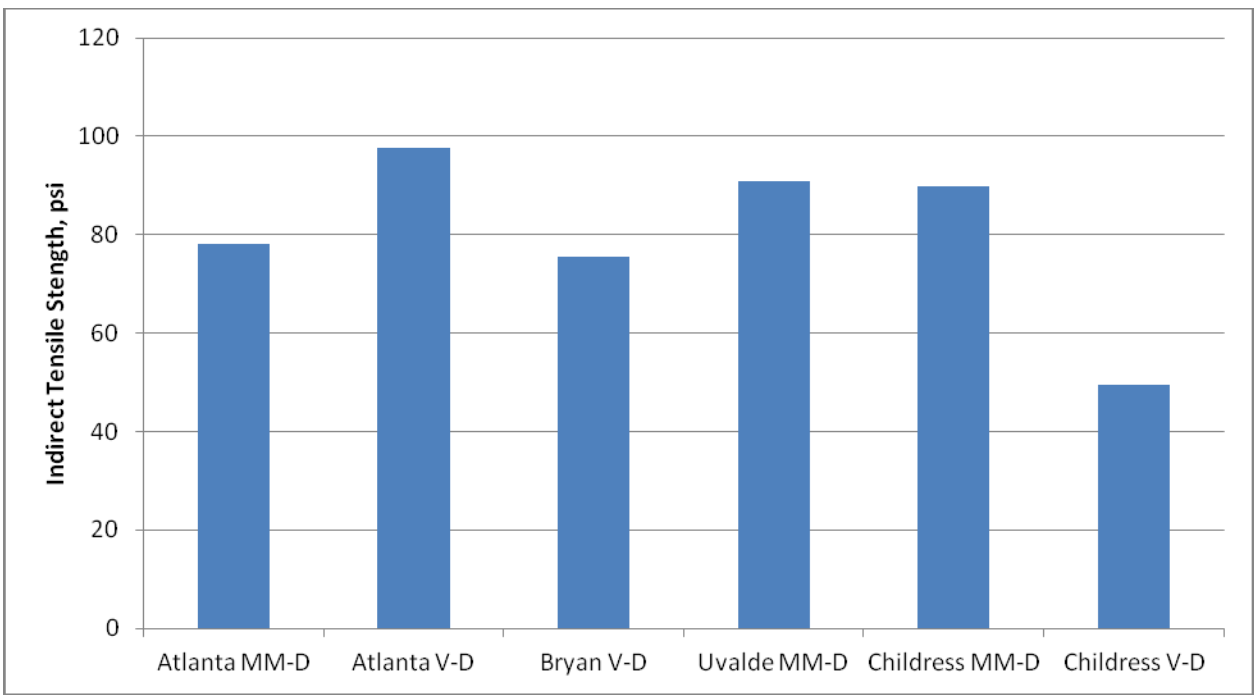


Figure 14. Indirect Tensile Strength of Field Test Section Mixes.

Figure 15. Los Angeles Abrasion Machine Used for Cantabro Test.

Figure 16. Texas Gyratory LRA Specimen before and after Cantabro Test.

Figure 17. Cantabro-Tested Specimens at Decreasing Flux Oil Contents from Left to Right.

The Hveem stability test results and Cantabro results are shown in Figure 18 and Figure 19, respectively. As flux oil content increased, the Cantabro loss generally decreased for most of the flux oils (except the used motor oil) as shown in the attached figure. This is as expected since more binder added to the mix should prevent raveling. In addition, the Cantabro test was able to distinguish between a good and bad flux oil. The used motor oil provided very little cohesion and binding capabilities to the mix and note in the following graphs that the Cantabro Loss was over 40 percent regardless of the quantity used.

The Hveem stability is a good test to determine rutting resistance of LRA but it does not indicate when a mix is too dry. In fact, the drier the mix, the better the Hveem stability (see attached figure). Given that used motor oil was used as one of the flux oils, one could assume that potentially anything that meets viscosity requirements for the flux could be used as the additive to LRA and still pass the Hveem stability requirements, yet give very poor field performance in terms of raveling.

A proposed Cantabro loss of 15 percent maximum is being proposed as a specification limit due in part to the results shown in Figure 20 of all of the test section materials that are known to have good field performance and are all below 15 percent loss on the Cantabro Test.

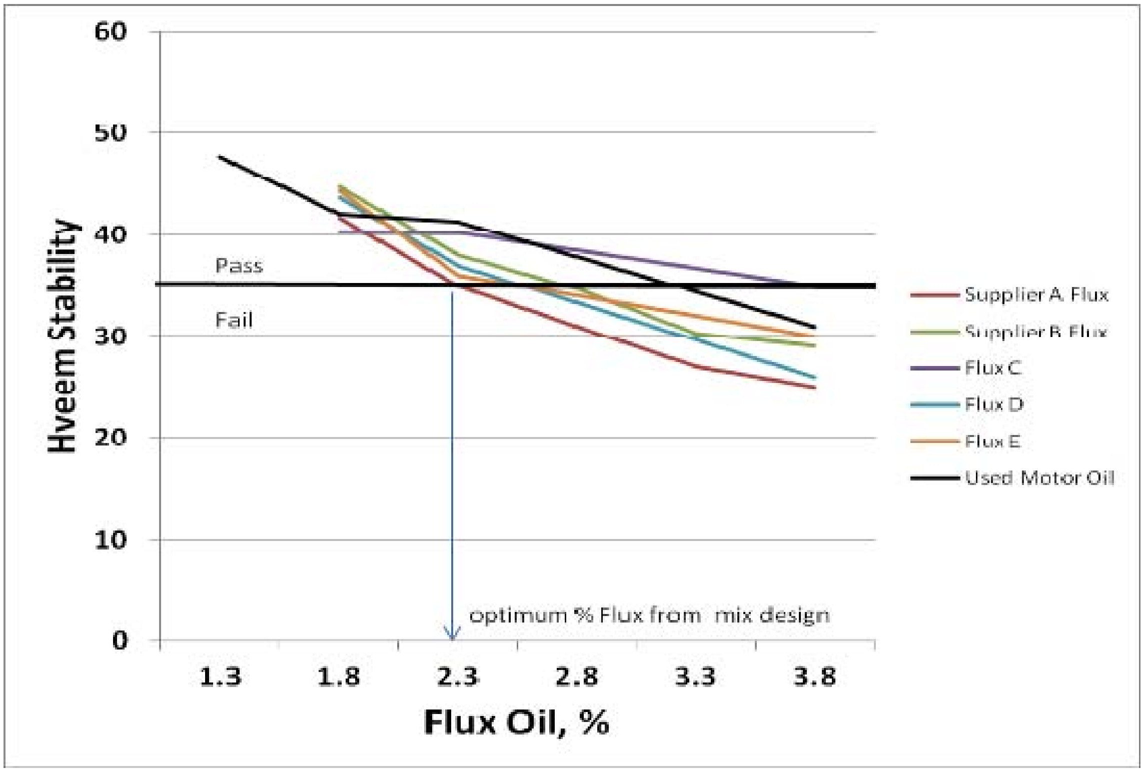


Figure 18. Hveem Stability at Different Flux Oil Contents and Types.

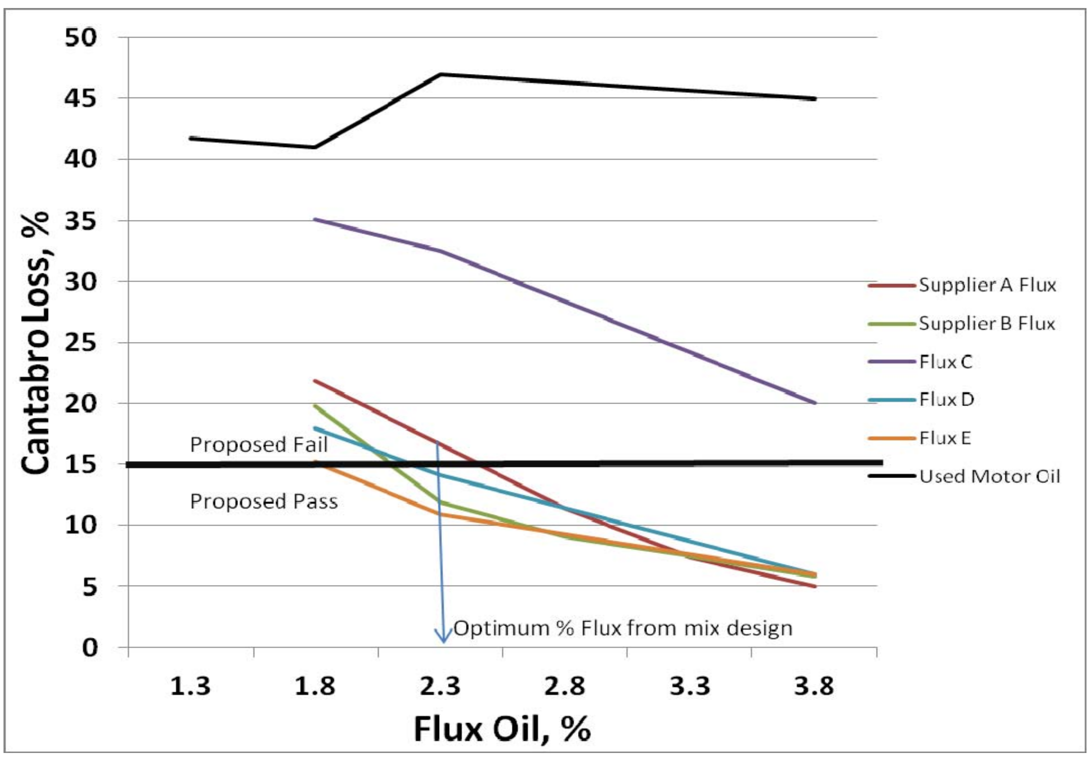


Figure 19. Cantabro Loss at Different Flux Oil Contents and Types.

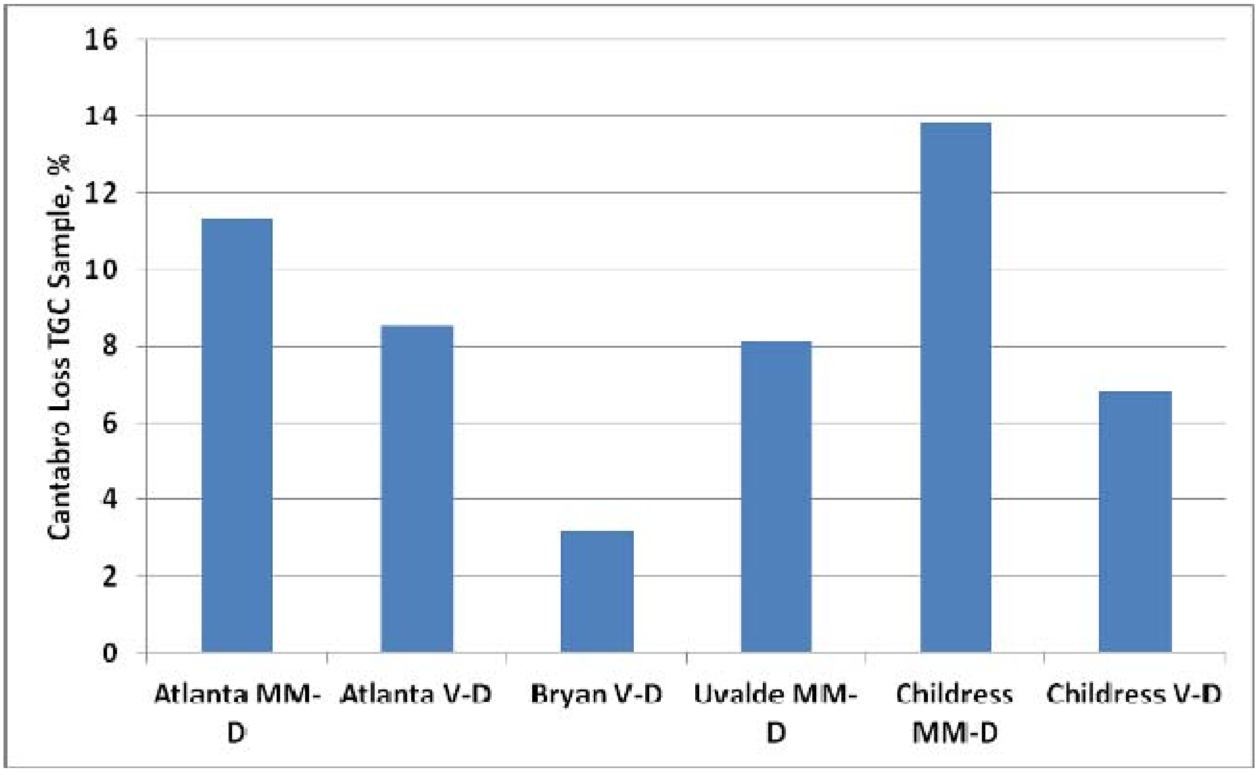


Figure 20. Cantabro Loss of Samples from Field Test Sections.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The primary conclusions regarding a proposed test and specification are summarized below:

- As flux oil content increased, the Cantabro loss generally decreased for most of the flux oils (except the used motor oil). This is as expected since more binder added to the mix should prevent raveling.
- In addition, the Cantabro test was able to distinguish between a good and bad flux oil. The used motor oil provided very little cohesion and binding capabilities to the mix and note in the following graphs that the Cantabro Loss was over 40 percent regardless of the quantity used.
- Hveem stability is still good detector of unstable mix as was evidenced in Dimmit County in the Laredo District where the LRA mix rutted but TTI's tests on the millings from the surface indicated the mix failed Hveem stability (Figure 21).
- While Hveem stability is a good test to determine rutting resistance of LRA it does not indicate when a mix is too dry. In fact, the drier the mix, the better the Hveem stability. Given that used motor oil was used as one of the flux oils, one could assume that potentially anything that meets viscosity requirements for the flux could be used as the additive to LRA and still pass the Hveem stability requirements, yet give very poor field performance in terms of raveling.
- A specification limit of 15 percent maximum for the Cantabro loss test is being proposed as a specification requirement.
- The typical Cantabro test is conducted on a Superpave Gyratory Compacted specimen. However, the test has been modified in this research to be performed on a Texas Gyratory Compacted specimen. In fact, the test can be performed on the specimen that is used to conduct the Hveem stability test since that test is nondestructive.
- Balancing both a Hveem stability test and Cantabro Loss test, both rutting and raveling performance requirements should be met (Figure 22).

Figure 21. Rutting Failure of LRA Overlay in Dimmit County, Laredo District.

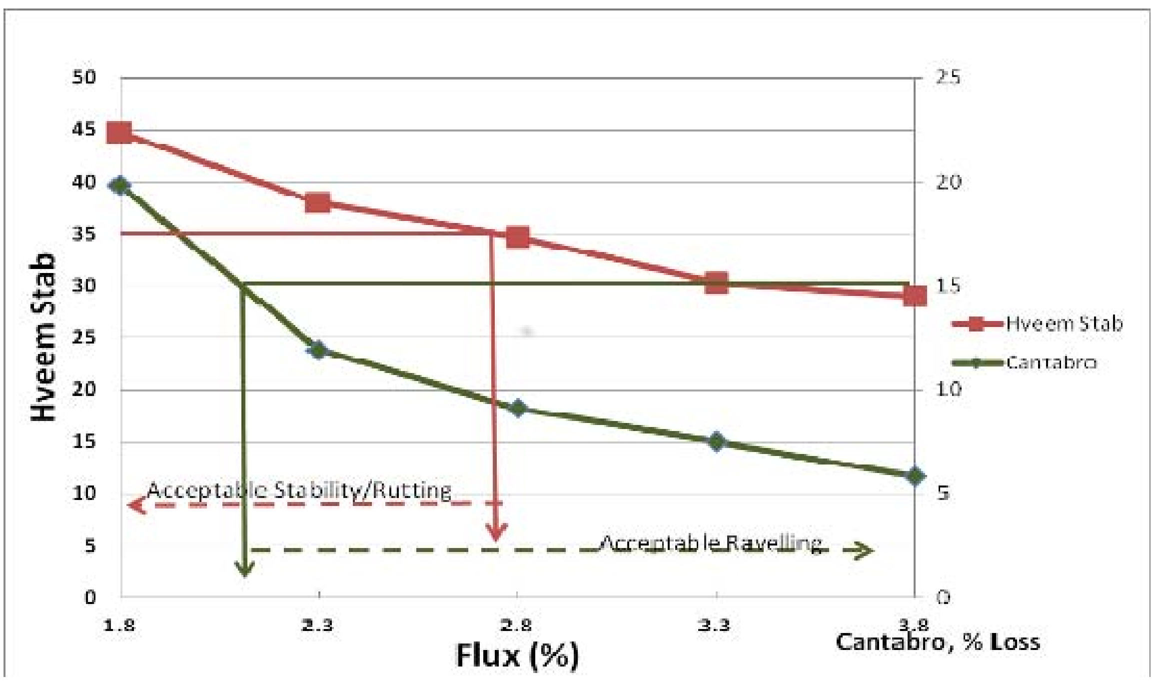


Figure 22. Approach to Balance Hveem Stability and Cantabro Loss Requirements to Achieve Acceptable Field Performance of LRA.

RECOMMENDATIONS

The following specification modification is proposed in italics/red for Table 1 of both Item 330 and DMS 9210. Since this criteria was based on limited testing, it is recommended that the test be performed for information only prior to full implementation to further validate the proposed criteria.

Table 1. Mixture Properties.

Property	Test Method	Requirement
Hveem stability, min	Tex-208-F	35[1]
Cantabro loss, % max	***Tex-245-F[3]***	***15***
Laboratory-molded density, %	Tex-207-F	89.0 ± 2
Theoretical maximum specific gravity of Bituminous mixtures	Tex-227-F	N/A
Bitumen content, % by wt.	Tex-236-F	6.5 to 11.0
Water and light hydrocarbon volatiles, % Max	Tex-212-F, Part II	6.0
Boil test, %	Tex-530-C	10[2]

1 Cease operations if two consecutive tests fail. CST/M&P may waive this requirement if other information indicates the next material to be produced will meet the minimum value specified.

2 May be increased or eliminated when directed by CST/M&P.

3 Tex-245-F shall be modified to use sample produced from Texas Gyratory Compactor instead of the Superpave Gyratory Compactor. The same specimen used to perform the Hveen stability test (which is a nondestructive test) may be used to perform the Cantabro Loss.

The testing sequence to be performed on a single Texas Gyratory Molded sample is shown in Figure 23.

IMPLEMENTATION CONSIDERATIONS

- Supply LA Abrasion Equipment to several district labs.
- Perform LMD, Hveem, and Cantabro testing at the district level on shipments of LRA.
- Compile data along with any reports of performance issues to evaluate specification criteria.

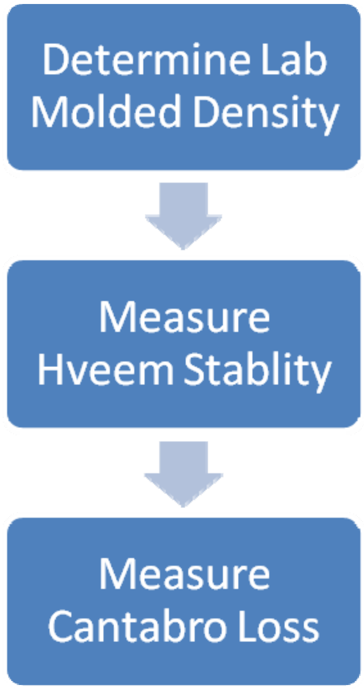


Figure 23. Proposed Testing Sequence for Single Texas Gyratory Molded Specimen.